Energy Services for the Millennium Development Goals

Achieving the Millennium Development Goals

MillenniumProject
Commissioned by the UN Secretary-General and supported by the UN Development Group

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ESMAP
Energy Sector Management Assistance Programme

The UN Millennium Project is an independent advisory body commissioned by the UN Secretary-General to propose the best strategies for meeting the Millennium Development Goals (MDGs). The MDGs are the world's quantifed targets for dramatically reducing extreme poverty in its many dimensions by 2015 – income poverty, hunger, disease, exclusion, lack of infrastructure and shelter – while promoting gender equality, education, health, and environmental sustainability.

The UN Millennium Project is directed by Professor Jeffrey D. Sachs, Special Advisor to the Secretary-General on the Millennium Development Goals. The bulk of its analytical work is performed by 10 task forces, each composed of scholars, policymakers, civil society leaders, and private-sector representatives. The UN Millennium Project reports directly to the UN Secretary-General and the United Nations Development Programme Administrator, in his capacity as Chair of the UN Development Group.

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Foreword

The world has an unprecedented opportunity to improve the lives of billions of people by meeting the Millennium Development Goals (MDGs), the international community's time-bound and quantified targets for addressing extreme poverty in its many forms. At the request of UN Secretary-General Kofi Annan, the UN Millennium Project has identified practical strategies to meet the MDGs, emphasizing the need for scaled-up investments in health, education, and infrastructure, alongside efforts to promote gender equality and environmental sustainability.

A common finding of the ten Task Forces of the UN Millennium Project has been the urgent need to improve access to energy services as essential inputs for meeting each MDG. Without increased investment in the energy sector, the MDGs will not be achieved in the poorest countries.

Under the leadership of Professor Vijay Modi of Columbia University, the Project has collaborated with ESMAP, UNDP, and the World Bank to prepare *Energy Services for the Millennium Development Goals.* The report underscores the strong links between energy services and achieving the MDG outcomes and puts forward a practical strategy for providing improved energy services to the world's poor. As a major contribution to our understanding of how to achieve the MDGs, the authors propose quantitative and time-bound energy targets for low-income countries and derive goal-oriented strategies for meeting them.

This report has been prepared by a group of leading experts who contributed in their personal capacity and volunteered their time. I am grateful for their thorough and skilled efforts, and am certain that this report will make an important contribution to achievement of the Millennium Development Goals. In particular, I hope that developing countries will find the report helpful as they prepare their first MDG-based development

strategies. I recommend it to anyone who is interested in how energy services contribute to the achievement of the Goals.

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November 2005

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Executive Summary

The Millennium Development Goals (MDGs) are the international community's bold commitment to halving poverty in the world's poorest countries by 2015. While some of the world's poor countries have seen tremendous success in poverty reduction over the past decades and are on track to achieve the MDGs, many others are lagging. This report specifically addresses the role of energy services in meeting the MDGs in the lagging countries. Energy services refer to the services that energy and energy appliances provide. Such services include lighting, heating for cooking and space heating, power for transport, water pumping, grinding, and numerous other services that fuels, electricity, and mechanical power make possible. The core message of the report is that energy services are essential to both social and economic development and that much wider and greater access to energy services is critical in achieving all of the MDGs.

UN Secretary-General Kofi Annan commissioned the UN Millennium Project as an advisory body to recommend practical ways to help every country to achieve the MDGs. The UN Millennium Project brought together experts from around the world—from academia, civil society, government, the private sector, and multilateral organizations—to make recommendations on how the international system can ensure that the MDGs are achieved.

In line with the UN Millennium Project more broadly, this report on energy addresses three crucial components: firstly, a rigorous understanding of the energy services that drive and, when absent, impede progress towards achieving the MDGs in different parts of the world; secondly, a clear sense of the operational challenges faced by the world's poorest countries in providing these services; and thirdly, a systematic set of recommendations as to how these energy challenges can be met.

Just two glaring statistics illustrate the scale of the energy services gap that the poor face. Worldwide, nearly 2.4 billion people use traditional biomass fuels for

cooking and nearly 1.6 billion people do not have access to electricity. Without scaling up the availability of affordable and sustainable energy services, not only will the MDGs not be achieved, but by 2030 another 1.4 billion people are at risk of being left without modern energy. Conversely, by scaling up the availability of affordable and sustainable energy services, there is a greater chance of achieving the MDGs, as energy services have a multiplier effect on health, education, transport, telecommunications, safe water, and sanitation services, and on investments in and the productivity of income-generating activities in agriculture, industry, and tertiary sectors.

The report shows linkages between all of the MDGs and energy and argues that much greater quality and quantity of energy services will be required to meet the MDGs. The report also illustrates the distinct roles of women and men in relation to the provision and use of energy services, the critical importance of associating women with the provision of modern energy services, as well as the distinct routes needed to scale up energy services in rural and urban areas.

Key Recommendations

Achieving all of the MDGs will require much greater energy inputs and access to energy services. Failure to include energy considerations in national MDG strategies and development planning frameworks will severely limit the ability to achieve the MDGs. As such, the following key recommendations point to priority energy interventions which national governments should take to support achieving the MDGs at the national level. They should:

1. *Place the issue of energy services at par with other MDGs.*
   - Integrate energy within national development strategies by adopting a goal-oriented approach to address the combined energy needs of social institutions and productive activities for cost-effective energy service delivery. This will require both flexibility in prioritizing programs and coordination across ministries of finance, economic management, energy, industry, health, education, agriculture (or rural development), water and sanitation, and transport.

2. *Adopt legal and regulatory frameworks that will provide incentives for effective partnerships among government institutions (including local governments), private-sector utilities and other operators, and community organizations.*
   - Take into account the needs and socioeconomic conditions of the poor in defining the respective obligations of the service providers and poor customers.
   - Allow for a wide range of technologies to ensure safe technical solutions in service provision.

3. *Improve the affordability, availability, and safety of cooking fuels and practices.*

- Enable the use of modern cooking fuels through regulatory reforms; investments in the handling, transport, and distribution of fuels; and well-designed subsidies (or safety nets) for the poor.

- Reduce the first-cost burden of LPG[1]/kerosene stoves/cylinders and reduce the incremental recurring costs associated with the use of modern fuels. These measures can encourage fuel switching especially in urban and peri-urban settings, where there is already a market for traditional biomass and charcoal.

- Adopt measures to increase the sustainable production of biomass and exploit linkages of biomass production with agriculture, agroforestry, animal husbandry, waste treatment, ecosystem services, forestry, carbon credits, and income generation.

- Support efforts to develop and adopt the use of sustainable biomass and biomass-derived fuels, improved stoves, and practices that reduce exposure to harmful emissions. Increase the efficiency of conversion of biomass to biomass-derived cleaner fuels.

4. *Adopt strategic, institutional, and financial measures to ensure wider access for households and small businesses in urban and peri-urban settings to services such as illumination and power, information and communication technology (ICT), refrigeration, and other beneficial uses.*

- Reduce the cost burden of connection and distribution fees to enable electricity access for the poor in urban and peri-urban areas. A combination of strategies such as working with community organizations, lowered unit costs, subsidies, financing, and payment mechanisms can reduce the first-cost burden.

5. *Adopt measures to ensure reliable electricity supply to households, businesses, public institutions, commercial establishments, and industry.*

- Enable payment and cost-recovery mechanisms that will ensure the financial health of energy service delivery entities so that they can provide reliable service and expand services.

- Create incentives to increase generation capacity and invest in distribution infrastructure to serve a larger population.

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[1] LPG stands for Liquified Petroleum Gas. LPG is a mixture of propane and butane, gases that can be easily liquefied under pressure for ease of storage and transport in specialized canisters.

6. *Provide access to mechanical power (for water lifting/delivery systems and agroprocessing) and electricity for public facilities (health clinics/centers, schools, government offices, and community centers) in all rural communities.*

- Aggregate demand across multiple social and income-generating needs within the community, thus lowering unit costs. Location of these services for small businesses and/or cooperatives at some central point within a rural community can lead to even greater aggregation of demand, further lowering unit costs as well as unlocking local private capital.
- Emphasize immediate wider access and scalability through use of low-cost transitional technologies since these will be substituted eventually as affordability and energy demand evolve as income levels increase.

7. *Take a flexible approach to selecting from a wide range of technologies as well as a wide range of institutional structures for the delivery of energy services.*

- Include the entire spectrum of primary energy sources, distribution and end-use technologies from which proven, robust, and cost-effective technologies can be chosen for implementation at larger scales with appropriate standards.

8. *Develop energy infrastructure and institutions that directly benefit women and the poor.*

- Energy services delivery mechanisms for household, productive and social sector uses should take into account the distinct energy services used by men and women and how their availability impacts men and women in economic and social terms
- Women should be included at all points of the project, policy and development planning process both as energy providers and energy users.

9. *In order to develop and rapidly scale up energy services, enhance human capacity through energy-related education, training, and research.*

- Training needs to include regulators, financiers, policymakers, technicians, community outreach workers, and people with local business skills/entrepreneurs to support the delivery of services.

10. *Incorporate the cost of energy service delivery needed to support the achievement of the MDGs into all national MDG strategies.*

- A costing methodology using the example of Kenya is presented in Appendix II. It can serve as one of the methodologies that can be used for other countries.

Structure of the Report

Chapter 1 explores global patterns of energy use among the wealthy and the poor as a basis for understanding the challenges that lie ahead in expanding access for the poor, with special emphasis on the impacts of traditional energy consumption. It then briefly describes the overall findings of the UN Millennium Project. Chapter 2 details the extensive interconnections between the MDGs themselves and energy needs throughout the poorest parts of the developing world. Chapter 3 discusses MDG-compatible energy services and proposes three time-bound, quantitative energy service targets for meeting the MDGs. Chapter 4 describes concrete national energy strategies for meeting these targets, and considers each of the three main areas for intervention in greater detail, with attention to technological, financing, geographic, and other aspects of possible solutions. Chapter 5 discusses a variety of issues related to planning and implementation, particularly the institutional and financial factors that can hinder the efforts to expand energy access for the poor, and Chapter 6 offers summary conclusions.

CHAPTER 1: Meeting the MDGs— The Energy Challenge

At the United Nations Millennium Summit in September 2000, world leaders placed development at the heart of the global agenda by adopting the Millennium Declaration from which the Millennium Development Goals (MDGs) were later extracted. The MDGs provide concrete, time-bound objectives for dramatically reducing extreme poverty in its many dimensions by 2015— income poverty, hunger, disease, exclusion, and lack of infrastructure and shelter—while promoting gender equality, education, health, and environmental sustainability. These were reaffirmed by all world leaders at the 2005 World Summit in New York. This report addresses how the energy services needed to achieve the MDGs can be provided.

Many regions are off-track to meet the Goals. Sub-Saharan Africa is the epicenter of a global crisis, and as a region is off track in meeting all of the MDGs. Despite significant progress, East and South Asia still have the largest absolute number of poor people, with more than 270 million in East Asia and 430 million in South Asia living below the poverty line, all vulnerable to droughts, natural disasters, and other shocks. Latin America, despite relatively lower rates of poverty, has failed to make significant progress toward the Goals in the past decade, with large pockets of poverty and high and stagnant inequality. The former Commonwealth of Independent States (CIS) countries in Central Asia have regressed on several social indicators and face tremendous social, economic, and environmental challenges.

The Importance of Energy Services

Even though no MDG refers to energy explicitly, improved energy services— including modern cooking fuels, improved cookstoves, increased sustainable biomass production, and expanded access to electricity and mechanical power—are necessary for meeting all the Goals (see Box 1). The link between

energy services and poverty reduction was explicitly identified by the World Summit on Sustainable Development (WSSD) in the Johannesburg Plan of Implementation (JPOI), which called for the international community to: "Take joint actions and improve efforts to work together at all levels to improve access to reliable and affordable energy services for sustainable development sufficient to facilitate the achievement of the MDGs, including the Goal of halving the proportion of people in poverty by 2015, and as a means to generate other important services that mitigate poverty, bearing in mind that access to energy facilitates the eradication of poverty" (ESMAP 2002a, p. 2).

Cooking with fuelwood, crop residues, and dung is associated with a significantly higher disease burden than other forms of cooking, due to indoor air pollution. Cleaner fuels and cookstoves that facilitate lower smoke exposures, as well as improved ventilation of cooking areas, can reduce the disease burden from smoke, lower child mortality rates, and improve maternal health. Greater efficiency, combined with enhancements in biomass fuel availability through such programs as agroforestry, can also reduce the time and transport burden of women and young girls who collect biomass, thereby increasing opportunities for education and income-generating work. These and other improvements can all lessen the pressure on fragile ecosystems.

Electricity is critical for providing basic social services, including education and health, where lack of energy often undermines sterilization, water supply and purification, sanitation, and refrigeration of essential medicines. Electricity can also power machines that support income-generating opportunities such as pumping water for agriculture, food processing, apparel production, and light manufacturing. In rural areas, lack of modern energy services can decrease the willingness of more-educated workers (such as teachers, doctors, nurses, and extension agents) to reside in those areas, further limiting services and opportunities to local populations. Similarly, those who have left such communities and fared well elsewhere are less likely to return to an area without modern services.

Since the evidence linking provision of energy services with achievement of social objectives and generation of economic growth is strong and well documented, this report recommends strategies for achieving the MDGs and maps out policy changes and investments required for improving access to energy services in urban and rural areas. Chapter 2 discusses these critical links in more detail.

The particular focus of this report is to address the role of energy services in the poorest countries that are caught in a poverty trap. Modern forms of energy such as electricity, natural gas, clean cooking fuels, and mechanical power are necessary to increase the productivity of agriculture and labor, improve the health of the population, lower transaction and transport costs, and reduce risks through better information. They therefore serve as a foundation supporting a virtuous cycle of growth.

Energy services are the benefits that energy carriers produce for human well being. Examples of energy services include heat for cooking, illumination for home or business use, mechanical power for pumping or grinding, communication, and cooling for refrigeration. Energy services can be derived from a variety of energy carriers. For instance, illumination can be produced by fuels or by electricity. Mechanical power can be produced from kinetic or potential energy of water, from kinetic energy of wind, from a liquid fuel, or from electricity. Energy carriers, in turn, can be derived from a variety of primary energy sources; electricity for example can be generated from hydropower, petroleum, solar, or wind energy. From the point of view of the user, what matters is the energy service not the source. Whether in business, home, or community life, what matters are the reliability, affordability, and accessibility of the energy service. Therefore, it is essential to have a clear understanding of which energy services are needed to support the MDGs, and to examine the role that different energy carriers can play in providing these services in the most practical and affordable fashion to support human development at large.

Where are the Energy Poor?

In many of the poorest countries, a large fraction of the population is unable to access modern energy services at all, and those who do have access often pay dearly for energy services of much lower quality—meaning that the services are erratic and unreliable. A substantial fraction of the population relies on biomass or dung for cooking fuel and heat; on kerosene wick lamps, batteries, or candles for lighting; and on human or animal energy-based mechanical power for tilling and weeding land, grinding and crushing, agroprocessing, or transport. The poorest households spend a large portion of their total income and human resources on energy because some forms of energy are absolutely essential to meeting such basic needs as cooked food and transport. Insufficient and unreliable power limits the ability of enterprises to expand their activities, to be competitive, or to create new activities or jobs. The largest concentrations of the 'energy poor,' those people who are both poor and who also lack access to modern forms of energy, are currently in sub-Saharan Africa and South Asia.

One measure of energy poverty at the level of the poorest is the inability to cook with modern cooking fuels and the lack of a bare minimum of electric lighting to read, or for other household and productive activities after sunset. These minimum needs correspond to about 50 kilograms of oil equivalent (kgoe) of annual commercial energy per capita; this estimate is based on the need for approximately 40 kgoe per capita for cooking and 10 kgoe used as fuel for electricity.[2] This represents just the most basic household energy needs

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[2] kgoe is the unit used as a common metric to quantify energy supplied using a variety of sources and carriers by converting them into oil equivalent units.

for cooking and lighting; not included are energy consumption for agriculture, transport, community-level needs such as grinding and social services, or industrial, commercial, and government activities. Even in India, where annual commercial energy consumption per capita is between 400 and 500 kgoe, the poor often cannot afford, or may not have access to, 50 kgoe. This reflects both income inequality and limited availability, since energy is crucial not only for households, but also for industry, commercial enterprises, small and medium businesses, educational institutions, government offices, public transportation systems, health clinics, water supply systems, communication infrastructure, and street lighting.

Lack of reliable supply can impair a person's ability to use modern energy services. For example, even if one can obtain an electricity connection, as is generally the case in an urban area, the supply may be unreliable or the connection unaffordable, or both, and hence energy services that are best derived from electricity may remain inaccessible. For those living in slums, many factors can further hamper access to electricity services, such as lack of street addressing, lack of formal housing registration, and tariff structures and payment mechanisms that are not adapted to the customer base. A combination of these factors and other broader issues affecting the performance of the utilities (for example, theft of electricity, legal structures to enforce power purchase contracts, the institutional structure of the utility itself, and the inability to enforce bill collection) can lead to lack of investment in electricity generation and distribution networks, or in development of fuel supply infrastructure, making it even more difficult to extend services to those not served.

In addition to generation or supply shortfall and insufficient distribution infrastructure for efficient energy carriers (such as electricity and clean gas or liquid fuels), the lack of access to end-use appliances, particularly those that impact women (such as mills, motors, and pumps), further hampers the use of modern energy services.

An examination of current national electricity consumption per capita highlights the differences between equatorial and non-equatorial regions in general, and between sub-Saharan Africa and the rest of the world in particular. Figure 1 is a map showing current per capita electricity use by country. Figure 2 shows the actual and projected number of people without electricity, by region, over several decades. In most parts of the world, investments in energy services have outpaced population growth. The steep fall in the number of people without access to electricity is particularly noticeable in East Asia during the 1980s and 1990s. In South Asia, it is expected that falling fertility rates and increased investments will substantially reduce the number of people without access. The only region where the expansion of services has not kept pace with population growth is sub-Saharan Africa, where the total number of people without access to electricity has increased steadily and is projected to continue to do so for the next couple of decades.

Figure 1.
World map of electricity use per capita by country

Source: UNDP 2004b.
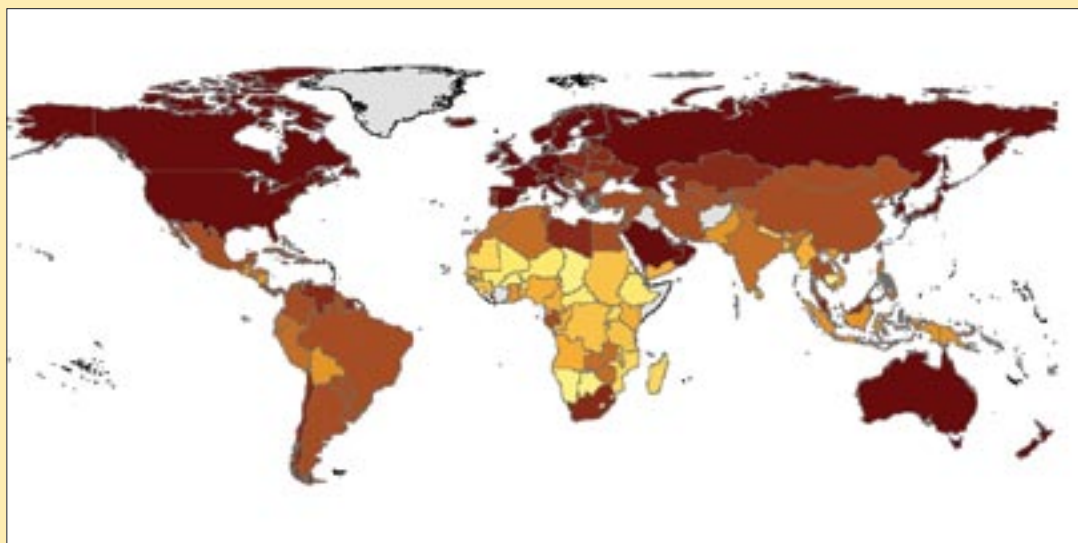
Electricity consumption per capita, kWh, 2001

☐ No data	☐ 51–75	☐ 251–500	☐ 2,501–5,000
☐ 0–25	☐ 76–100	☐ 501–1,000	☐ 5,001–30,000
☐ 26–50	☐ 101–250	☐ 1,001–2,500	

Figure 2.
Number of people (actual and projected) without electricity, 1970–2030, by region

Source: IEA 2002b.
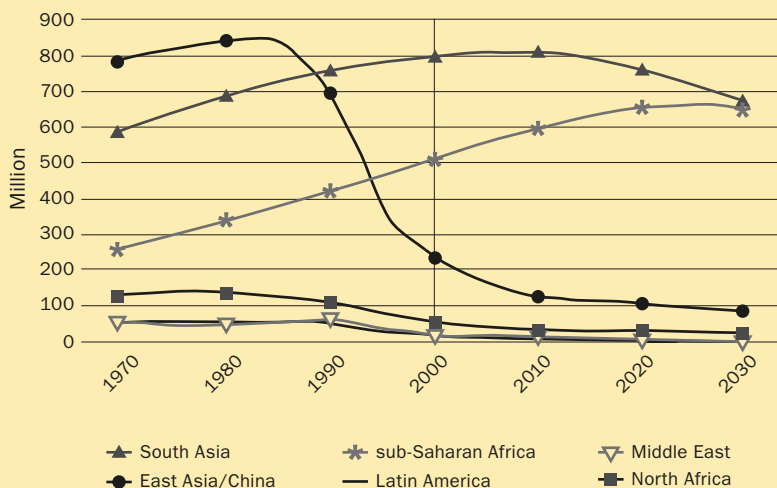
However, the direct use of solid biomass—a variety of solid fuels such as charcoal, fuelwood, stalks and other farm waste or dung—is widespread in the poorest parts of the world. Thus another way to determine where the energy-poor are is to look at geographical and quantitative data on the number and distribution of people who rely on traditional biomass fuels for cooking and heating (See Figure 3 and Table 1). The lack of access to improved cooking fuels is most extreme in sub-Saharan Africa, followed by South Asia.

**Figure 3.
Percentage of
households using
traditional biomass
fuel, by country**

Source: Gordon et al. 2004.
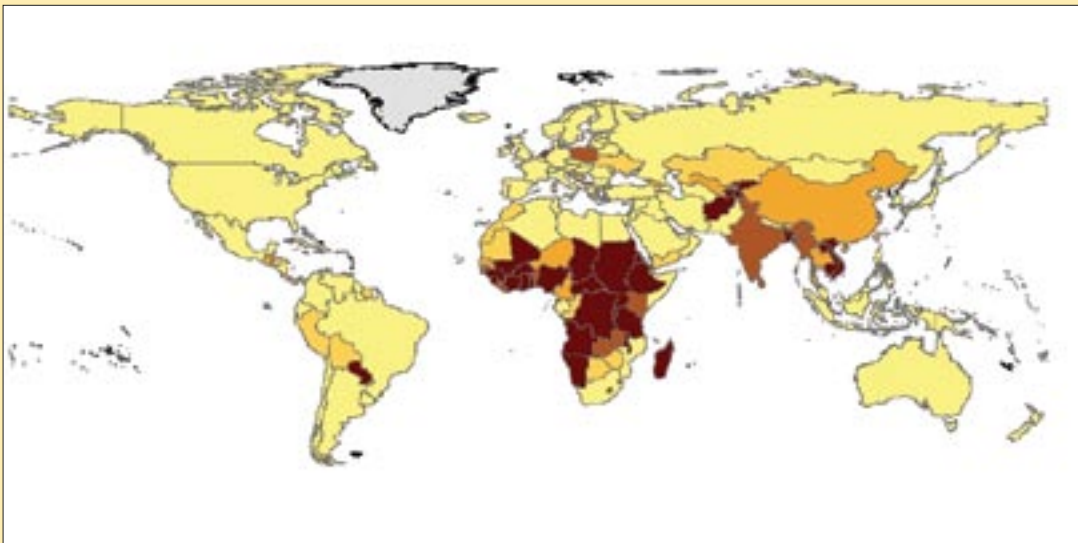
Households using biomass fuel (%)

☐ <50	☐ 70–80	■ >90
☐ 50–70	☐ 80–90	☐ No data

	Million	% of total population
China	706	56
Indonesia	155	74
Rest of East Asia	137	37
India	585	58
Rest of South Asia	128	41
Latin America	96	23
North Africa/Middle East	8	0.05
sub-Saharan Africa	575	89
Total, Developing Countries	2,390	52

Table 1.

Number of people relying on traditional biomass for cooking and heating in developing countries, 2000

Source: IEA 2002b

Meeting the Energy Challenge

Progress toward providing greater access to modern energy services has been slow, due to a combination of interrelated circumstances. These include low income levels among the unserved population; lack of financial resources for service providers to build the necessary infrastructure and reduce first-cost barriers to access; weak institutional, financial, and legal structures that could otherwise encourage private investment; and lack of long-term vision and political commitment to scale up services.

Can the many obstacles limiting access of the poor to modern energy services be overcome by 2015? Our conclusion is that this can be done, but many concrete actions will be needed from all stakeholders. This conclusion rests, in large part, on the successful programs undertaken in many developing countries in recent decades. For instance, in considering the question of whether 2.4 billion people can make the transition from solid fuels to cleaner-burning fuels, it is worth noting that the proportion of Brazil's population using modern cooking fuels such as LPG increased from 16 percent in 1960 to 78 percent in 1985, eventually reaching nearly all by 2004. Similarly, the 1.6 billion people worldwide who are without access to electricity may take heart in the examples set by Tunisia, where the electrification program expanded service from 6 percent of the population in 1976 to 88 percent in 2001; Morocco, where electrification rates reached 72 percent in 2004 (Morocco, Office National de l'Electricité 2005); and China, where electrification rates reached 97 percent in 2004, thanks to sustained political commitment, public funding that combined domestic resources and borrowings from the Development Banks and other sources, and effective cost-recovery tariffs and mechanisms from users.

National Strategies to Achieve the MDGs

The UN Millennium Project was commissioned by UN Secretary General Kofi Annan to put forward the best strategies for achieving the MDGs. Its central finding is that the MDGs are achievable in the 10 years remaining to 2015, though barely. The world has at its disposal the knowledge, tools, and resources to cut poverty by half in a decade. No new international commitments are needed to achieve the MDG. Existing commitments made at the Millennium Summit, the Monterrey Conference on Financing for Development, and the World Summit on Sustainable Development in Johannesburg, and reaffirmed at the 2005 World Summit, are sufficient, if implemented. The focus must now be on implementation. To this end, the UN Millennium Project has developed 10 key recommendations summarized in Box 2.

Box 2.
The 10 key recommendations of the UN Millennium Project

The UN Millennium Project, an independent advisory body to UN Secretary-General Kofi Annan, has issued the following key recommendations, which are described in more detail in its report: *Investing in Development: A Practical Plan to Achieve the MDGs*.

Recommendation 1
Developing-country governments should adopt development strategies bold enough to meet the Millennium Development Goal (MDG) targets for 2015. We term them MDG-based national development strategies. To meet the 2015 deadline, we recommend that all countries have these strategies in place by 2006. Where Poverty Reduction Strategy Papers (PRSPs) already exist, those should be aligned with the MDGs.

Recommendation 2
The MDG-based national development strategies should anchor the scaling up of public investments, capacity building, domestic resource mobilization and official development assistance. They should also provide a framework for strengthening governance, promoting human rights, engaging civil society, and promoting the private sector.

Recommendation 3
Developing-country governments should craft and implement the MDG-based national development strategies in transparent and inclusive processes, working closely with civil society organizations, the domestic private sector and international partners.

Recommendation 4
International donors should identify at least a dozen MDG 'fast-track' countries for a rapid scale up of official development assistance (ODA) in 2005, recognizing that many countries are already in a position for a massive scale up on the basis of their good governance and absorptive capacity.

Recommendation 5
Developed and developing countries should jointly launch, in 2005, a group of Quick Win actions to save and improve millions of lives and to promote economic growth. They should also launch a massive effort to build expertise at the community level.

Recommendation 6

Developing-country governments should align national strategies with such regional initiatives as the New Partnership for Africa's Development (NEPAD) and the Caribbean Community (and Common Market), and regional groups should receive increased direct donor support for regional projects.

Recommendation 7

High-income countries should increase official development assistance (ODA) from 0.25 percent of donor GNP in 2003 to around 0.44 percent in 2006 and 0.54 percent in 2015 to support the MDGs, particularly in low-income countries, with improved ODA quality (including aid that is harmonized, predictable and largely in the form of grants-based budget support). Each donor should reach 0.7 percent no later than 2015 to support the Goals and other development assistance priorities. Debt relief should be more extensive and generous.

Recommendation 8

High-income countries should open their markets to developing country exports through the Doha trade round and help Least-Developed Countries (LDCs) raise export competitiveness through investments in critical trade-related infrastructure, including electricity, roads and ports. The Doha Development Agenda should be fulfilled and the Doha Round completed no later than 2006.

Recommendation 9

International donors should mobilize support for global scientific research and development to address special needs of the poor in the areas of health, agriculture, natural resource and environmental management, energy and climate. We estimate the total needs to rise to approximately US$7 billion a year by 2015.

Recommendation 10

The UN Secretary-General and the UN Development Group should strengthen the coordination of UN agencies, funds, and programs to support the MDGs, at headquarters and country level. The UN Country Teams should be strengthened and should work closely with the international financial institutions to support the Goals.

Meeting the MDGs by 2015 requires a major a shift in development practice. Low-income countries and their development partners currently plan around modest incremental expansions of social services and infrastructure. The UN Millennium Project recommends instead a bold, 10-year investment framework aimed at achieving the quantitative targets set out in the Goals. Rather than strategies to 'accelerate progress toward the Goals,' countries need strategies to 'achieve the Goals,' which in turn requires a different approach. Instead of asking "How close can we get to the Goals given current financial and other constraints?" countries should ask the question, "Which investments and policy changes are needed to meet the Goals?"

As agreed by all 191 member states of the UN at the 2005 World Summit, each country should be empowered to adopt and implement a national

development strategy to achieve the MDGs. Existing strategies, including PRSPs, need to be aligned with the Goals. An integrated approach will include strategies in the areas of rural and urban development (including provision of infrastructure such as clean drinking water, sanitation facilities, energy, and transport), health, education, gender equality, environmental sustainability, science and technology, and public sector management. Thus energy services remain a key component of any such strategy.

An MDG-based national development strategy will outline human resource, infrastructure, and financial needs and determine what support is necessary from the international community. Developing countries need to craft and implement such MDG-based strategies in transparent and inclusive processes, working closely with civil society organizations, the domestic private sector, and international partners. The countries' international development partners—including bilateral donors, UN agencies, regional development banks, and the Bretton Woods institutions—can provide critical support to the preparation and implementation of MDG-based national development strategies. In particular, official development assistance should be sufficient to fill the financing needs and subject to clear accountability. This also assumes that recipient countries make their own reasonable efforts at increasing domestic resource mobilization and at facilitating private-sector participation.

Achieving all of the MDGs will require much greater energy inputs and access to energy services. Failure to include energy considerations in national development strategies and development planning frameworks will make it impossible to achieve the MDGs.

CHAPTER 2: Energy and the MDGs

Without energy services of adequate quality and quantity countries cannot meet the MDGs. This chapter summarizes the available evidence linking energy services and the Goals and Targets of the Millennium Declaration. We show that energy services directly affect income poverty and other dimensions of poverty, such as gender inequality, poor health, lack of education, or lack of access to infrastructure services. An excellent summary of these linkages was developed by the United Kingdom's Department for International Development (DFID) and is presented at the end of the chapter.

Growth and Income Poverty Reduction[3] (MDG Target 1)

Modern energy services help drive economic growth by improving productivity and enabling local income generation through improved agricultural development and non-farm employment. When they are available to all income groups, modern energy services are also an invaluable means of improving social equality.

Productive uses of energy are particularly important to economic growth. Modern fuels and electricity, for example, help boost household income by providing lighting that extends livelihood activities beyond daylight hours. They power machines that save time and increase output and value added. By providing additional opportunities for employment, energy services also enable farmers to diversify their income sources, and thus mitigate the inherent risks associated with agriculture-dependent livelihoods. Energy is important in supporting productive activities in both formal and informal sectors.

Another way modern energy services contribute to economic growth is by reducing unit costs. Due to the inefficiency of commonly used items such as

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[3] Text based on UNDP 2005.

batteries, candles, kerosene, and charcoal, the poor often pay higher unit costs for energy than do the rich. The use of more efficient fuels can reduce the large share of household income spent on cooking, lighting, and keeping warm, thus saving families much needed income for food, education, health services, and other basic needs.

There are vastly different energy consumption levels across countries and regions, primarily dictated by large disparities in income. Energy consumption is highly correlated with higher GDP per capita, as illustrated in Figure 4.

Figure 4.
Commercial energy consumption and GDP, 2000

Source: United Nations Common Database, 2000.
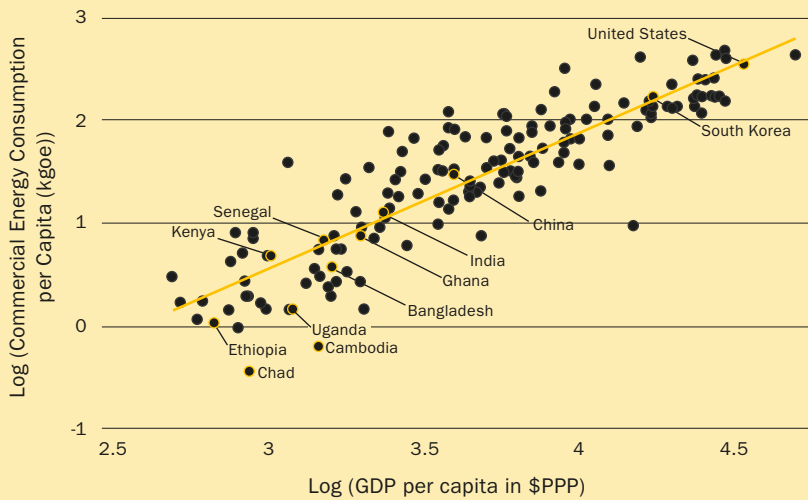
Note: This is a log-log plot of per capita commercial energy consumption (kgoe) vs. GDP (in$PPP). In a log-log plot, the x- and y-axis numbers 0, 1, 2, 3, 4 … correspond to 1, 10, 100, 1,000, 10,000…

Table 2 shows the UNDP Human Development Index (HDI) rank, annual per capita commercial energy consumption (in kgoe), and electricity consumption (in kilowatt hours or kWh) for several countries. It also shows measures of poverty such as the per capita income in purchasing power parity dollars ($PPP) and the percentage of the population earning below US$1 per day and US$2 per day (where income is also in $PPP). The data show that there is considerable variation among poor countries; however, these differences are small relative to the energy consumption of wealthy countries. Note that biomass energy sources are not included here, that a significant portion of the energy consumption is not household consumption, and that commercial energy consumption across households also varies. Low commercial energy use is also correlated with high infant mortality, illiteracy and fertility, and with low life expectancy (UNDP 2000, p. 42).

Table 2

GDP per capita, energy consumption, and poverty in selected countries, with emphasis on sub-Saharan Africa

Sources: HDI country rankings from UNDP 2004b; GDP, population, and income data from World Bank 2004b; per capita electricity consumption from UN Department of Economic and Social Affairs (personal correspondence, March 2004); per capita commercial energy consumption from United Nations Common Database.

HDI Rank	Country	GDP per capita		Electricity consumption per capita	Commercial energy consumption per capita	Population below income poverty line (%)[e]		
		US$ 2002	$PPP 2002	kWh 2001	kgoe 2000	US$1 per day[f] 1990–2002	US$2 per day[g] 1990–2002	National poverty line 1990–2001
8	United States	36,006[a]	35,750[a]	13,241	7,725	–	–	–
9	Japan	31,407	26,940	8,203	3,730	–	–	–
28	Korea, Rep. of	10,006	16,950	6,632	3,284	<2.0	<2.0	–
72	Brazil	2,593	7,770	2,122	717	8.2	22.4	17.4
94	China	989	4,580	1,139	561[b]	16.6	46.7	4.6
119	South Africa	2,299	10,070	4313	2,649[c]	7.1	23.8	–
127	India	487	2,670	561	318	34.7	79.9	28.6
131	Ghana	304	2,130	404	120	44.8	78.5	39.5
146	Uganda	236	1,390	66	26	82.2[d]	96.4[d]	44.0
148	Kenya	393	1,020	140	96	23.0	58.6	52.0
157	Senegal	503	1,580	151	128	26.3	67.8	33.4
165	Malawi	177	580	76	27[h]	41.7	76.1	65.3
167	Chad	240	1,020	12	5[h]	–	–	64.0
170	Ethiopia	90	780	30	29	26.3	80.7	44.2
174	Mali	296	930	34	18[h]	72.8	90.6	63.8
176	Niger	190	800	41	33[h]	61.4	85.3	63.0

[a] Practical issues arising in the calculation of the PPP US dollar GDP make these values different.
[b] Does not include Hong Kong, Macao, and Taiwan, China.
[c] South African Customs Union.
[d] UNDP 2003; World Bank 2003.
[e] Data refer to the most recent year available during the period specified.
[f] Poverty line is equivalent to US$1.08 (1993 $PPP).
[g] Poverty line is equivalent to US$2.15 (1993 $PPP).
[h] Estimate, UN Statistics Division.
– Not available

These and other data illustrate that increased energy consumption correlates closely with both income levels and economic growth. For example, an increase from 30 to 300 kgoe in primary commercial energy consumption has a strong association with dramatically improved living standards.

While the selection of countries in Table 2 is arbitrary, it is designed to represent a wide range of income levels. It shows important general patterns among sub-Saharan African countries as well as among middle-income developing countries. The three columns of poverty data show that while Brazil and China enjoy, on average, considerably higher GDP per capita than the poorest countries, they nonetheless have significant poor populations. Considered broadly, these data suggest that it is not unrealistic to associate per capita commercial energy consumption levels of about 500 kgoe—a value based on a nation's total, not just residential, consumption—with a substantial reduction in the number of poor for the poorest countries. Simplistic as this analysis is, a review of studies that attempt rigor in obtaining the precise energy–economic growth relationships have failed to provide estimates that are much better. This is due to variations in other key factors, such as a country's economic structure, its geography, the particular domestic energy resources and technologies available, and the costs of energy to consumers.

In addition to the level of energy consumption, the *type of fuels* used also varies across countries by income levels. Figure 5 shows the contribution of various energy sources to the total average per capita final energy consumption of one hundred developing and transition countries. The countries are grouped according to their share of population living on less than US$2 per day.

It is instructive to observe which modes of final energy consumption grow, and by how much, with decreasing poverty levels. What is evident here is the dramatic difference in the topmost segment of the bar graph (liquid fuels) between a representative country with more than 75 percent of the population living below US$2 per day and one with 40–75 percent living on less than US$2 per day. Liquid fuels are used primarily for transportation and, to a lesser extent, in industry and households. While Figure 5 masks the differences in energy use patterns in individual countries, it illustrates, in an aggregate sense, the importance of transportation and fuel needs within a country's combined energy sources.

Once again, the figure suggests that, when comparing countries represented by the first bar on the left (countries with greater than 75 percent of the population living with incomes below US$2 per day) with those represented by the second bar from the left (countries with 40–75 percent of the population earning less than US$2 per day), an increase in per capita non-biomass energy consumption from about 50 to 400 kgoe is observed. For countries with the largest proportion of population living on less than US$2 per day, biomass is the single most important source of energy, largely due to the heating and cooking needs that people cannot go without. This is a similar level of primary energy

Figure 5. The share of energy sources to the energy consumption of 100 developing and transition countries, by poverty levels and energy type
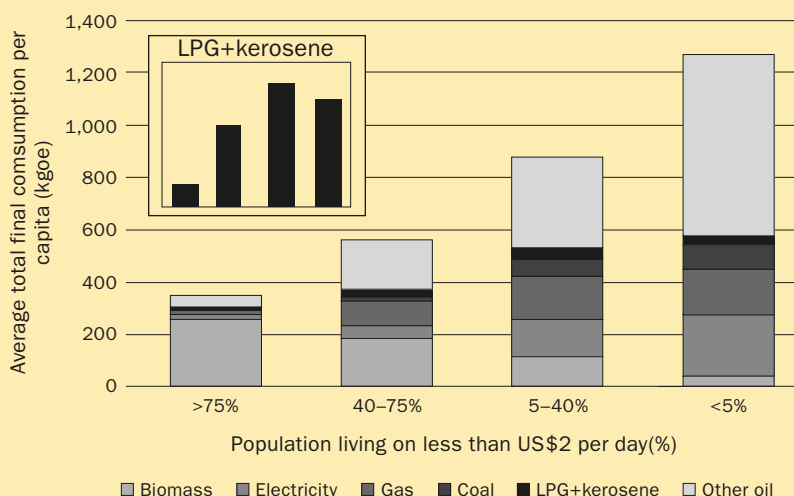
consumption that was suggested earlier based on the experience of China and Brazil as indicated by Table 2. This discussion provides us with a rough quantitative estimate of the overall level of primary energy consumption that includes all modes of consumption and not just household consumption.

At the household scale, modern energy services directly contribute to economic growth and poverty reduction. They create opportunities for income generation, reduce unit costs, and enable increased income from agriculture or animal husbandry by permitting pumping for supplementary irrigation, which lessens the risks associated with rainfed systems and enables increasing crop and pasture productivity as well as switching to higher-value crops. Indirect contributions to economic growth may come in the form of freeing up time for other productive activities, improved health and education, improved access/ supply of clean drinking water, and reduced local environmental degradation.

At the village, town, city and national scale, lack of reliable and affordable electricity supply can also become an impediment to income-generating industrial, commercial, and service activities. A recent United Nations Economic Commission for Africa report (UNECA 2004) finds the current energy infrastructure in many African countries to be simply insufficient to support export diversification and ultimately sustainable economic development.

The increased productivity of human capital provided by energy services is evident in the developed world. For example, electricity can allow people to operate computers and file servers, and use telephones and the Internet, which can in turn lead to a large increase in the productivity of human labor. A single trained professional can provide services to a much larger number of people with improved transport and ICT. Mechanical power or electricity that can be then used for mechanical power can also provide opportunities for

businesses such as agroprocessing, carpentry, welding and businesses that rely on refrigeration.

A recent comprehensive effort to measure the social benefits of rural electrification in the Philippines attempted to quantify, in monetary terms, the benefits of electricity access (ESMAP 2002d). Based on survey data obtained from rural communities, the study estimated the improved educational opportunities and conditions electrification would provide to rural populations. The authors estimated the total benefit of providing electricity to a typical, non-electrified Philippine household to be US$81–US$150 per month. Benefits accruing to individual wage earners were estimated to be roughly US$37 due to 'improved returns on education and wage income.' Survey respondents consistently affirmed in large majorities that electricity was an important part of their children's education by increasing and improving the quality and duration of indoor lighting enabling study at night. However, the study's authors also concluded that electricity provides increased entertainment opportunities (particularly television) that can become a distraction from children's study. In spite of the fact that the task is fraught with analytical difficulties, the authors found significant benefits in terms of opportunity costs from time saved, lower-cost lighting, and improved productivity in home businesses. Other studies also point to the positive relationship between educational opportunities made possible by electric lighting and higher lifetime earnings (Fitzgerald et al. 1990).

Given that the role of energy in catalyzing growth and poverty reduction is unquestionable, securing the supply of primary energy and securing the demand to sustained services is paramount to achieving the MDGs. A rapid increase in oil prices, as brought about by a sudden disruption in supply, uncertainty within the oil markets, or by strong demand, has important implications for energy security, macroeconomic growth, and poverty reduction. Although price hikes certainly affect industrial countries, their effect is generally more pronounced in developing countries, with major differences between net oil importers and net oil exporters.

For net oil importing developing countries, a rapid rise in oil prices weakens economic growth and exacerbates poverty. The direct effect on an economy is felt through a worsening balance of payments and the subsequent contraction of the economy or increased external borrowing required to restore the balance of payment equilibrium. For example, it is estimated that a sustained US$10 a barrel price increase would amount to a 1.5 percent loss in GDP among the world's poorest countries (ESMAP 2005b; IEA 2002a). Price hikes in primary energy sources also mean increases in consumer prices for essential products such as kerosene used for cooking and lighting by many poor people and a considerable increase in transportation costs, beyond what the poor can afford. This in turn leads the poor to go back down the energy ladder, for example, switching from kerosene to charcoal or fuelwood and putting more pressure on

forestry and land resources; returning to walking rather than using fuel-powered transport; and spending less time on productive activities.

For developing countries that are net exporters of oil, price hikes mean increased foreign exchange earnings and the opportunity to accelerate development. Paradoxically, this opportunity is fraught with challenges. There is ample evidence to suggest that, in the absence of good governance and prudent monetary and exchange rate policies, resource-rich countries are not necessarily achieving higher rates of growth. The challenges of managing resource revenues in ways that avoid or minimize the harmful monetary impact associated with sudden foreign exchange windfalls—commonly referred to as the 'Dutch disease'–and avoiding excessive rent seeking cannot be overlooked.

Therefore, from the perspective of both importing and exporting countries, energy security is tantamount to a country's ability to expand, diversify, and optimize its energy resource portfolio and a level of services that will sustain economic growth and poverty reduction. It is in this light that energy security should become a key focus of energy policies in developing and middle-income countries. It should be analyzed not only in its macroeconomic dimensions—its impact on a country's ability to service foreign debt, attract foreign investment, manage fiscal resources, and mitigate environmental impacts on land degradation and air quality—but also in its microeconomic dimensions, from the perspective of the enterprises that strive to remain competitive in the face of rising prices and from the perspective of poor households that already spend a large share of their income on energy services.

Hunger (MDG Target 2)

Energy in the form of heat is required to cook 95 percent of the basic staple foods that form the basis of human nutrition. Most cooked food also requires water, which must be pumped and transported. Growing food crops also requires energy inputs for planting, irrigation, harvesting, and post-harvest processing. In most places, women have the primary responsibility for cooking based on the social division of labor.

The availability and use of both traditional and modern cooking fuels therefore have important linkages to hunger. The amount of energy needed for household cooking needs is commonly estimated at 1 gigajoule (GJ) 'into the pot' per capita per year, which can rise as high as 10 GJ per capita per year once efficiency of cooking methods such as biomass burning over a three-stone fire are accounted for.

Since the poor—particularly in urban areas—devote a high share of their incomes to obtaining cooking fuels, they are vulnerable to changes in the price of energy carriers. For example, rising costs of imported fuels or charcoal can lead to a higher incidence of hunger since such increases prevent the poor from cooking and processing their food. The poorest families typically dedicate 80 percent of total household energy expenditure to fuels for cooking and heat

and only 20 percent for fuels and batteries to produce light. This is because there is little choice whether or not to meet basic subsistence needs (Reddy 1999).

In communities heavily reliant on biomass fuels, farm waste (in the form of crop residues and manure) can be an important part of the energy supply. The UN Millennium Project Task Force on Hunger recommends replenishing soil fertility at the lowest possible cost through practices that may otherwise use the biomass for cooking and heating (UN Millennium Project 2005b). Use of modern fuels or improved stoves can allow a greater proportion of farm waste to be returned to the soil. Modern cooking fuels can also indirectly increase farm productivity by freeing up women's time and effort, in particular by reducing the work required for biomass collection, which is particularly detrimental to the health of childbearing women. Where appropriate, agroforestry can play an important role by expanding the total supply of biomass available locally, thus enabling biomass use both as cooking fuel and as a farm input while reducing the burden of fuel collection.

Education (MDG Target 3)

Particularly for school-age girls, improved access to modern energy services can free time for going to school and for after-school study. Energy scarcity creates time pressure on children to collect fuel, to fetch water, and to participate in agricultural work, and contributes to low school enrollment. There is documented evidence of the positive correlation between improved access to modern energy services and educational achievements. In Mali, girls' scholastic achievements were measurably higher after the introduction of village level mechanical power for grinding, pumping, and threshing services (UNDP 2004a or b). King and Alderman (2001) summarize studies that show that investment in infrastructure saves time spent collecting water and fuelwood and benefits all household members; in particular, such infrastructure investments result in fewer interruptions to women's paid work and to girls' schooling. Schultz (1990) suggests that girls are constrained in their schooling in part by the demands placed on their time and suggests that the use of electricity and refrigeration could reduce households' dependence on the labor of girls. Reflecting the complexity of the problem, Glick and Sahn (1999) argue that increased income is also important, since even when electricity access is available in urban areas domestic work obligations continue to limit female schooling for the very poor.

Another important dimension to the provision of efficient education services is the availability of qualified teachers. One of the most often cited factors affecting teachers' retention in rural areas is the lack of access to modern energy services, in particular lighting and power that enable a minimum quality of life and connectivity. Energy and ICT in schools can also enable access to educational material, distance learning, and continuing education for teachers.

All of these linkages are critical in supporting the achievement of universal primary education as well as the equal participation of boys and girls in education at large.

Gender Equality (MDG Target 4)

Access to energy services affects men and women differently, and the specific energy services used by men and women differ based on the economic and social division of labor in the workplace and at home.

It would be hard to imagine a family in the developed world today spending one or more hours every day gathering biomass such as wood, agricultural residues, and dung, when they could instead buy cooking fuel for the same purpose at a price that reflects income from five or fewer minutes of work. Yet this is the burden of women in the developing world. The disproportionate ammount of daily time and effort women and young girls spend gathering solid fuels and water for household chores could be used for other income-producing activities, family subsistence, or education. The time spent gathering biomass varies with geographic location, land ownership, the time of the year, climatic events, and loss of control over local resources. Figure 6 shows time-use data from Tanzania.

Figure 6.
Time spent (in hundreds of hours) and the transport burden (measured in tonnes km), in Tanzania, per person and per year, disaggregated by gender and tasks

Source: UNDP 1997
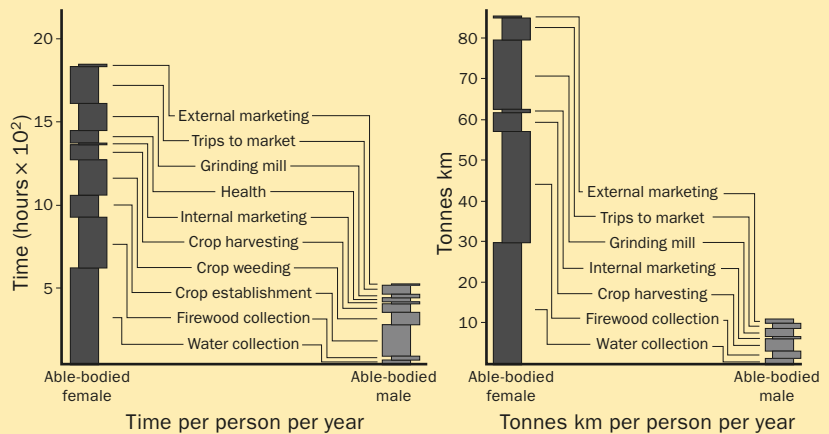
A study in rural India found collection time for wood to be 37 hours per month (ESMAP 2002b). The benefits to health may be even greater (see Box 3).

In addition to the time and effort spent gathering fuel, there are related needs that arise from the need to fetch water and carry supplies and products to and from markets. Frequently water is fetched by girls and women in plastic containers that are either head-loaded or carried strapped on the back, from a water source (river, spring, or a stream) likely to be at a lower elevation or lifted

Box 3.
The impact of energy on women's lives in rural India

Source: ESMAP 2004a.

1. The long, unrecognized hours spent on arduous, unhealthy, and unpleasant tasks have sometimes been cited as a development outcome for rural energy projects. But the main motivation for rural energy programs justifiably has been generally improving the quality of rural life, conserving fuel, and alleviating deforestation. This study shows that the impact of adopting modern energy services by rural women may be even more significant than was previously assumed by development researchers. As a consequence, in designing rural energy programs it is not unreasonable to pay more attention to the problems women have in obtaining a reliable and efficient energy supply.

2. Women in India typically spend much of their time on the hard work involved in caring for their families. They often work 12 to 14 hours a day, most of which is unpaid and recognized mainly within the family. In addition, some of those hours are spent in an extremely unhealthy environment. Respiratory illness and eye problems are common among women who cook on traditional *chulhas* (Smith 1998). Infant mortality may also be higher among children raised in such homes (Hughes and Dunleavy 2000; Claeson et al. 1999; Mishra et al. 1997). This study supports the findings that women who use biofuels lead the most burdensome lives. Of the three biofuels, firewood involves the most drudgery in terms of time and effort needed to collect it on a regular basis, but in terms of time spent cooking it is a better alternative than agricultural residues or dung. In any event, most women use a combination of these fuels to meet their energy needs.

3. The use of LPG or kerosene stoves relieves women of much of the most arduous tasks involved in cooking for their families and permits them to lead a relatively comfortable and healthy life. Household electrification also has positive consequences for women in terms of their general quality of life, including an increased likelihood that they will read, watch television, and earn income. Having lights at night increases their ability to read in the evening after dark. However, the advantages of electrification could be exploited even more, as there still is a puzzling underinvestment in appliances such as mixers, grinders, blenders, and others that could help women with their daily household work.

4. While the Government of India in association with many other non-governmental private organizations has instituted various programs to address rural energy problems, the execution, pace, and rigor of implementation has been uneven. The results of this study indicate that such programs are essential to bringing about greater independence of women, principally through reducing the time spent on such tasks as fuelwood collection, food preparation, and cooking. In addition, the subordinate position of women in rural society needs to be recognized in the development and implementation of rural energy programs. Many recent studies indicate that the consultation with and participation of those benefiting from development programs lead to a greater likelihood of their success.

5. Kerosene, LPG, electricity, and improved stoves do appear to have a significant impact in terms of reducing arduous tasks performed by women in rural households. Besides improving the quality of life, in some cases electricity can be used for productive and income-producing activities inside the home. Although not all households or all women in rural households will take advantage of the benefits made possible by the modern use of energy, the benefits for the majority of households are cumulative and worthwhile. In this context, energy policymakers need to pay more attention to the impact of modern rural energy services and how they affect the lives of women.

from a well. Mechanical power—perhaps from a windmill, a diesel generator, or an electric motor—can provide the means to lift the water to a storage tank. Modern energy services through use of electric or fuel-operated pumps can make it easier to bring water supply closer to home. Rosen and Vincent (1999) report that households (primarily women) spend an average of 134 minutes per day collecting water and that the time saved by bringing water supplies closer to households is likely to dominate estimates of the benefits of improving rural water supplies.

The time spent collecting fuelwood also reduces the proportion of daylight hours otherwise available. These hours may be critical to other income-generating activities such as commercial foods vending, which is facilitated by improved heating and lighting; agricultural processing using mechanical power; beer brewing, and many trading activities. The costs of energy inputs into these businesses are high and the lack of more-affordable alternatives limits the income-generating opportunities faced by women. Case studies show that access to modern energy services can greatly improve the profitability of these businesses as well as the quality and quantity of the traded product (Misana and Karlsson 2001). For example, in West Africa, motorized mills increased the daily production of shea butter by 200 percent, decreased fuelwood consumption for processing, and increased incomes significantly. Thus an important way in which improved energy services contribute to gender equality is by enabling productive work that is primarily undertaken by women.

Modern energy services facilitate ICT and ease political engagement for those unable to travel far from the home and village. Women also directly benefit from public health facilities closer to home, and with modern energy services the functioning of health clinics in rural areas is improved, as discussed in the following section.

Health (MDG Targets 5–8)

There are close linkages between health issues and energy use, and between the quality of health services and the availability of quality energy services.

There is increasing evidence that the burning of solid biomass fuels for cooking in indoor environments, especially using traditional stoves in inadequately ventilated spaces, can lead to an increased disease burden. WHO now estimates that the impact of indoor air pollution on morbidity and premature deaths of women and children is the number one public health issue in many developing countries, particularly for the poorest segments of the population. Once again, women (including mothers with young children)—who carry out a disproportionate amount of cooking activity—are also likely to share a disproportionate disease burden. There has been substantial recent progress in measuring, examining, documenting, and identifying quantitative links between the use of solid cooking fuels and the associated disease burden (Ezzati and Kamen 2001; von Schirnding et al. 2002; Warwick and Doig 2004). In

addition to the respiratory health burden posed by the use of traditional fuels, women also face health dangers such as vulnerability to cuts, animal bites, falls, sexual attack, and back injuries as they travel long distances to collect and carry traditional fuels for home use (UNDP 2000, p. 49).

Recent studies have detailed the relationships among three variables—fuel type, kitchen type (indoor versus outdoor), and kitchen ventilation—and exposure to particulate matter experienced by those within household cooking and living areas (ESMAP 2002c, 2003, 2004b). The studies note that two factors—use of solid fuel and lack of ventilation—were associated with the highest particulate matter levels, adding that women responsible for cooking experienced the highest exposure. These studies have suggested that a combination of interventions—including ventilation, behavior changes, and fuel switching—may offer health advantages. Meanwhile, they suggest the adoption of the use of the household environmental health indicator—*levels of access to clean fuel and to ventilation*—as an air-quality-related parallel to that of the widely accepted indicator for water and sanitation—*levels of access to clean water and to sanitation.*

Smoke produced during the combustion of solid fuels contains a number of pollutants such as particulates, carbon monoxide, and formaldehyde. In households with limited ventilation (as is common in many developing countries), exposures experienced by household members—particularly women and young children who spend a large proportion of their time indoors—have been measured at levels many times higher than health-based WHO guidelines and national standards (Bruce et al. 2000 ; Smith et al. 2003). Exposure to small particulates (less than 10 microns in diameter) is believed to be a risk factor for acute respiratory infections (ARI) and acute lower respiratory infections (ALRI). Such exposure also appears to be associated with chronic bronchitis (assessed by symptoms) and chronic obstructive pulmonary disease (COPD—progressive and incompletely reversible airways obstruction), particularly among women. Smith et al.(2003) report evidence from China that exposure to coal smoke in the home markedly increases the risk of lung cancer, also particularly in women. Though tentative, evidence is accumulating that indoor air pollution is associated with other important child and adult health problems, such as low birth weight babies and blindness in adults (Mishra et al. 1999). It is estimated that 1.6 million deaths per year (of which 60 percent are female) in developing countries are associated with the inhalation of indoor air smoke from the use of solid fuels. This makes indoor air pollution the fourth leading cause of premature death in developing countries (Bruce et al. 2000).

A recent World Bank (2004a) report on policies and actions for achieving the MDGs states that, in 1999, some 10 million children under the age of five died in low-income countries—2.1 million in India alone. Using Indian health survey data, World Bank researchers have concluded that investments targeted at improving environmental conditions, including access to piped

water, electricity and separate kitchens with clean cooking fuels, can substantially reduce child mortality (van der Klaauw and Wang 2003).

Health care infrastructure even in the smallest clinics and health centers relies on refrigeration for vaccines and sterilization. Illumination for patient care after dark, for operating theaters, and for public safety surrounding hospitals increases the health systems' ability to serve poor populations. Improved lighting and hygiene from clean water would help reduce women's mortality rate at childbirth. Modern fuels and/or electricity are essential for these functions. Electricity is essential for many medical instruments, illumination, medical record keeping, communications facilities for reporting medically significant events, and medical training.

The global HIV/AIDS pandemic has many direct and indirect linkages to energy services. Global evidence suggests that education and awareness campaigns, including those using radio and television, which require electricity, are essential to educate at-risk populations about prevention and treatment options in the most affected areas. Another key linkage is the role energy services can play in substituting for labor in areas where labor shortages exist as a result of HIV/AIDS. Research in Kenya (Muchena et al. 2005), and on the impact of AIDS on available labor for the livestock (Engh et al. 2000), non-timber forestry (Barany et al. 2001), and other agricultural sectors, shows dramatic labor shortages throughout sub-Saharan Africa, even in densely populated areas such as Kisii in Kenya (800 persons km^{-2}). As a result of labor shortages, food shortages are reported as well, for example in Zimbabwe (UNAIDS 1999).

Environmental Sustainability (MDG Target 9)

The way energy is produced, distributed, and consumed affects the local, regional, and global environment through land degradation, local air pollution, acidification of water and soils, or greenhouse gas emissions. Biomass harvesting without sustainable agroforestry management can lead to land degradation, including soil and water resources, and vegetative cover. Fossil fuel use, exploration, transportation, transformation, and distribution will have some unavoidable detrimental effects on the environment. The strong linkages between the production and use of all energy forms are central to the climate change debate, particularly the long-term impact on, and risks for, developing countries, with the likelihood that the poorest populations are increasingly vulnerable.

The world is not short of technologies and technical solutions. For example, modern diesel engines in Europe are much cleaner today than the higher-emission older technologies still used in many developing countries that do not have environmental regulations. Natural gas is a much cleaner fuel than oil and can replace liquid fuels for power generation and even transportation. Pipelines may be a better way to transport aggregated fuel supplies than trucking. Shifting to such improved technologies can significantly reduce the environmental pressure resulting from energy use.

An important question is whether fuelwood collection—for use in rural areas, for sale in urban areas, or for charcoal production—causes or contributes to deforestation. Most studies identify the conversion of forests to agricultural use and their nationalization—denying unorganized, underprivileged people, particularly women, access to natural resources—as the main drivers of deforestation (e.g., Leach and Mearns 1988; Sarin 1991; UNDP 2000; ESMAP 2005a). Depletion of the forests may also result from timber sales or commercial charcoal production. Furthermore, it appears that fuelwood scarcity may also result from deforestation caused by other factors. When a forest resource is severely depleted—due to reasons other than fuelwood collection—continued fuelwood collection may indeed make the problem worse. This circumstance, along with already depleted soils, may create a situation where biomass waste or dung that could help restore the soil is used as cooking fuel; interventions with modern fuels may offer a way out of this vicious circle.

In reviewing two decades of fuelwood crisis in Kenya, Mahiri and Howorth (2001), conclude that, in this context, the causes and dynamics of deforestation differ in urban and rural areas, suggesting local specificity. The problem of indiscriminately felling trees and the resulting environmental degradation may exist near urban centers, but in rural areas the situation is intricately tied in with land use and control; those who can consolidate land by building a fence are able to increase their wood supply, but those who cannot have declining access to fuelwood. In a meta-study, Geist and Lambin (2002) analyze the frequency of proximate causes and underlying driving forces of deforestation, including their interactions, as reported in 152 sub-national case studies from Asia (55 studies), Africa (19 studies), and Latin America (78 studies). Only in Africa does wood extraction for fuelwood contribute significantly to tropical deforestation.

In considering the environmental impact of energy use, greenhouse gas (GHG) emissions are a key concern. It is essential to draw a distinction between fossil fuel use in the poorest LDCs where energy consumption and GHG emissions are low both per capita and in aggregate and where the primary concern is the local environment, and fossil fuel use in industrialized and rapidly industrializing countries, where per capita emissions and aggregate emissions are much greater and therefore more significant on a global scale. This distinction is the basis for the principle of 'common but differentiated responsibilities' for emissions mitigation and reduction which is at the heart of global accords on climate change. Much of the growth in fossil fuel consumption in developing countries will come from increased industrial and transport use as a result of economic growth. This growth will permit economic transitions, which in turn will decrease these countries' vulnerability arising from their present high dependence on land-based production activities such as agriculture and fisheries. Current fossil fuel consumption levels in tropical sub-Saharan Africa are so low that even if these countries increased at an annual rate of 10 percent (the

annual rate at which China's consumption grew during the 1971–97 period), by 2015, the associated per capita GHG emissions will remain at levels that are less than 5 percent of those in the high-income countries today.

The distinction is even greater when the LDCs are compared to industrial nations. By way of example, United States carbon dioxide emissions per capita are nearly 200 times those of Ethiopia. This is due largely to the fact that Ethiopia's cooking fuel consists predominantly of biomass, and much of its electricity is produced from hydropower (both nominally renewable resources). So even if Ethiopia's fossil fuel consumption were to increase six-fold by 2015 (this would imply a rate of growth far higher than that achieved at any time in even the fastest growing countries), its per capita carbon dioxide emissions would still be thirty times less than those of the United States. Countries that experienced dramatic economic growth in the last two centuries can now afford to make large-scale investments in modern energy services that do not rely on fossil fuels, biomass, or hydroelectric power.

Overall, increased GHG emissions from sub-Saharan Africa are not likely to have any significant impact on the world climate, nor have any mechanisms been identified that suggest that the region's own GHG emissions will have feedback effects on climate locally. Moreover, natural gas and LPG produce far less potentially detrimental emissions, at least to the immediate user, than wood or dung. Furthermore, a switch to modern cooking fuels would not be limited by world resources or by GHG emissions, as Smith (2002) noted: "Even if all 2 billion people shifted to LPG for household fuel, it would add less than 2 percent to global greenhouse gas (GHG) emissions from fossil fuels. In terms of human health, a shift to LPG would actually result in a net reduction of human exposures to air pollution that would be substantially larger than today's total exposure from all fossil fuel emissions." When considered on a global scale, the energy source choices of the poorest countries are not the most threatening from an environmental perspective. Meeting domestic economic growth and social development requirements in line with the sustainability of the domestic resource base should be the overriding concern in these cases.

There may, however, be significant impacts of climate change on the energy sector in sub-Saharan Africa due to the region's high reliance on biomass and hydropower. For example, changes in precipitation can be felt through loss or variability in hydroelectric potential, variations in runoff (which can lead to siltation, with subsequent impact on hydroelectric power generation), and impacts on biomass (and hence fuelwood and charcoal) production. Despite their low total and per capita carbon emissions, the poorest are more vulnerable to these and other impacts of climate change and are expected to experience greater pressure to adapt.

In some circumstances, it may be prudent for the poorest to consider leapfrogging to newer low carbon and/or renewable technologies even if they may not be strictly cost-competitive at present. Such circumstances may arise when

other factors such as the cost of reliance on imports, domestic job growth, and effects on the environment and tourism are taken into account. Goldemberg et al. (2004) argue that Brazil's commitment to ethanol from sugarcane—a move that involved high initial costs—paid off since Brazil has become the most efficient sugarcane producer. Similar long-term benefits from investment in renewable energy-based electricity generation and/or biomass-based technologies may accrue on a case-by-case basis. Such technologies should definitely be considered as alternatives to fossil-fuel-based energy systems, even if fossil-fuel-based options continue to be cost effective and play a significant part in meeting developing countries' energy needs for decades to come.

Water Supply and Sanitation (MDG Target 10)

At the community level, water and sanitation are linked to energy through a variety of needs. Some of the benefits from water services powered by improved energy services—such as reductions in mortality and morbidity that could be gained through expanded access of the poor to piped water—are discussed above in the section on the MDG health targets. Other, similarly important needs include boiling water for basic health and medical uses and pumping water for household, agricultural, and potentially commercial uses. At a larger scale, approaching the national or regional level, hydropower provides synergistic links in energy production and water management. Meeting the MDG target of increasing the supply of safe drinking water and basic sanitation will require investments in infrastructure that utilizes modern energy, especially electricity, to deliver services to poor people and communities.

Summary

It is clear that energy services have an impact on all of the MDGs and associated targets. Access to energy services facilitates the achievement of these targets. Failure to consider the role of energy in supporting efforts to reach MDGs will undermine the success of the development options pursued, the poverty reduction targets, as well as the cost effectiveness of the resources invested. Table 3 summarizes the linkages between energy and the MDG targets discussed in this chapter.

Table 3.
Important linkages between energy services and the Millennium Development Goals

Source: DFID 2002.

Goal 1: Eradicate extreme poverty and hunger

Importance of energy to achieving the Goal

- Access to affordable energy services from gaseous and liquid fuels and electricity enables enterprise development
- Lighting permits income generation beyond daylight hours
- Machinery increases productivity
- Local energy supplies can often be provided by small-scale, locally owned businesses creating employment in local energy service provision and maintenance, fuel crops, etc.
- Privatization of energy services can help free up government funds for social welfare investment
- Clean, efficient fuels reduce the large share of household income spent on cooking, lighting, and keeping warm (equity issue—poor people pay proportionately more for basic services)
- The majority (95 percent) of staple foods need cooking before they can be eaten and need water for cooking
- Post-harvest losses are reduced through better preservation (for example, drying and smoking) and chilling/freezing
- Energy for irrigation helps increase food production and access to nutrition

Goal 2: Achieve universal primary education

Importance of energy to achieving the Goal

- Energy can help create a more child-friendly environment (access to clean water, sanitation, lighting, and space heating/cooling), thus improving attendance at school and reducing drop-out rates
- Lighting in schools helps retain teachers, especially if their accommodation has electricity
- Electricity enables access to educational media and communications in schools and at home that increase education opportunities and allow distance learning
- Access to energy provides the opportunity to use equipment for teaching (overhead projector, computer, printer, photocopier, science equipment)
- Modern energy systems and efficient building design reduces heating/cooling costs

Goal 3: Promote gender equality and empower women

Importance of energy to achieving the Goal

- Availability of modern energy services frees girls' and young women's time from survival activities (gathering firewood, fetching water, cooking inefficiently, crop processing by hand, manual farming work)
- Clean cooking fuels and equipment reduces exposure to indoor air pollution and improves health
- Good quality lighting permits home study and allows evening classes
- Street lighting improves women's safety
- Affordable and reliable energy services offer scope for women's enterprises

Goal 4: Reduce child mortality

Importance of energy to achieving the Goal

- Indoor air pollution contributes to respiratory infections that account for up to 20 percent of the 11 million child deaths each year (WHO 2002, based on 1999 data)
- Gathering and preparing traditional fuels exposes young children to health risks and reduces time spent on child care
- Provision of nutritious cooked food, space heating, and boiled water contributes towards better health
- Electricity enables pumped clean water and purification

Goal 5: Improve maternal health

Importance of energy to achieving the Goal

- Energy services are needed to provide access to better medical facilities for maternal care, including medicine refrigeration, equipment sterilization, and operating theatres
- Excessive workload and heavy manual labor (carrying heavy loads of fuelwood and water) may affect a pregnant woman's general health and well being

Goal 6: Combat HIV/AIDS, malaria, and other major diseases

Importance of energy to achieving the Goal

- Electricity in health centers enables night availability, helps retain qualified staff, and allows equipment use (for example, sterilization, medicine refrigeration)
- Energy for refrigeration allows vaccination and medicine storage for the prevention and treatment of diseases and infections
- Safe disposal of used hypodermic syringes by incineration prevents re-use and the potential further spread of HIV/AIDS
- Energy is needed to develop, manufacture, and distribute drugs, medicines, and vaccinations
- Electricity enables access to health education media through information and communications technologies (ICTs)

Goal 7: Ensure environmental sustainability

Importance of energy to achieving the Goal

- Increased agricultural productivity is enabled through the use of machinery and irrigation, which in turn reduces the need to expand quantity of land under cultivation, reducing pressure on ecosystem conversion
- Traditional fuel use contributes to erosion, reduced soil fertility, and desertification. Fuel substitution, improved efficiency, and energy crops can make exploitation of natural resources more sustainable
- Using cleaner, more efficient fuels will reduce greenhouse gas emissions, which are a major contributor to climate change
- Clean energy production can encourage better natural resource management, including improved water quality
- Energy can be used to purify water or pump clean ground water locally, reducing time spent collecting it and reducing drudgery

CHAPTER 3: MDG-Compatible Energy Services and Targets

Without a certain minimum, but absolutely essential, amount of energy—for example, the energy needed to cook food and stay warm in cold climates—human existence would be impossible. But a society needs more than this life-sustaining amount of energy in order to be productive, educate its children, and ensure good health and access to water and sanitation for its citizens and other essentials. How much more energy, and in what form, is sufficient to meet the MDGs?

This chapter attempts an answer to this challenging question, which must be answered as part of countries' efforts to prepare MDG-based national development strategies. It first describes the types of energy that households and societies need to have access to if the MDGs are to be achieved, and then proposes a set of quantitative and time-bound energy targets for meeting those specific energy needs. These targets lay the foundation for the discussion of specific technology options and implementation challenges in the next chapters.

Types of Energy Access Needed

Modern energy services are essential for the development of productive activities that raise the incomes of the poorest, for basic health and educational needs, for many water supply systems, and for progress on other aspects of the MDGs. Meeting the Goals requires access to at least three types of energy services: (1) energy for cooking, (2) electricity for illumination, ICT, and appliances to support household and commercial activities and the provision of social services, and (3) mechanical power to operate agricultural and food processing equipment, to carry out supplementary irrigation, to support enterprises and other productive use, and to transport goods and people.

Energy for Cooking

Most food must be cooked before it can be ingested and transformed into human energy—the primary input for the essential activities of agricultural production and transportation in poor economies. Thus sustainable, reliable, and least-cost access to cooking fuels is among the most basic energy needs for the world's poor. There are multiple pathways by which those cooking with traditional solid biomass fuels can benefit from switching at least partially to the use of clean-burning cooking fuels. While the precise mechanisms are not all fully understood and quantified, there is now substantial evidence that this switch leads to positive outcomes for multiple MDGs. The multitude of short- and long-term benefits to health, productivity, agriculture, the environment, and women's welfare that modern cooking fuels provide suggests that a rapid scale up of modern cooking fuel distribution systems should be an important part of the strategy to meet the MDGs.

The annual amount of energy required for cooking varies with the type of food, fuel, and stove used and the specific cooking practices of a household. More than 80 percent of the heat generated while cooking with wood on a traditional three-stone fire does not end up 'in the pot,' whereas with kerosene and LPG nearly half can, doubling the cooking efficiency per unit of energy consumed. Diet is also a factor in energy needs. Cecelski (1987) reports that coastal communities in Peru and Ghana, where fish consumption is high, use much less cooking fuel than inland villages relying on hard staples such as maize, cereals, potatoes, and cassava. When most of the food eaten is prepared at home, the yearly need for energy per capita for cooking ('into the pot') is about 1 GJ with few exceptions and within about a factor of two. In most of the poorest households, this need is primarily met by burning roughly one half tonne per person per year of firewood (also crop residues and dung) in open fires—depending upon the kind of wood, its water content, and the kind of fire. A family of six thus uses about three tonnes of biomass each year. If cooking fuel needs were met exclusively by either LPG or kerosene , and accounting for energy efficiency of these fuels and typical stoves, the amount used would be about 40 kg of LPG (or about 45 kg of kerosene) per person per year. In practice, a combination of different fuels is frequently used, including biomass, biomass-derived fuels (such as charcoal or biogas), and fossil fuels.

For food preparation, process heat, and transportation, other energy carriers are generally more suitable than electricity. These include natural gas; LPG; liquids such as kerosene (a petroleum-derived fuel that is liquid at atmospheric pressure and does not need a specialized container, but is not as clean burning as LPG); ethanol (or ethanol-derived gel fuels); or dimethyl ether (DME, an energy carrier that could be derived from solid biomass and may emerge in the near future as a potential carrier); and diesel or petrol for transportation. For cooking, gaseous and liquid fuels have many benefits in addition to convenience. As income increases, they are increasingly preferred to traditional fuels

such as solid biomass due to the high and quick heat produced and the relative cleanliness of the technology. Energy and fuels for cooking are particularly important for meeting MDGs 1, 3, 4, 5, and 7.

Electricity for Lighting, ICT, and Appliances

Along with liquid fuels, electricity deserves special consideration as an energy carrier. Electricity is primarily produced from mechanical power. Mechanical power can be derived from high-grade heat from a multitude of possible sources, including chemical energy carriers like coal, oil, natural gas, and biomass which is used to power turbines that produce electricity. Geothermal heat, heat from nuclear fission, and the potential energy of water at an elevation in hydroelectric power plants can also produce electric power. It is also becoming increasingly cost-effective to generate electricity from wind (where strong sustained winds are available) and through direct conversion of sunlight using photovoltaic (PV) cells. PV is clean and can be scaled down to a few watts, and is thus ideal for household consumption. But PV technology still has a high initial cost and some recurring costs that have not declined as rapidly as expected due in part to the need for 'balance of system' components like batteries needed for storage.

Electricity can be distributed through centralized systems or electricity grids or through decentralized systems in which the electricity is consumed near or at the point of generation. Many renewable energy applications are engineered to provide decentralized electricity but can also be grid connected when the electricity is generated on a large scale as in the case of a wind farm. Hybrid systems combining conventional and renewable energy sources can also be used to generate decentralized electricity. In general, urban areas are within closer reach of electric power grids and rural areas face greater challenges in reaching them.

Electricity from all sources is important to support productive activities both at home and in the marketplace; to support the delivery of social services such as education, health care, and functioning public sector offices; and to produce illumination for use at home. Electricity supports modern information and communication systems and enables the public sector to function and the private sector to produce value-adding activities within the economy. Electricity for illumination is particularly important for MDGs 1, 2, 3, 6, and 7.

Mechanical Power for Agro/Food Processing, Water Pumping, Enterprises and Other Productive Uses

Mechanical power is important for meeting the MDGs, and its direct use in some contexts could make it possible to bypass intermediate conversion to electricity. Mechanical power produced in engines has a variety of valuable uses that are most important in rural areas, including transportation, pumping water, irrigation, intensification of agriculture (tractors and farm equipment),

processing of agricultural products (moving, crushing, grinding), among a multitude of other uses. These systems rely on the availability and affordability of common transportation fuels such as diesel. When available in rural areas, mechanical power can displace human and animal labor and greatly increase economic productivity and livelihoods. As noted earlier, access to mechanical power for water pumping and transport, food milling, and agricultural processing has a particularly direct effect on freeing the time of women and children for human development. In rural areas where the electricity grid will be slow or unlikely to reach, decentralized mechanical power from conventional or renewable energy is extremely important to reduce poverty and increase economic options. Mechanical power is particularly important for MDGs 1, 2, 3, 5, and 7.

Setting Energy Targets for Meeting the MDGs

The Millennium Declaration does not stipulate specific targets for energy services. It does, however, specify numerical time-bound targets for each of the MDGs. These targets represent milestones in addressing extreme poverty in its many dimensions—income poverty, hunger, disease, lack of adequate infrastructure and shelter, and exclusion—while promoting gender equality, education, and environmental sustainability. While modern energy services are an essential element enabling a country to meet these Goals, it has been difficult to establish quantitative causal relationships between energy and progress toward the MDGs.

Identifying such targets is difficult because energy needs are highly diverse. First, countries need affordable and reliable access to energy in order to carry out many productive activities that generate income, initiating the process of economic growth and poverty reduction. Second, countries need energy to alleviate many broader conditions that can prevent people from contributing to and benefiting from economic growth. Third, the agroecology, geography, and unique composition of the local economy also matter in determining the type of energy carriers and services that are required.

In full recognition of these complexities, a workshop was held in New York City in October 2004, under the sponsorship of the UN Millennium Project, to identify possible energy targets in support of the MDGs. This workshop drew on the insights of many of the world's foremost experts on the role of energy in development (the attendees are listed in Appendix I). An attempt was made to evolve a vision comprising a set of energy services that could provide a way forward toward meeting the MDGs by 2015. The overriding conclusion from this workshop was that energy services must be explicitly addressed within the planning for poverty reduction and for meeting the broader MDGs. Where energy is found to be a crucial and limiting input, provisions for reliable and low-cost energy services must be made in a detailed and practical manner. The group recommended the following

energy targets for 2015, deemed necessary for meeting the MDGs in each country:

- **Enable the use of modern fuels for 50 percent of those who at present use traditional biomass for cooking. In addition, support (a) efforts to develop and adopt the use of improved cookstoves, (b) measures to reduce the adverse health impacts from cooking with biomass, and (c) measures to increase sustainable biomass production.**
- **Ensure reliable access to electricity to all in urban and peri-urban areas.**
- **Provide access to modern energy services (in the form of mechanical power and electricity) at the community level for all rural communities.**

In setting forth these objectives, workshop participants acknowledged and drew upon crucial insights of current development thinking that also underlie the MDGs. Meeting the MDGs will require many synergistic interventions, necessitating a combination of high impact, least-cost, and scalable means.

Attention to the household level, and the health and welfare of poor women, is addressed particularly, but not exclusively, through the target for cooking fuel. The target for electricity services for the urban and peri-urban poor recognizes that access to mechanical power generally is already present in urban areas. It also anticipates the global demographic transition toward urbanization currently under way. The target acknowledges the inherently lower cost for added access in urban and peri-urban areas, and potentially lower technical losses; it recognizes that the population targeted has greater ability to pay due to greater density of demand; and it recognizes the need to support industrial and commercial growth in urban areas. Access to both mechanical power and electricity are also needed in rural areas. A cost-effective approach would emphasize availability of electricity at the community level to support delivery of social services such as health, education, potable water, and agriculture extension that would enable even the poorest to benefit in an equitable fashion. Access to mechanical power is particularly important for rural areas as it can provide power for productive uses. The mechanical power target recognizes the gap in access between rural and urban areas and the need to fill this gap.

The workshop participants also addressed the analytically difficult question of financing. The broad consensus was that low-initial-cost technologies are essential for a rapid scale up of services even if some of the technologies may be transitional. For example, in the short term, improving supply and use of solid biomass for cooking may indeed be the most viable option, at least in rural areas, even though modern liquid and gas cooking fuels are desirable. Moreover, intermittent demand for energy services for agroprocessing and supplemental irrigation, as well as low-level demand in the evening hours for lighting, might be best met by low-initial-cost technologies even though the recurring costs per unit hours of service are high in the short term.

Focusing on three key energy entry points—cooking fuels, electricity in urban areas, and mechanical power and/or electricity at central points in rural areas—can be a means of focusing national MDG plans and development strategies on those energy interventions that will have the greatest impact on MDG targets in the shortest timeframe. The longer-term objective of universal access to electricity remains valid, but experience within the energy and development communities over the last 30 years has shown that progress toward this goal has been slow. By suggesting three priority areas of intervention, MDG planners and national authorities can focus on the concrete investments, delivery systems, and public policies for a narrower range of energy options as a means to overcome poverty.

Significantly, the very important role of fuels in addressing human health and welfare as well as the status of women has received relatively less attention over the years in both energy sector management and development planning at large. An accurate estimate of the number of people who do not have access to mechanical power for pumping, grinding, and food processing is not even known. As most of this work is done by animals and unpaid people, women in particular, current economic costing methodologies often overlook the significant role that this category of energy service plays in rural development. This chapter has highlighted the essential roles played by all three proposed energy entry points in achieving the MDGs.

CHAPTER 4: Strategies and Technology Options for Meeting the Energy Targets

The MDG-consistent energy targets outlined in the previous chapter specify energy services but not specific technologies. In the poorest countries, energy services should be provided using proven, robust technologies that are cost-effective and can be implemented at scale. If modern energy services are to truly make progress on multiple MDGs, they must serve many different economic and social sectors and employ multiple technologies in as flexible a manner as possible, while still taking advantage of the economies of scale that large systems may offer. The design of energy systems and programs must not only solve technological and economic problems, but must also draw upon and incorporate the priorities and lessons of development history that have come to emphasize the needs of women, community ownership, and the importance of both economic and environmental sustainability.

Chapter 3 identified key energy services—energy for cooking, electricity for urban and peri-urban areas, and community-level modern energy services (with a focus on mechanical power and electricity) for rural areas—that should be targeted for expansion in order to achieve the MDGs, as an essential component of any MDG-based national development strategy. This chapter discusses strategies for reaching the three MDG-consistent energy targets, taking into account economic, geographic, and demographic variations among countries. See Box 4 and Table 4 for examples of these variations. These practical strategies can assist countries in designing the energy components of national development strategies for meeting the MDGs.

Box 4.
Factors that influence the cost and efficacy of energy services in urban and rural areas

City size and density have been important factors in determining social complexity and technological evolution (Ausubel and Herman 1988). The size and density of a city enable specialization, bring people together, and lead to new businesses and products. To ensure that these engines of growth flourish it is important that their unique technical problems of communication, transport, and energy are addressed. High population densities in urban areas lead to higher densities of energy consumption and allow economies of scale (Marchetti 1975).

Urbanization is increasing in the developing world; in 1999, about 40 percent of the world's 1.3 billion poor people lived in peri-urban agglomerations. For a variety of reasons—irregular tenure to dwellings, shared spaces, ill-defined responsibilities for payment, and low consumption levels—the urban poor may be poorly served by energy systems. They tend also to pay high prices both for relatively poor kerosene-based light and for low-quality biomass cooking fuels. Slum dwellers are frequently ignored and bypassed in favor of rural populations in spite of their active participation in the economic growth of the city.

The growth of secondary cities with sufficient density presents opportunities for relatively inexpensive extension of modern energy services to a greater proportion of a country at lower cost. The percentage of the population that lives in cities larger than 50,000 people is shown for a few sub-Saharan African countries in Table 4, which also presents data on reliance upon traditional biomass cooking fuels and access to electricity. The table also highlights the tremendous difference, in the rare cases where data are available, between the availability of electricity to urban and rural residents—a difference that tends to be an order of magnitude or greater, particularly in the poorest countries.

Perhaps the most profound influence on the cost and viability of various energy technologies and systems in rural areas is the distribution of people—in terms of both need and ability to pay. For all major energy types considered here, the question of how demand can be aggregated across multiple service needs and multiple households or communities is a crucial one in determining how many of the poor can be reached, and at what level of service, in a cost-effective manner. Rural populations may, though do not always, present highly disaggregated demand patterns for cooking fuel, electricity, mechanical power, and transportation. Meeting this dispersed need often requires very different basic energy technologies, system designs, billing systems, and other features than are necessary or viable in urban and peri-urban areas. This can be further complicated by the higher levels of poverty that usually prevail in rural areas. For rural areas where the poor are very cash-poor, energy services may require delivery in smaller, more portable, less expensive units that help to meet what may be a more dispersed and intermittent need.

Table 4.

Urban and rural dimensions of energy use in selected sub-Saharan African countries

Sources:
a. CIESIN, 1999; b. IEA 2002b; c. GNESD 2004; d. ARFEPREN 2004;
e. Clarke and Wallsten, 2002; f. Gordon et al. 2004

	National population (millions)[a] [1999]	National electrification rate (%)[b] [2000, 2004]	Urban electrification rate (%)[d] [2004, 2002]	Rural electrification rate (%)[d] [2004, 2002]	National reliance on solid cooking fuels (%)[f] [2004]	Share of population in secondary cities (%)[a] [1999]
Ethiopia	61.7	4.7	13.0	0.7	> 95.0	8.0
Ghana	19.7	45.0	82.5	20.9	95.0	25.0
Tanzania	32.8	10.5	39.0	1.0	> 95.0	27.0
Kenya	29.5	7.9	20.0	1.7	85.0	13.0
Niger	10.4	< 1.0[c]	36.6	0.2[e]	> 95.0	17.0
Senegal	9.3	30.1	68.9	6.0	79.0	43.0
Chad	7.5	–	9.4	0.1[e]	95.0	13.0

– Not available

Box 5.
Energy efficiency

Increased energy efficiency—whether during generation/production, transport/transmission, or end use—can have wide-ranging benefits. The full extent of these benefits is difficult to capture in developing countries, where low-initial-cost appliances/technologies might be preferred, capital for replacing inefficient equipment might not be available, and regulatory/technical standards might be inadequate. Energy efficiency standards for appliances (for example, for lighting and refrigerators) in developed countries suggest that, at least in the urban, commercial, industrial sectors, it may be possible to use a combination of awareness, technical standards, and pricing policies that can create a long term win–win situation for both energy providers and consumers.

There are significant opportunities for improving energy efficiency in the rural sector as well, such as in charcoal production, the use of cooking fuels and in lighting (whether kerosene or electricity-based). But these are more difficult to address since the human and capital resources to address these at scale are frequently inadequate. Careful evaluation of the multiple impacts of inefficiencies in production/use are needed to suggest investments in: (1) research, (2) technology transfer, (3) product development/testing, (4) training and capacity building, (5) regulation, monitoring, and enforcement, and (6) supply and distribution chain development so that the economic and social benefits of energy efficiency and energy conservation can be realized.

Energy for Cooking

MDG-consistent target:

- **Enable the use of modern fuels for 50 percent of those who at present use traditional biomass for cooking. In addition, support: (a) efforts to develop and adopt the use of improved cookstoves, (b) measures to reduce the adverse health impacts from cooking with biomass, and (c) measures to increase sustainable biomass production.**

Meeting this target requires reducing by 50 percent the share of those who use traditional biomass for cooking. Traditional biomass fuels consist of fuelwood, crop residues, or dung burnt in open fires, or charcoal burnt in a stove. With the exception of charcoal, in rural areas these fuels are generally gathered by family members from their own or community land. A combination of increasing incomes and decreasing ease with which biomass fuel can be collected is creating a market in these traditional fuels. In many urban and peri-urban areas, the cost of using these fuels is approaching the recurring costs of using modern cooking fuels. This segment of the population would be prime candidates for switching from traditional biomass to modern cooking fuel. Discussed here are the implementation challenges associated with this switch.

The target also recommends additional measures to support the use of improved cookstoves, increased biomass production, and cleaner use of biomass fuels for those unable to switch to modern cooking fuels. The implementation challenges of meeting this target are specific to the local economy.

Synergistic strategies for poverty reduction as well as social development should also lead to increased incomes, making it possible to at least partially close the affordability gap in using modern cooking fuels.

Implementation and Policy Options for Fuel Switching

In areas of higher income and higher population density, a desirable outcome is substituting LPG or kerosene for solid biomass fuels. Otherwise, the energy demands of dense, urban populations are met with purchased fuelwood or charcoal. The costs of these solid fuels incorporate the potentially high transport costs and, in the case of charcoal, low conversion efficiencies. Also, because they are frequently obtained from sources that are not sustainably managed, their prices do not reflect the cost to the environmental commons. Thus from the health, time-saving, and environmental perspectives, there is widespread agreement that the choice of LPG or kerosene is desirable even though they are fossil fuels. Moreover, in many urban areas of sub-Saharan Africa (for example, Accra in Ghana), charcoal and fuelwood are almost the same cost as more modern fuels per unit of energy 'into the pot' (Ahiataku-Togobo 2002).

Perhaps even more than lighting, the upfront costs and the recurring costs of modern cooking fuels such as LPG and kerosene are difficult to afford if the distribution and sale of these fuels is entirely on a cost recovery basis. It is difficult for households making less than US$4 per day (in real US$) to afford the recurring cost of fuel immediately, since household fuel costs alone could be as much as US$0.40 per day (assuming daily consumption of 0.50 kg LPG per household per day and costs of US$750 per tonne if LPG at port is US$450 per tonne and transport, filling, and distribution costs are US$300 per tonne). In contrast, kerosene is easier to carry, transport, and buy in smaller quantities; but as a poisonous, flammable, clear liquid at room temperature it is potentially unsafe to handle without adequate knowledge of use. Nevertheless, because kerosene can also be clean-burning with a proper stove it has the potential to be a transition fuel for cooking. The stoves cost less, and distribution costs are lower as well.

A combination of top-down interventions such as removing taxes, lowered transport and distribution costs (through road/port infrastructure), improved handling and storage facilities at ports, bulk purchases of fuels, and impetus from the government through suitable regulatory reform can assist in lowering the costs of LPG and kerosene. In addition, bottom-up approaches can encourage market development through provision of smaller LPG cylinders and low-cost stoves, upfront payments that are spread out over a longer period, and consumer education. In areas where the bottleneck is the financing of capital costs (for example of an LPG stove and cylinder) and not the recurring costs immediate opportunities exist for policy interventions to support the market penetration of these commercial energy products.

A range of policy measures and implementation instruments are available. For example, the direct subsidy or a form of lease/finance mechanism, and bank loans, can lower the initial costs of the stove and cylinder and reduce the lumpiness of payments. This is particularly important in the rural areas where cash incomes are limited and the initial cost of a cylinder and stove can reach US$40 to US$70. Technical measures, such as the provision of a range of canister sizes with particular emphasis on easy-to-carry smaller canisters can facilitate the marketability of these new energy sources. Institutional measures such as building up partnerships that draw on the strengths of the public sector (village or district government, national, international); the private sector (small and medium-sized enterprises or SMEs, companies and investors); and local institutions (community organizations, NGOs) help create viable new markets. For example, energy service companies that provide energy to customers on a fee-for-service basis have proved quite successful in Sri Lanka, India and other countries. Partnerships between international LPG companies and local companies are important to bring to investors the knowledge of the local markets. Once an effective program is in place, increased use of LPG in urban areas can allow larger bulk imports of LPG, also reducing unit costs.

There is no unanimous view regarding the role of subsidies for recurring fuel costs. Suitably designed targeting to identify those who need subsidies, an exit strategy for those whose consumption and income grow beyond thresholds of eligibility to subsidies, and bill collection schemes that minimize collection costs can all help to ensure that subsidies are indeed reaching the poor with minimum leakage or waste. Two large-scale fuel subsidy programs—one in Brazil, which is viewed as a success, and one in India, which is commonly considered a failure—provide conflicting evidence.

Brazil's energy strategy serves as a useful example of how a government subsidy program can positively and dramatically affect the rate and extent of penetration of modern energy services. Jannuzzi and Sanga (2004) present data on the penetration of LPG (from 18 percent of households in 1960 to 98 percent in 2004) and the concomitant decline of traditional fuel use in the Brazilian residential sector. In the period 1960–85, penetration of fuelwood and kerosene fell from 61 and 20 percent, respectively, to 28 and 7 percent, indicating a shift away from these fuels for cooking and lighting. During the 30-year period beginning in 1973, the inflation-adjusted per capita subsidy (based on the entire participating population) was less than US$1 per year (see Box 6). Brazil's example shows that both across-the-board and targeted subsidies can advance the penetration of modern energy services to the poor, including those in rural areas. Depending upon the depth of a country's poverty, however, the percentage of the population in need of subsidy support will vary, as will the size of the subsidy. Brazil's experience, particularly for LPG, shows that effective scale up can occur and that a program can be revised to become more efficient as it progresses.

In India, LPG subsidies benefited the richest segments of the population and so from an MDG perspective were less successful. During the last decade, the annual LPG subsidy in India has varied between US$0.50 per capita (in the mid-1990s) and US$1.50 per capita (in 2002). However, the bulk of the LPG and hence the subsidy was consumed by about 30 percent of the population—by income, nearly the top half of urban populations and the top 20 percent of rural populations. Thus in 2002, the annual LPG subsidy was about US$5 per beneficiary (or about US$25 per family), with the total annual subsidy amounting to US$1.3 billion (Gangopadhyaya et al. 2005).

A comparison of government programs in India promoting use of 'clean' fuels, such as kerosene and LPG, illustrates some differences in results from ongoing versus 'first cost' subsidies (Viswanathan and Kumar 2005). In the state of Himachal Pradesh, subsidies for LPG, combined with subsidies for use of pressure cookers to increase energy efficiency, resulted in greater penetration of clean fuels into rural areas. However, a universal price subsidy may present problems in the long term, such as continued high burden on the state government budget as well as the fact that as much as 80–90 percent of the benefit of the subsidy may accrue to the richest households, and to urban households,

In Brazil, penetration of LPG services was aided substantially by government programs and subsidies over three decades, during which LPG subsidies helped to keep energy prices essentially stable. Particularly for LPG, the results of the program were dramatic, allowing penetration of LPG (and city gas) to rise from 18 percent nationwide in 1960 to 98 percent of households in 2004. The penetration in rural areas, at 93 percent, is particularly impressive given the difficulty of reaching what are often low-density populations. Other important factors, together with subsidies, helped the widespread dissemination of LPG: the continued support from the government through the state oil company PETROBRAS (which was in charge of LPG production) and strong participation by the private sector (which was responsible for the distribution and retail sales to consumers). These private firms received a guaranteed profit margin and concession rights for regional distribution.

Jannuzzi and Sanga (2004) examine the three-decade period between 1973 and 2003, during which an effective cross-subsidy scheme played a key role in the rapid and comprehensive adoption of LPG. During the program's initial period, from 1973–2001, prices for LPG and other petroleum derivatives were administered by the central government and kept uniform across the country for all customers. The LPG subsidy varied over time, averaging around 18 percent of the retail price. Jannuzzi estimates the cumulative value of this portion of the program, corrected for inflation and domestic LPG prices, at US$2.9 billion; at an average per capita LPG consumption of 2 GJ, or roughly 40 kg per year, this represents a per capita, inflation-adjusted annual subsidy of US$0.73.

In 2001, as part of a broader deregulation of markets for petroleum products, LPG prices were liberalized and collective subsidies were eliminated. This was accompanied by the establishment of a voucher program subsidizing only those families with a monthly per capita income that was not more than one half of the minimum-wage income. (Currently the minimum wage is roughly R$240, or US$76.50 per month.) As of 2002, the number of families participating in the targeted subsidy plan was 6.7 million (at a cost of US$349 million), and this increased to 7.9 million families—or roughly 20 percent of Brazil's population—in 2003 (at a cost of US$462 million). This annual subsidy cost averages US$58 per family, or roughly US$16 per capita for a family of 3.5 (IBGE 2004). This transition to a deregulated market also produced some adverse impacts that need to be analyzed so lessons can be drawn. Many households not included in the new voucher scheme (there were problems in identifying qualified households at the time) switched back to fuelwood because they could not afford the price rises; and imperfect competition in several regions of the country and the creation of cartels aggravated the impacts on consumers in the poorest and more remote areas of the country.

Overall, the average per capita subsidy rose with the price increases following deregulation—from approximately US$1 for the 1973–2001 period (in constant dollars) to US$16 in 2004, after price liberalization. However, with liberalization in 2001, the net expenditure of the government decreased by almost half due to the smaller number of participating, low-income families. Overall, Januzzi and Sanga found the costs of the program to be low relative to the benefits of providing greater access to a better cooking fuel. Furthermore, after subsidies helped to establish an LPG market in Brazil, it has been sensible policy to redirect the subsidy toward only the low-income consumers who are most affected by changing prices.

rather than the rural poor. The use of subsidies to encourage penetration of clean and modern cooking fuel has been variously effective. The uneven effectiveness of particular programs, however, does not appear to argue against the use of subsidies per se. Instead, it suggests that a variety of factors, including the manner in which subsidies target specific populations, the percentage of a subsidy relative to both the fixed and recurring costs of the energy service, and the institutional framework through which a subsidy is implemented, as well as other factors, all play key roles in outcomes.

Implementation and Policy Options for Biomass-based Approaches

Especially in rural areas, where modern cooking fuels remain both unavailable and unaffordable for many, the use of solid biomass for cooking is likely to continue for some time. So long as solid biomass continues to be used for cooking, there is a need to address the issues of health, availability, and the sustainability of the biomass production. Hence the MDG-consistent target takes a three pronged approach to the use of biomass fuels by recommending:

a) efforts to develop and adopt the use of improved biomass cook-stoves,
b) measures to reduce the adverse health impacts from cookstoves with biomass, and
c) measures to increase sustainable biomass production.

Improved cookstoves. Sustainable production and availability of solid biomass is strongly tied to local agroecology, land ownership (household and communal), and socioeconomic conditions. However the use of solid biomass is frequently in three-stone open fires, and as discussed in Chapter 2, is a significant source of exposure to smoke and indoor air pollution. Hence the most widely implemented of the proposed targets is the promotion of improved stoves for cooking with wood and charcoal. In the case of charcoal, there is documented improvement: improved charcoal-burning stoves are particularly effective and adoption rates tend to be high, since the fuel itself is dearer than firewood and offers greater returns to efficiency.

In contrast, in spite of considerable efforts over several decades, wood cookstoves development and implementation is at a nascent stage compared to the scale of the need. The varying size, composition, and moisture in wood; different styles of cooking; the sometimes multiple purposes that the wood fire serves; and the lack of sustained funding all contribute to the lack of 'proven' household wood stoves. Not all stoves with lower fuelwood consumption lead to lower harmful emissions. A sustained research effort is needed on the development of stoves as well as on combined with household modifications such as chimneys, smoke-hoods, windows, and eaves spaces, and improved cooking practices.

Health impacts. In contrast to efficiency concerns, most improved wood stoves have not addressed the problem of smoke and particulates exposure in the home. However, there is now increasing recognition of the importance of

this issue, and systematic efforts are in progress to develop stoves that produce less smoke and/or ventilate smoke out of the immediate cooking environment. Substantially greater effort is needed to develop such stoves and facilitate their adoption, along with measures to reduce high exposure levels from stoves that burn wood, dung, and crop residues. Some key strategies for smoke reduction are behavioral, including proper drying, cutting, and storing of firewood, as well as soaking of grains and other preparatory steps to reduce cooking times. While stove designs can vary widely in cost, complexity, and suitability for a given locale, these behavioral approaches tend to be very low-cost and widely applicable.

Sustainable biomass production. Charcoal production that is efficient and sustainable (through woodlots or agroforestry) and use of improved charcoal stoves can provide a convenient cooking fuel, reduce harmful emissions within the household, and generate local employment opportunities. However, concerns of indiscriminate felling of trees and related impacts on biodiversity, as well as the possibility of build up of high carbon monoxide levels, make the issue a complex one requiring careful examination at the local level. In areas where an invasive species of trees has taken over the landscape and the species itself is a good source of fuelwood, efficient conversion to charcoal offers particularly attractive opportunities. Technologies for efficient conversion from wood to charcoal are not prohibitively complex and can be readily adopted.

One example is *Prosopis julifora*, which is now found in many parts of India and East Africa on otherwise degraded lands. Techniques that allow regulators to ensure the source of wood that went into making the charcoal offer an entry point for sustainable charcoal production. Similar entry points are available where waste biomass in the form of sawdust, husk, and charcoal dust are available. The same species is also particularly attractive for biomass gasification, a technology that allows efficient capture of the calorific value of the wood in the form of 'producer gas' that can then be used for producing electricity. This means of electricity production has not worked so well, however, at the village scale, and certainly not at the household scale. Plants that generate several hundred Kilowatts operate 24 hours per day, 7 days per week, and feed into the grid. These larger plants can provide the economic benefits that accrue from scale and from the ability to retain a team of skilled personnel to operate the plant.

The production of biogas in anaerobic digesters using animal manure, nightsoil, and vegetable waste can be attractive where such waste and water are available. There are multiple benefits that can accrue. The carbon to nitrogen ratio of the slurry leaving the digester is a better source of fertilizer than materials fed into the digester. Also, biogas is a clean cooking fuel with the potential for Clean Development Mechanism (CDM) credits equivalent to nearly 20 kg of CO_2 for each kg of methane burned. Having tethered animals may have other advantages for land use practices. The key bottleneck remains the finicky

nature of the digester and the need for adequate learning and training in the construction and use of a digester. Biogas production is especially attractive at commercial facilities where large animals are kept commercially, lowering transaction costs. If community-level aggregation can be achieved, this can also offer economies of scale.

Several other biomass-based systems offer potential entry points based upon local agroecologies and land use. These include tree species (for example, *Jatropha curcas* and oil palm) and plants or crop residues (for example, sugarcane bagasse, maize, and soybean) that can be used to produce liquid or gel fuels. The land and labor inputs required by these systems need to be carefully balanced with the multiple potential benefits such approaches provide. Perhaps the greatest benefit of such technologies is the potential they offer for rural job creation, and yet for these approaches to be successful, they require a local investment in research and the skills to develop and adapt complex technologies to rural conditions.

In the near future, measures to increase biomass production are recommended. Such measures are most likely to succeed when on-farm biomass production occurs synergistically with increased agricultural output and income. Agroforestry is one example of such an approach. Fallow tree species have the ability to provide as much as three to five tonnes of woody biomass per hectare on an annual basis while also adding nutrients to the soil. One or more tree species either on the farm or in community woodlots or area closures can provide multiple benefits such as watershed management, soil conservation, nutrition, and fuelwood, and can provide the opportunity for additional income since the availability of biomass reduces the time and effort spent looking for cooking fuel.

Electricity for Urban and Peri-urban Areas
MDG-consistent target:
- **Ensure reliable access to electricity to all in the urban and peri-urban areas.**

Here and elsewhere in this report, electricity is considered as an energy carrier with certain optimal uses, rather than as a specific technology. Electricity is an ideal medium for such end-uses as lighting; use of appliances such as radios, televisions, and equipment and devices used in numerous industrial and commercial establishments; and communication devices.

In some cases, this implies general technological solutions without the need to specify precise interventions or to 'pick technologies.' For instance, there is agreement that for those in urban and peri-urban settings, the effective unit cost of lighting using kerosene lamps is nearly one to two orders of magnitude higher than the most expensive thermal generation of electricity. If the cost of disposable dry cells for radios and lighting and poorly charged lead-acid batteries for lighting or television are added, it becomes clear that, based

upon the costs that the urban poor already pay for less-efficient energy sources, they can afford the recurring costs of electricity generation and maintenance of the generation, transmission, and distribution infrastructure. By switching to electricity, they would avail themselves of a much better quality of energy service in the form of higher-lumen light, lower-cost use of radio or television, and reduced time and transportation for battery charging. What the urban poor may not be able to afford is the initial cost of an electricity hookup and possibly lumpy utility bills. This initial cost, however, can be as low as US$200 per household even in peri-urban settings. There is a sense that, if the poor can overcome the first cost of access, they can actually pay the recurring costs of low consumption levels of electricity. Moreover, the utility's recovery of recurring costs can aid in achieving higher electricity penetration rates, facilitating near universal access in urban and peri-urban settings in the next 10 years.

Reliability of electric supply is equally important. The cost of unreliable service, through inefficient substitution, through lost productivity and revenue for businesses, or as a result of damaged goods (for example, if refrigeration capacity is lost) and appliances can lead to a high effective cost of electricity. Many businesses that rely on newer communication and computer technologies demand reliable and 'clean' electric power supply. For these businesses to remain competitive in the global marketplace, it is critical that quality of electricity infrastructure is not sacrificed for the sake of cost. In a sample survey of private businesses in 69 countries, respondents most frequently cited loss of productivity and impediments to new investment and business creation as the effects of poor infrastructure (Brunetti et al. 1997). The low cost of connecting the peri-urban population to the grid can be exploited as an advantage leading to a win–win situation for consumers and electricity providers (ESMAP 2001b).

In the urban context, aggregation of demand led to the emergence of centralized systems as the technology of choice. Factors such as higher population density, the presence of government and commercial establishments, and higher cash incomes have generally favored urban and peri-urban areas as the lowest-cost regions for early electrical grid creation and expansion. Methods to spread out first costs, innovative financing schemes, and marginal improvements to further reduce costs have been more effective at expanding access than in rural areas, where first costs are much higher. Thus in urban areas, the barrier to access for individual homes is the up-front cost associated with bringing the wire to a home. In spite of this, reaching the urban poor with electricity remains a challenge and hence the electricity penetration rate in some urban areas remains low.

A key factor in the lag in expansion of service even to urban populations is the failure to meet recurring costs. To understand this problem, one needs to recognize that low recurring costs of electricity are achieved technologically through aggregation of demand across many users—tens of thousands of households as well as major industrial and commercial customers—all served

by large power-generation plants. This degree of aggregation was historically achieved through formation of institutions such as utilities that generally did not have service to the poorest as their first and highest priority. Over time, a combination of factors has led, in the case of some utilities, to a range of financial and technological failures that make it difficult even to continue providing reliable services. These factors include subsidies for the recurring costs of those who could actually afford to pay, poor financial management of state-owned utilities, theft of electricity by those who were excluded from access, poor enforcement of service termination rules for failure to pay, and lack of financing for poor households and small enterprises.

In such situations, it is difficult to raise capital to increase generation capacity, or to recover costs through tariffs and billings. With the deterioration of the financial situation of the utilities, the quality of service further deteriorates. Where the rich can afford back-up generators, the poor bear the brunt of poor-quality service, including those not yet connected to the utility. They have neither the financing from the utility for the initial hookup nor the benefit of subsidized electricity supply available to the better-off. Where large-scale infrastructure investments are needed to extend the service to fast-expanding urban areas, raising the needed financing will be equally difficult, with high perceived risk and expected long payback periods.

There are financing, institutional, regulatory, and technological solutions that are available to successfully solve these problems. A considerable body of work has been developed to address the issue of how to support the development of financially healthy and efficient providers of reliable services for the poor. Some of the better practices are outlined here.

- With careful utility management, review of cost structures and standards, and bulk purchases, the initial costs of hookup can be further lowered.
- Initial hookup costs can be partially recovered by spreading the initial costs over a longer period and by cross-subsidization. However, governments need to recognize that subsidies of the initial hookup costs may be necessary for the poor.
- Governments can ensure that utilities are able to recover the recurring cost of generating electricity, in order to protect the financial viability of the investment.
- Allowing smaller independent power producers to operate under a regulated environment can make it possible for these producers to buy electricity from or to sell electricity to the grid.
- Bill collection alternatives, including prepaid smart cards, community billing, and lifeline tarrifs, could reduce costs for electricity services.
- Regularization of tenure for slum dwellers can increase the size of the market and formalize electricity demand, thus reducing costs and barriers to service access

The fact that electricity is often 'tapped off' illegally in urban poor areas is a testament to the desire of the poor to have access to the benefits that electricity provides, such as illumination, radio and television, and the ability to use machines and appliances that create jobs and incomes. In many cases, the fees recovered by informal sector middlemen who charge for these services outside of the utilty structure testifies to poor families' willingness to pay for electricity, even at a high cost. The public safety, social service, and economic benefits from aggregation of demand are compelling reasons to make electricity service provision to urban and peri-urban areas a priority in national strategies to achieve the MDGs.

Modern Energy Services for Rural Communities

MDG-consistent energy target:

- **Provide access to modern energy services (in form of mechanical power and electricity) at the community level for all rural communities.**

Mechanical power has assisted human beings for centuries in reducing the drudgery of such work as lifting water, grinding cereals, and crushing seeds and nuts for oil. With the development of engines (with end-use equipment directly connected to the engine) and then with the advent of electricity (through the use of motors), mechanical power became widely accessible and is frequently the first use of energy that is critical to the poor after the availability of cooking fuel. Productive uses of mechanical power, especially those that benefit women, can end up providing both social and economic benefits simultaneously. Where grid electricity is viable, meeting mechanical power needs is possible. Alternatively, when grid electricity is not a viable option, stand-alone mechanical power is the first priority. An emphasis on flexibility is crucial in identifying least-cost options for particular geographic, technological, demographic, and economic conditions in order to provide mechanical power.

Access to mechanical power can improve productivity of human labor and reduce drudgery of work, freeing up the time of women and girls in particular. In many rural areas, even community-level access to mechanical power is unavailable.

While the widespread use of electricity even in the developed world has only occurred over the last century, electricity has now come to be indispensable to the functioning of government, public institutions, health care facilities, and business/commercial/industrial establishments. Modern energy services delivered in a sustainable manner are essential for progress toward the MDGs in rural areas. Publicly supported electricity expansion, as advocated here, would first and foremost guarantee reliable service to community health and education facilities and for agricultural extension, thus meeting basic needs and enhancing social capital. Community health facilities, such as clinics and healthposts, need appliances such as microscopes, centrifuges, refrigerators for

storing vaccines and blood samples, and other services that generally require electricity. Schools need electricity for computing, visual aids, scientific experiments, lighting, and communications. Community-level communication services—in the form of phone kiosks, Internet stations, and others—are also made possible by electricity.

Establishing rural nodes with mechanical power and electricity services within rural communities would also dramatically reduce the cost of additional grid connections and extensions in the immediate vicinity, unlocking local capital and opening new opportunities for small-scale, private investment at the local level. Such private investment is already observed in rural areas where expansion occurs (as illustrated in Figure 7).

Figure 7.
Unlocking local capital by bringing the grid closer

...to a rural school or clinic...

...lowers costs for additional electricty access locally...

...fostering wealth-generating and labor-saving opportunities.

An electrical connection from the distant grid...

Mill
ICT
Water pumping

Household connections
Light manufacturing
Local shops and services

Or a stand-alone power source, such as a diesel generator or renewable energy-based system...

Mill

...can provide similar services and options for expanded connections nearby.

Water pumping

Local shops and services
Light manufacturing
Household connections

Meeting the MDGs requires that coordinated and simultaneous efforts are made in all social sectors as well as in poverty reduction. This allows the possibility of planning across multiple sectors, in which case a natural aggregation of demand can occur within a community, producing significant cost reductions.

The dispersed and possibly remote nature of rural settlements has always posed a challenge for the provision of infrastructure, whether it is roads, electricity, or telecommunications. Moreover, the reliance of a rural economy on agriculture, livestock, forest products, or fishing places larger demands on mechanical power that are specific to the particular nature of rural income-generating activity, its processing needs, and the mode of irrigation if any. The

lack of large anchor industrial and commercial customers, the seasonal and dispersed nature of agricultural loads, and peaky household demand make it technologically more difficulty to service a rural area with grid electricity infrastructure. If road infrastructure is poor, the tasks of maintenance, meter reading, and bill collection also become difficult. Finally, population densities can vary widely.

For all these reasons, both centralized and decentralized approaches can be viable means of addressing the issues arising out of the community-level targets for mechanical power and electricity in rural areas, depending on context. The technology options for community access are examined here in terms of centralized and decentralized approaches, followed by a brief discussion of options for access at the household level.

Technology Options for Centralized Approaches in Rural Areas

In urban areas, centralized approaches are generally the obvious choice, providing an interconnected grid serving thousands of households in addition to public institutions and businesses. In rural areas with no electrical service at all, a centralized system can still be viable—particularly if envisioned as a grid serving public institutions, community centers, and small businesses—even when household electrification is not cost-effective. With the use of motors, these community electricity connections can meet both electricity and mechanical power needs simultaneously.

The cost-effectiveness of centralized systems in rural areas will be determined by overall population density, aggregation of various social needs, whether households are 'nucleated' into villages or spread more evenly over the landscape, and distance between community centers and any pre-existing grid power. These factors determine the cost of transmission and distribution infrastructure, which are the dominant cost component when extending service in rural areas. High-density but dispersed (as opposed to nucleated) rural settlements (for example, the population around Lake Victoria in East Africa) represent a large fraction of the population without significant access to modern energy services. For this population, the average distance between community centers (serving one or more clinics, schools, markets, or kiosks) is generally no more than two kilometers. This density of community centers allows people to exploit networked options for electricity service. Such centralized systems have the added benefit that they can provide low marginal cost access for small businesses located in the vicinity of the community centers

In planning larger-scale, centrally planned and administered systems, issues such as reducing unit costs to expand access to larger populations and recovering operating costs become more important. Since transmission line costs tend to dominate initial capital expenditures for grid and mini-grid electrification projects, reducing these costs can significantly impact the overall costs and extent of rural electrification. What is clear is that there are considerable

variations in materials and labor costs across countries. Figure 8 shows a comparison of medium voltage line costs per kilometer varying from US$2,000 for India to US$18,000 for Mali for the same configuration. Some of the variation in cost is because of availability of low-cost materials (such as inexpensive cement in India for concrete poles), varying standards, and topography and transport. However, bulk purchase and lowered transport costs alone could lead to significant savings. A combination of high penetration rates ensured by government policies and lowered line costs can have dramatic effects on the cost of a new connection.

Figure 8.
Variation in total three-phase, medium-voltage line cost (labor and materials) for selected countries

Source: ESMAP 2000, p. 10.
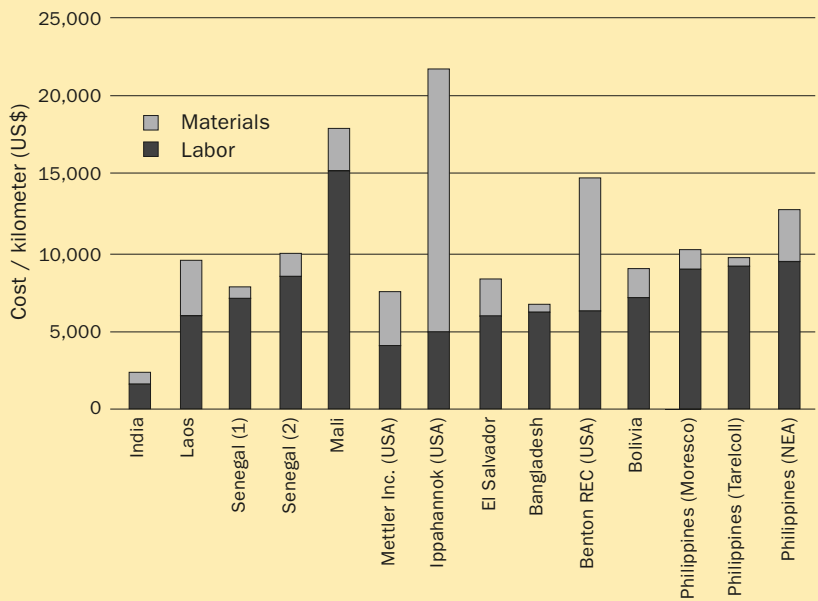
In envisioning a centralized system that provides electricity to community centers and public institutions, there is much to learn from the successful rural electrification programs of Tunisia and South Africa (among other countries). These countries have carried out cost-effective electrification programs at rates that can achieve national coverage in two to three decades, the details of which offer innovative approaches to expanding access to low-consumption consumers in rural environments. These cases provide evidence of how large-scale, mission-oriented approaches to rural electrification have succeeded in reducing costs per connection, increasing the efficiency of billing and other aspects of management, and otherwise establishing a set of best practices to be studied in future planning.

A recent program undertaken by the Tunisia Electricity and Gas Company (STEG) achieved dramatic cost savings, which in turn contributed to a remarkable rate of cost-effective electricity grid expansion (Cecelski et al. 2004). As part of a multisectoral approach to the extension of a range of infrastructure and services to rural communities, Tunisia's electrification program expanded services from 6 percent of the population in 1976 to 88 percent in 2001, including bringing electricity to 35 percent of people living in rural areas. The technical strategy of the program was to use a combination of three-phase and single-phase power lines, preferentially extending less-expensive, single-phase wire to rural communities. This approach saved an estimated 30–40 percent over the cost of medium-voltage (MV) lines, 15–20 percent on MV/low-voltage (LV) substations, and 18–24 percent on the system overall relative to what the same expansion would have cost with the previous ratio of MV and LV lines. In addition, the Tunisian program carried out such other aggressive cost-cutting measures as use of single wire earth return (SWER) design, shorter poles (saving 20 percent on cost), equipment standardization, and bulk buying. Administrative innovations, such as decentralized planning and improved corporate management practices, contributed to efficiency at the institutional level. As an indication of the program's success, Tunisia has set rural electrification for all as a minimum standard for public service and has set a goal of 100 percent electrification, through a variety of grid-based and off-grid technologies, by 2010.

South Africa's national electrification program showed similar success, driving down costs of both connections and payment schemes by reducing administrative overhead and loss. Electrification in South Africa grew from about 36 percent of households in 1990 to 67 percent in 2000, with more than 3 million new customers. Dramatic reductions in the capital investment costs per customer of rural electrification suggest that appropriately planned rural systems need not be much more expensive than urban systems (Gaunt 2005). Between 1996 and 2001, the national average cost per rural electric connection decreased by 40 percent in current terms and 70 percent after taking into account inflation, eventually becoming the same as an urban connection cost. The savings were achieved by adopting designs that match the network technology and capacity more closely to the requirements of the customers (greater application of single-phase instead of the traditional three-phase distribution at medium and low voltage), broad application of prepayment metering, and revised industry standards and implementation procedures. Using low-capacity, low-cost grid connections, South Africa's rural electrification program can supply substantially more energy than photovoltaic systems for a similar or lower cost. The South African experience with prepayment metering is a development of significant note, since this can allow consumers to purchase a service in small quantities and at the same time ensure low-cost bill collection. These payment methods dramatically

reduce the fraction of costs that are purely administrative for servicing a household with low consumption.

The institutional and regulatory issues that apply to centralized urban systems also apply to centralized systems in rural areas. From these and other examples, a wealth of knowledge is now accumulating about best practices in structuring the roles of government, investors and donors, service provider institutions, and NGOs. Some of these are lowering or eliminating tax burdens; standardization and certification of systems; supporting programs for training in the design, maintenance, and safe use of these systems; and credit and delivery mechanisms.

Technology Options for Decentralized Approaches in Rural Areas
The options for creating access through decentralized systems cover a wide range, from a stand-alone system for a single community center to a mini-grid connecting many community centers or institutions. The choice of a technology for a stand-alone system would depend upon the amount and kind of power (mechanical or electric) needed. This section does not address all technology and cost options in detail but instead aims to identify key factors that influence system choices.

For a variety of reasons—geographical sparseness, availability of a local renewable resource, community centers spaced far from each other, different times at which electricity provision is installed, or simply the lack of coordination among the various implementing agencies —the lowest-cost option for a given community center may be a stand-alone system.

Those who live in lower-density rural areas—as in many parts of Africa, including the Sahel—present an even greater challenge. These areas can be defined (somewhat arbitrarily) as having 100 or fewer persons per square kilometer, which corresponds to an upper limit of about 10 to 20 households per square kilometer. Where there are nucleated settlements (even though each settlement is far from the others), aggregation of community-level needs, both social and economic, is the likely situation. In such a situation, community-level access could be provided in conjunction with productive use functions, using a single stand-alone system with enough mechanical and/or electric power to serve all the functions, as has been done with the multifunctional platforms (MFPs) in West Africa. This intervention allows women direct access to mechanical power, including end use devices powered by the engine, through cooperative ownership of the platform with wider access to the community through user fees (see Box 7).

The success of the MFPs suggests that it is not enough just to make energy services available, but that it is necessary to ensure that end-use devices critical to women and men are actually made available to them and are owned by them. What has been central to the success of this model is that the consumer does not bear the full cost of the equipment that generates

Box 7.
Diesel-powered multifunctional platform (MFP) in Mali

Source: Anderson et al. 2004.

By many measures, Mali is one of the poorest and least-developed countries in the world. As of 2001, more than 70 percent of the population survived on less than $1 (PPP) per day, and the nation falls very near the bottom (172 of 175) of the UNDP's Human Development Index (HDI). Geography and energy are key factors in Mali's poverty: nearly three-quarters of Mali's population of roughly 12 million lives in semi-arid rural areas, where poverty is most severe and yearly variations in rainfall can have drastic economic impacts. Rural villages tend to be small (1,000 to 2,000 people) and dispersed, and electrification is virtually nonexistent. Biomass constitutes the vast majority (90 percent) of the country's energy supply, particularly in rural areas, where women and girls are responsible for the time-consuming and labor-intensive work of fuel collection.

Beginning in 1993, the UN Industrial Development Organization (UNIDO) and the International Fund for Agricultural Development (IFAD) initiated a program to decrease the burden of fuel collection, to supply labor-saving energy services, and to promote the empowerment of women through the provision of the 'multifunctional platform' (MFP) to rural villages. The MFP is a 10-horsepower diesel engine with as many as twelve modular components in an integrated system that can supply a variety of services. These include mechanical power for time- and labor-intensive work such as agricultural processing (milling, de-husking) and electricity for lighting (approximately 200–250 small bulbs), welding, or pumping water.

Although the benefits of these services are shared by many people in the villages, those who acquire, own, manage and control the platform itself are women's organizations. This is not only to ensure that women and children benefit directly, but also to create a group with the necessary skills to ensure the MFP's long-term viability, while building capacity and empowering women generally. Women's groups are responsible not only for owning and managing the system, but also for covering between 40 and 60 percent of the MFP's initial cost; this amounts to as much as US$2,600 of the US$4,300 total cost for construction and installation. The remaining US$1,700 or so is provided by the program, which is donor-supported.

In 1998, UNDP and the Government of Mali began supporting the program's implementation phase, which installed nearly 500 MFPs between 1999 and 2004, reaching an estimated 100,000 rural women in villages. Each MFP intervention—from a feasibility study, to installation, to operation—lasts about two years. Capacity building and institutional support is strongest in the earlier phases, then tapers off, leaving the rural women's village groups in charge of the platform's operation, relying on a network of private suppliers, technicians, and partners. Benefits observed in 12 villages studied suggest that freeing up women's time has led to multiple benefits such as increased cash income, higher food consumption, and higher girl to boy ratios in schools.

Overall, the MFP program in Mali offers compelling evidence that time saved in the lives of women and children, combined with the added socioeconomic and capacity benefits to women's groups of controlling and managing the MFP as a resource, can confer substantial benefits to health and welfare.

or uses the energy, nor the cost of the technical assistance to develop the program. Rather, these costs are borne by the community, as a local utility (even a small one) would have to do. Individuals pay a fee for services that captures the variable cost of running the system plus some aspect of the overall or fixed costs of the system. The investment for the system at large falls on an organized community entity, business or NGO, thereby separating the burden of investment from the benefit of the service at the point of consumption by the user.

In low-density rural areas where there is no nucleation, the key question is likely to be whether the community centers, public institutions, and economic needs are near each other. In such cases, education and health facilities could be powered by stand-alone systems that rely on small-scale renewables or a diesel generator. Where some degree of aggregation is present in the form of existing community centers (even though households themselves are dispersed), a mini-grid connecting the centers and powered by diesel generators may be viable. These would also permit use for productive functions on a fee-for-service basis. Low-density areas are likely to have poor access to transport, unreliable fuel supply, and lack of maintenance facilities. In these areas, the high initial cost of stand-alone and robust off-grid technologies may actually turn out to be cost-effective in the long run.

Technology Options for Household-level Electricity Services in Rural Areas

The energy target for rural areas has primarily addressed access to mechanical power and electricity at the community level. If one imagines a 10-year time horizon for energy and other development planning, it is prudent to anticipate a transition in which individual households shift from a low level of illumination and communication (provided by kerosene lamps and dry cells for radios) to electricity-based illumination and use of such appliances as television and eventually to power-demand levels that require grid electricity. With this transition in mind, it is important to recognize approaches that permit energy services such as electricity-based household illumination and basic communication services without a grid. These services could be provided with a single, central node for a community. Box 8 provides details of some of the economic and technical factors that favor adoption of electricity as an energy carrier for key lighting and communication services.

If households are tightly clustered in nucleated settlements, a local mini-grid may also be viable for household-level electricity supply. This mini-grid could be powered from a centralized system or a decentralized system such as micro-hydro, wind, or diesel genset. The electricity system in Urambo Village, Tanzania describes an independent rural cooperative successfully operating a diesel mini-grid serving 250 co-operative members (see Box 9).

In rural households, consumption of energy for non-cooking related services such as lighting and communications is likely to be relatively small. Even here, one can anticipate great improvements in efficiency, affordability, and environmental impact for some services, with a transition to electricity as an energy carrier from such commonly used fuels as kerosene. Many in rural areas currently rely on kerosene wick lamps. In addition to producing smoke and soot, due to the low efficiency inherent in converting heat to light, these kerosene lamps tend to provide approximately 20 lumens and consume 20 to 30 liters of kerosene per year when used for three to four hours per day. The service provided amounts to a minimal amount of light—generally insufficient for reading, at an annual cost of roughly US$13—and includes potential risks from smoke and open flame.

In contrast, the following electricity-based example sets an arbitrary but useful standard for home lighting at a minimum level of about 300 lumens, which can provide light sufficient for reading and, if desired, room illumination in the evening for simple tasks. Although this minimum standard represents an increase in light level of at least one order of magnitude above that provided by kerosene, it can be produced cleanly and efficiently from a 7W source using a compact fluorescent lamp.

If one adds to this basic lighting service additional electricity for communication devices (radio, cell phone)—amounting to 3W—one can anticipate a total need of 10W for 3 to 4 hours a day for each rural household. This corresponds to about 15 kWh per year per household. The actual consumption level would vary by household, depending upon the cost of service, individual ability to pay, and form of payment.

The power for light and communications could be provided by a portable battery, recharged at a central point in a town or village, which would likely be at least as close as the point of purchase for the kerosene currently used. And, at even US$0.40 per kWh—a cost achievable with a diesel generator —the yearly cost of electricity would total roughly US$6, far less than the expense of the kerosene for which it would be a substitute. If electricity from some other source (for example, the electric grid or a microhydro facility) is available at a central point within the community, the recurring costs would be further lowered. The results, then, of a transition to electricity provided by portable batteries charged at a central access point would include improved lighting, expanded access to energy for communications, and reduced indoor air pollution from kerosene, all at a substantially reduced cost.

While solar PV technology is also ideally suited for meeting low loads of 30 to 40 Wh per day, to ensure autonomy over three days people would need a solar home system of about 20W peak capacity. Such a system would cost about US$150 to US$200 today, including batteries and a charge controller. While the initial costs of such a system are significantly higher, limiting access to fewer people, the recurring costs are lower, primarily due to battery replacement costs.

Although this system currently serves only about 10 percent of the village, the possibility for extending service to the poorest in the community might include a state-supported, cooperative-operated program that could either provide a lifeline rate with limited consumption (of roughly 2 to 3 kWh per month) or low-cost, battery-charging services.

As of 2001, only an estimated 2 percent of Tanzania's rural households had access to electricity services. As a strategy for accelerating rural electrification, the national electric utility (TANESCO) and the Stockholm Environmental Institute (SEI) recommended the creation of rural electricity cooperatives operating independently of the national utility. The first in Tanzania, the Urambo Electric Consumers Cooperative Society (UECCO)—based in Urambo Village in the Tabora region—was established in 1993 by the Urambo District Council with assistance from SEI, TANESCO, and the Swedish International Development Agency (Sida). UECCO began operation in 1994, after first rehabilitating the generation and transmission infrastructure of the pre-existing local electricity system (three diesel generators of 85–100kW and ~11 km of power lines) and establishing the financial and institutional foundation necessary (writing by-laws, creating a development committee, hiring and training local employees, and setting share prices, connection fees, and tariffs).

By 2002, UECCO employed three workers (two technicians and one accountant) and provided electricity service to approximately 250 cooperative members, mostly households, totaling an estimated 2,000 persons, or 10 percent of the village. Customers consumed an average of ~250W per connection, for around 4 hours per day, totaling roughly 35 kWh per month. Even as the customer base expanded, the system has provided reliable service: electricity was provided for 97 percent of the scheduled hours in 2002. Diesel-to-electricity conversion efficiency was equal to or better than that achieved by TANESCO's comparable plants. Tariffs for most customers are billed according to consumption and metered at the household level. Through this system, the coop's tariff income generally meets its operating expenses, which consist primarily (80 percent) of fuel costs, with the remainder going to maintenance and salaries. The development committee held periodic meetings to adjust tariffs.

It is noteworthy that UECCO's tariff as of October 2002 was US$0.47 per kWh, more than 10 times the rate for electricity supplied through TANESCO's grid. The viability of UECCO's system at this price suggests that TANESCO's service is perhaps too heavily subsidized. In a day-to-day sense, the system is largely technologically and financially viable, even at a penetration rate of only 10 percent within the village. The possibility of establishing a 'lifeline' service, as low as 2–3 kWh per month may be an option, though in the past users have preferred metered consumption to flat rates with an upper limit on consumption.

Important challenges remain: Committee meetings, at which tariffs are established or changed, tend to be far too infrequent to effectively respond to wide swings in fuel costs, leading to budget deficits for UECCO. Also, though tariffs effectively cover most of the day-to-day expenses of UECCO, they do not recover sufficient capital for large-scale, occasional repairs. Generator breakdown and other similar events have required additional donor assistance. Finally, there remain some users who, due to lack of available meters at the time of their connection, are charged a flat rate and are probably substantially over-consuming relative to their tariff payments.

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In high-density rural areas, a geographically well distributed grid network that forms the backbone for community services can allow one to leverage household-level services through reduced-cost electricity connections. A medium-voltage electric line to a community center would facilitate dramatically reduced cost for a household connection within a radius of approximately 500 meters of each transformer spaced, for example, every 1 kilometer along the MV line. While few people would be able to immediately afford such a connection, it allows a utility to combine the reduced costs of connecting to existing nodes with possible micro-credit and/or private financing to increase rural supply options. Where grid electrification has occurred, the financial health of the utility and attention to institutional structure are critical. A lack of transparent mechanisms to meet generation cost can lead to unreliable and erratic supply, which in turn jeopardizes service to the truly needy.

Stand-alone solar home systems also allow household-level basic electricity access; they are far more convenient than a portable battery and have the added advantage of being independent of the local grid or service provider. Bangladesh is presently experiencing an impressive growth of this market segment, with sales averaging 25,000 modules monthly. Emerging technologies could reduce the cost of such decentralized systems. Supportive policies such as tax incentives, technical standardization, and possible CDM funding would encourage such market development, which in turn would eventually reduce the costs of these options for the poor as well.

Energy Technology Options and the Environment

This report advocates the adoption of increasingly cleaner energy technologies with economic growth as opposed to expensive solutions that 'leapfrog' to the cleanest possible technology immediately. To quote from a DFID report, "Consideration of the positive environmental aspects of renewable energy sources must be balanced against meeting practically, quickly and efficiently the immediate energy needs of the poor with whatever energy services are accessible," and "The dangers of not allowing the stalemate to be broken could be devastating for a population that is already weakened by poor health. Moreover the technology choices made in meeting the immediate energy needs of the poor need not be permanent" (DFID 2002, p. 23). Hence the advantages and disadvantages of fossil fuels, particularly the environmental impacts, need to be weighed in a broader context of needs. As explained in Chapter 2, current and future emissions of GHGs are not caused primarily by the poorest people and the principle of common but differentiated responsibility for GHG emissions reduction is a globally agreed principle.

CHAPTER 5: Implementation Challenges

Planning and delivery of energy services are made extremely challenging by the fact that, perhaps more than any other facet of development, energy touches upon virtually every aspect of society—from economic well being to social well being, and from the smallest scale dynamics of access and use at the individual and household level to the largest scale national and international issues. It is essential for energy planning to recognize the energy service needs of the economic and social sectors that will use energy services. An understanding of the needs and conditions experienced by those who will receive services requires coordination with the sectoral ministries. These are generally the ministries of energy, health, education, water and sanitation, telecommunications, industry, agriculture and/or rural development, and roads or transport. Energy services that rely on biomass for cooking cut across numerous sectors such as health, agriculture, forestry, environment, and improving the lives of women. The results of such planning need to be explicitly articulated in the national strategy for poverty reduction.

A central recommendation of this report is that countries develop strategies for increasing access to energy services as an integral part of their national development strategies to meet the MDGs. This chapter lays out some common implementation challenges that planners may need to address as they prepare MDG-based energy strategies. It highlights several 'system wide' interventions and policy choices to respond to crucial issues that will need to be addressed in any national energy strategy for the MDGs. It closes by outlining additional considerations that need to be borne in mind by energy planners and development partners as they develop and evaluate the energy component of a country's MDG strategy.

Challenges Facing Energy Institutions and Systems

Energy service providers in many developing countries face a host of challenges that can limit their ability to expand energy services to the poor on the scale required to meet the targets defined here. Some of these challenges include:

- technical problems such as electric utilities with limited generation capacity and losses in transmission and distribution that nonetheless face high and growing demand;
- difficulties with investment financing and operating-cost recovery, including the ability to set cost-recovery tariffs and implement collection mechanisms adapted to the ability to pay of all users, including the poorest;
- institutional issues such as the need for a proper regulatory and legal framework, as well as greater transparency and efficiency of utilities' management.
- the need for effective partnerships between the public sector (to provide the legal and regulatory framework and protect the needs of the poor), the private sector (to develop and manage energy service utilities), and communities and local governments (responsible for the public services' consumption of energy). For example, opportunities for adding generation capacity and developing local grids are frequently missed due to lack of a suitable framework that allows independent power producers to obtain licensing and feed electricity into the grid and local small utilities to develop.

It is crucial to address these institutional issues in order to improve the ability of energy-service providers to forecast energy supplies, to be financially viable, and to reliably meet the demands of current users and expand the services to new customers in pursuit of MDG-consistent objectives. Urban, peri-urban, and rural users would all benefit from the added reliability and predictability that financial, technical, and institutional health permits. The successful examples of sustained political commitment to creating incentive frameworks that have led to significant expansion of systems that have benefited the urban and rural poor (Thailand, Chile, Mexico, Morocco, South Africa) offer elements of solutions that can be replicated.

Finally, current trends in hydrocarbon fuel prices underscore the potential additional vulnerability of energy systems in net oil-importing countries. This vulnerability must be taken into account in planning energy systems and in designing incentive frameworks to increase energy efficiency and diversify energy resource portfolios and technological solutions. It also requires provision of an energy social safety net for the users most at risk.

Integrate Energy Planning and Implementation into a National Strategy

As this report shows, energy services are critical for achieving the MDGs and therefore must be part of any national strategy for meeting the Goals. Unfortunately, this is rarely the case in developing countries.

Many past national development strategies have either neglected or paid only lip service to long-term energy planning. Some of the shortcomings have included:

- insufficient resources overall, and particularly for the operation and maintenance of distribution and transmission systems;
- political expediency that favors one-time project allocations and fails to provide for the recurring costs of energy services used by public institutions;
- lack of long-term planning, transparency, and public participation during the planning, contracting, and implementation process;
- inadequate institutions and technical capacity to carry out planning studies, establish performance standards, create environmental impact norms, and monitor and enforce established rules.

As a first step, it is therefore recommended that countries systematically integrate their energy-sector development strategies into a comprehensive MDG-based national development strategy. In addition, the very importance of energy services to a wide variety of sectors and ministries poses a coordination challenge. Meeting this challenge requires country-level planning across the various ministries, including coordinated assessments of the quality and quantity of demand for primary energy sources, the delivery infrastructure, and the institutions responsible for the 'last-mile' of delivered energy services.

Planning should anticipate increasing demand in a manner that takes advantage of economies of scale, now and in the future. If it is recognized in the early planning stages that demand for these services will grow as access is increased, planners can create systems that will, at higher use rates, have dramatically lower per unit costs. These higher demand levels, which can be met with cost-recovery tariffs and pricing, can in turn lead to lower incremental costs for those whose initial needs are small.

Be Flexible in Energy Planning

It is recommend that policies be geared not toward promotion of specific technologies but rather toward supporting a diversity of energy technologies and service delivery models. This is crucial, since energy needs, technology costs, capacity for implementation and technical support, and many other factors can vary enormously from one context and time to another.

In addition, it is important to recognize the potential for synergies. The combination of local productive enterprises, local energy resources, technical improvements in production, efficiency improvements in use, emissions

control, and sustainable land-use practices can all add up, leading to productivity enhancement and simultaneous reduction in unit costs while allowing beneficial use of an otherwise potentially harmful energy source. One example of this is the use of fuelwood, perhaps from agroforestry practice, in conjunction with improved cookstoves and an improved cooking environment with suitable modification to the kitchen. Another example is the efficient and controlled production of charcoal from wood obtained from sustainably managed woodlots combined with use of efficient charcoal stoves.

It is also crucial that policies recognize and support the energy delivery systems that are evolving in poor communities in the absence of more organized efforts; lack of support for mini-grids or stand-alone diesel power can result in failure to take advantage of a tremendous opportunity to expand access for the poor. In Ethiopia, for example, the capacity of all imported diesel generator sets over the last 10 years is over one gigawatt (Melessaw Shanko, personal communication), exceeding the current installed hydropower capacity of the country. These mini-grids are addressing the need for access in areas without transmission and distribution systems. These systems may have higher financial unit costs than grid extension but have the advantage of being more quickly deployed until grid extensions can be operational. Utilities, NGOs, donors, and planners should recognize the role of these services and the private sector in development and ensure that these solutions are supported through financial assistance, technical support structures, and appropriate standards.

Design Effective Regulatory Framework

'Pro-poor' energy policies will need to be implemented within a regulatory framework that prioritizes the provision of energy services to poor communities and rural areas. Regulatory frameworks should be designed that use energy as an instrument to effectively deliver social needs, stimulate productive activities, enable work that adds value in agriculture and services, and spur economic growth.

Sustained political commitment is required to create a framework of market conditions amenable to energy-based approaches to poverty reduction. Macroeconomic policies and fiscal management should encourage economic diversification, the diversification of energy resource portfolios, the participation of communities and a larger number of private entrepreneurs in delivery systems, and the most efficient use of these resources through market incentives.

Reduce Costs through Financing Mechanisms and Subsidies

Economic barriers limiting access to energy services by the poor can come in a range of patterns. Evidence shows that, in most cases, the poor do pay for energy—often at much greater per-unit costs than higher-income consumers and for a lower quality of service (ESMAP 2005d). The poor also often

pay a much higher share of their disposable income (20–30 percent) than the higher income groups (5–10 percent). In other cases, high capital expenditures or recurring costs, irregular incomes, lack of access to credit, lack of legal residential status, and lack of formal legal assets for collateral can prevent the poor from obtaining energy services. Innovative financing and microfinance institutions also represent a very important development tool (Johansson and Goldemberg 2002, p. 13).

An approach will be needed that recognizes that the poor are likely to be excluded from accessing modern energy services if such services can only be provided on the basis of full-cost recovery. Where cost recovery through tariffs and prices is the only approach used, the penetration rate for service from formal service providers is generally low. Where a range of financing mechanisms are used—combining some public-sector financing (equity, debt, or subsidies), private-sector financing (equity, debt, self-financing from revenues), and community and users' contribution—the rate of penetration of service increases and is viable. However, programs that involve subsidies will need to focus on the public good/safety net component, be anchored on sound fiscal policies, and transfer the subsidies through transparent and predictable mechanisms. Further, they will need to avoid market distortions, as well as alternate scenarios in which subsidies for fuels and lifeline rates end up subsidizing the consumption of higher-income consumers, inefficient use of the energy service, or the activities of illegal service providers. In this regard, policies should ensure full-cost recovery from the commercial sector, public consumers, and from income groups who can afford to pay.

Access can be increased substantially if initial market penetration costs—the social engineering needed to enter the community—are shared between the public and the private sectors, and if capital costs for services are lowered overall. For electricity, suitable low-cost technologies (for example, concrete poles of the sort used in India and single wire earth return or SWER technology), locally appropriate standards, and reduction of administrative overhead can lower initial capital costs. In the case of modern cooking fuels such as LPG, it may not be adequate simply to reduce the initial costs since recurring costs are high. A combination of top-down interventions such as lowered transport costs, bulk purchase of fuels, and regulatory reform can do much to lower recurring costs. Meanwhile, consumer-responsive approaches can provide marketing innovations that smooth out payments and allow for smaller purchases by low-income consumers. Where recurring costs are the key factor, targeting to identify those populations, carefully designed subsidies with appropriate exit strategies, and low-cost billing schemes can limit long-term costs and reduce waste.

For both types of systems—those with prohibitive capital or recurring costs—improvements in infrastructure, financing mechanisms, and institutional framework can reduce the 'overhead' of providing a service in areas

where an ability to pay for the service already exists, particularly if these overhead costs are reduced to levels comparable to those in developed countries with high penetration of services.

It is also critical that policies be enacted that facilitate delivery of energy services. For example, policies can lead to the creation and strengthening of businesses and institutions that will provide energy services, and they can promote the kind of training that people who own, manage, and work in these businesses will need. National governments can assist by reducing import duties on energy-generation technologies and equipment for electricity generation, transmission, and distribution.

Enhance Human Capacity through Education, Training, and Research

To support national and regional infrastructure development, as well as consumer-responsive service delivery systems, education and training programs are needed for skilled technicians, planners, entrepreneurs, financial services and community workers. Gender balance in skill development and use is also key to ensuring that energy services respond to the different needs of men and women.

The place-specific nature of energy resources and related infrastructure will also require local research. For example, in order to exploit the geothermal resources in the Rift Valley of East Africa, people are needed with training in geology as well as geothermal engineering to carry out everything from exploration and drilling of test wells to design, construction, and maintenance of the power plants. To carry out the detailed analysis and management of environmental, social, and economic impacts of hydroelectric power plants would require experts in hydrology, earth science, engineering, economics, and social sciences. Although the need for technical capacity in Africa is great—and projected to increase—it is one of the least-developed aspects of most enterprises throughout sub-Saharan Africa. A recent UNIDO report (2004) emphasized the reluctance of African manufacturers and other firms to employ trained scientists, engineers, and technicians. Even in Zimbabwe, which historically has had the second-most advanced industrial sector in the region after South Africa, scientific and technical staff tend to make up less than two percent of the workforce, and these are overwhelmingly concentrated in food-processing firms, due to that industry's quality control and testing needs.

Moreover, energy services for rural areas are likely to require a variety of alternative ownership and market structures. If such structures—private companies, cooperatives, local consumer associations, public-private joint ventures, or local government initiatives—are to develop, trained people who can create and manage these institutions will be needed. Enhancing local research will lead to capacity building, technological developments that emerge from local needs and practices, and the emergence of standards.

Address Regional and International Issues

In addition to local and national needs, if energy services are to be viable over the long term and scalable in a manner that will serve the millions in need, they will have to address larger regional and international issues such as trade barriers, regional integration, and the transnational nature of many energy resources.

The growth and integration of regional infrastructure and markets can be a driver of economic and social development in Africa and many other regions of the developing world. The formation of regional power pools, transmission line networks across countries, and pipelines for fuels can all contribute to better utilization of capacity, lower costs, reduced variability of supply, and a more optimal mix of primary energy sources at any point in time. It is also clear that hydropower and geothermal resources do not follow political boundaries. The creation of joint agreements for sharing the costs of study, research, and development of new regional sources of energy such as those that cut across physical and political geographies can help reduce costs and aid development across nations. The development of shared oil, gas, and electricity infrastructure and markets—such as the Southern Africa Power Pool (SAPP), the West Africa Power Pool (WAPP), and the West Africa Gas Pipeline (WAGP)—are expected to bring multiple benefits to participating nations.

For many reasons—including economic efficiency and expansion of energy services—national governments and international lending and development institutions have targeted energy systems, particularly for electricity and petroleum products, for interconnection at the regional level. Sharing electricity generation capacity allows some countries to meet energy needs without relying entirely upon their local primary energy resources or having to expand their own generation. Also, there are great price differentials in Africa: household electricity tariffs range from roughly 16 cents per kWh in Mali to roughly 5 cents per kWh in Ghana (Layec n.d.). This suggests the potential for trade, expansion in generation and supply for those with a comparative advantage, and lower cost for buyers. Other benefits relate to the nature and size of the energy markets themselves. A larger market encourages private investment and allows for projects that are larger-scale, lowering supply costs and reducing the need for redundant facilities.

Integration of energy infrastructure can also have beneficial impacts on regional politics, peace, and security. It tends to decrease the macroeconomic risks for particular countries by helping them to diversify their energy sources. Integration also fosters economic cooperation and increases the costs of conflict (Stryker et al. 1997). In contrast, a lack of crucial infrastructure, or limited energy systems with high technical and 'non-technical' losses (often due to theft), are widely recognized as impediments not only to the provision of services offered by the infrastructure itself, but also other crucial elements of growth, such as trade (Oshikoya and Hussain 2002).

Multiple studies have considered the necessary preconditions, expected benefits, and strategies of implementation for regional electricity markets in a diverse range of developing-country settings. A study of these issues in South America by ESMAP and the Regional Integration Energy Commission (CIER, a professional association of electricity companies) outlined the changes in infrastructure and legal/institutional factors, such as harmonization of regulatory rules, needed to create a 10-country regional power market including most of the South American continent (ESMAP 2001c). Other studies have examined related topics—such as progress toward and barriers to energy-sector reform, as well as the potential for development of additional energy resources—for regional power markets in the Greater Mekong Sub-Region (ESMAP 2001a), in the Nile River Basin (ESMAP 2005c) and in the East African Great Lakes Region including Burundi, Rwanda, and Zaire (ESMAP 1989). Regional integration and power pools require functioning and independent regulatory authorities and inter-country agreement on overall energy policy. Some studies have cautioned about the potentially adverse impacts on the poor in terms of access to electricity in privatized markets that focus on trading wholesale electricity whereas the retail side of the market (the electricity that reaches the consumer) may in fact become less stable due to market volatility (Johansson and Goldemberg 2002, Ch. 3).

A frequently cited example of potential gains from integration of energy infrastructure—for Africa generally, but Central Africa in particular—is the potential for hydroelectricity generation and distribution. Some estimates for hydropower in Africa include 300 GW of continuous energy for the continent as a whole and 90 GW of continuous energy for the Democratic Republic of Congo. The latter estimate equates to nearly 800 TWh per year, a potential amount that is third behind estimates for China (1,320 TWh per year) and Russia (1,096 TWh per year) and ahead of both the United States (700 TWh per year) and Canada (530 TWh per year). The power generation guaranteed during low water output years is estimated to be 80 percent of the installed capacity for the Democratic Republic of Congo, and this is the highest guaranteed amount of any nation (Sarfoh 1993; Hammons et al. 2000). Power experts from around the world have argued for this resource as a basis for regional and additional continental interconnections, based on a five-region plan. These would enlarge the extent of Africa's interconnections—currently limited to three, in the West, South, and East—while expanding Africa's energy supply, creating opportunities for continental energy trade and export to Europe.

CHAPTER 6: Conclusion

While there is no MDG on energy, access to energy services, especially by poor people and communities, is essential to reaching all of the MDGs. More and better energy services are needed to end poverty, hunger, educational disparity between boys and girls, the marginalization of women, major disease and health service deficits, as well as environmental degradation.

Energy services are the benefits that energy supplies produce; they include cooking, illumination, pumped water, communication, and mechanical power. Every stage of the energy supply chain—including the generation, distribution, and consumption of energy—has multiple impacts on the economic, social, and often environmental aspects of the MDG agenda. This is as true for the girls who do not attend school because they collect fuelwood to meet family subsistence needs as for the underemployed men and women who cannot find productive jobs or access health services due to lack of electricity in urban slums. From the point of view of individual people, the focus needs to be on access to the affordable, reliable, and safe energy services that are essential to their daily well being, rather than solely on the source of the energy itself. Unfortunately, ministries of electricity or energy have often been isolated from development planning and investment discussions within other sectors in developing countries, working diligently to increase access to electricity while many other energy needs in the society at large are left unattended.

Whether energy is needed for jobs, water pumping, health services, cooking, illumination, or food processing, multiple sources of energy and diverse technologies can provide the energy services required. Grid-connected electricity or a stand-alone diesel generator can provide mechanical power to process agricultural products in rural areas. A kerosene lamp or a PV panel can provide home lighting. An MDG-based approach to development planning asks, what is the most cost-effective way to deliver this service to the rural areas and urban

poor? The response is that multiple technologies are required, depending on the resource availability and cost effectiveness of the delivery systems available.

This report has argued that three energy objectives are particularly important to support the MDG agenda because they have direct impact on multiple MDG targets. These three objectives are: increasing access to modern fuels and cleaner biomass systems for cooking and heating; ensuring access to electricity in all urban and peri-urban areas; and providing access to mechanical power and electricity at centralized points in rural areas. The explicit costing of interventions to reach these three objectives should form part of national MDG-based planning and budgeting exercises. Appendix II provides a detailed example of one approach to calculating the cost of meeting energy goals. Using Kenya as an example, the computation illustrates that both grid and off-grid electricity options are required and that a diversity of energy technology options needs to be employed; throughout the analysis, the differing impact of energy services on men and women and the relationship of energy to various MDGs are highlighted.

Delivery of the energy services needed to meet the MDGs requires consultation across multiple ministries, as well as engagement with business investors, community groups, and NGOs. Supportive policy and pricing frameworks are required not just in the energy sector but throughout each country's national development framework. The use of public funds to support priority energy interventions with a high social return is advocated, while subsidies for recurring energy costs at large are cautioned against due to the long-term economic cost. In the short term, the emphasis should be on increasing access to energy services through a variety of measures, including subsidizing household electricity connection fees, lowering the costs of stoves or LPG canisters for cooking, and providing community-based mechanical power through government investment.

These efforts will require institutional support and capacity building domestically and from the international community to ensure that policymakers, regulators, local business entrepreneurs, and technical personnel have the skills needed to support an energy system that delivers centralized and decentralized energy services depending on the national conditions.

Unfortunately, this report points to another stark conclusion: failure to include energy considerations in national development strategies and development frameworks will undermine the ability to reach all the MDGs. This does not need to happen. Successful examples of expanding access to modern fuels, electricity, and mechanical power exist and are featured here. These success stories show that Goal-oriented strategies for scaling up access to energy services are not only possible but also necessary to achieve the MDGs. They therefore must be an essential component of any national strategy to achieve the MDGs.

No new MDG is needed on energy. What is needed is to address energy needs within the entire MDG framework as a means to reduce poverty and improve human development in line with the Millennium Declaration.

Appendices

Appendix I: MDG and Energy Workshop (1 October 2004) Participants

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Edwin Adkins	Columbia University, USA
Moncef Aissa	Tunisia Electricity and Gas Company (STEG)
Harriette Amissah-Arthur	Kumasi Institute of Technology and Environment (KITE), Ghana
Fatih Birol	International Energy Agency (IEA)/Organisation for Economic Co-operation and Development (OECD)
Laurent Coche	United Nations Development Programme (UNDP)
Amadou Diallo	Yéelen Kura, Mali
Yassine Fall	United Nations Development Fund for Women (UNIFEM)/ United Nations Millennium Project
Cahit Gurkok	United Nations Industrial Development Organization (UNIDO)
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Stephen Karekezi	African Energy Policy Research Network (AFREPREN), Kenya
Dominique Lallement	World Bank
Susan McDade	United Nations Development Programme (UNDP)
Vijay Modi	Columbia University, USA

Jem Porcaro	United Nations Development Programme (UNDP)
Jeffrey Sachs	United Nations Millennium Project/Columbia University, USA
Jamal Saghir	World Bank
Guido Schmidt-Traub	United Nations Millennium Project
Melessaw Shanko	Megan Power Limited (MGP), Ethiopia
Minoru Takada	United Nations Development Programme (UNDP)
Griffin Thomson	United States Department of State
Robert Watson	World Bank

Appendix II: Computation of Annual Per Capita Costs of Meeting Energy Goals: The Example of Kenya

For the purpose of illustration, costing estimates to meet the three proposed energy targets are described here in greater detail. We wish to emphasize here that country priorities may vary and in many cases countries may adopt more aggressive timeframes to achieve targets. This costing is carried out for one country, Kenya, for illustrative purposes. What follows are estimates that are perhaps best seen as providing a framework for computing costs; the framework illustrates the scale of the costs to meet the targets in a country with low existing coverage in each of the targets.

The costing approach taken here follows the MDG needs assessment approach pioneered by the UN Millennium Project. The costing method requires some preparatory explanation. The energy targets are for the percentage of populations to be covered within 10 years. The difference between this target coverage and the current coverage represents a gap in coverage. This gap would be closed over a number of years using a strategy that presumably adds some planned amount of coverage each year. So additional annual coverage needed would depend upon existing coverage, the target, the change in population and the how the gap in coverage is distributed over the next 10 years. For simplicity, we have not taken population changes into account and the coverage gap is simply divided equally over 10 years in this costing, implying 10 percent new coverage each year. So for example if 70 percent of the country population is rural, and 95 percent of that rural population currently lacks access, and the target is to reach all rural population in 10 years, then the annual gap to be covered would be (0.70)(0.95)(0.1)*100 percent of the total population.

For Kenya, for example, the annual cost of extending grid electricity (or cost-effective, off-grid approaches) to institutions such as schools, clinics, and community centers (e.g., small business clusters, community water supply systems) for a rural population are estimated to be US$67 million. A detailed explanation of how this estimate is arrived at is described below. Annual national costs for each of the three targets are then summarized in Table II.1. This cost does not include the cost of household electrification in rural areas (as that is not a target as such).[4]

For macroeconomic comparisons across different interventions and across countries with different populations, it is useful to compute a per capita cost of this particular intervention. This annual per capita estimate is computed simply by dividing the annual national cost by the national population. So the

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[4] If this is indeed deemed to be a national priority then additional costs would need to be included. Note, however, that where grid electricity is anticipated at community scale, it would reduce the cost of household electrification.

annual per capita cost of this intervention (extending electricity to rural insti-
tutions) would be computed as US$67 million divided by the Kenyan popula-
tion of 35 million, thus obtaining a figure of US$1.91 per capita. Such annual
per capita costs for Kenya for all three targets are then summarized in the final
column of Table II.1. Table II.2 provides the demographic, geographic, engi-
neering, and cost assumptions that underly the cost computation for national
level interventions.

Table II.1
**Estimated annual
national and per capita
costs of energy
interventions in Kenya**

Source: authors' calculations

	Cost for national interventions (US$ millions)	Per capita cost (US$)
Improved cooking fuels (50% LPG stoves and fuel, 50% sustainable forestry)	**323**	**9.2**
LPG stoves and canisters	16	0.5
LPG fuel	260	7.4
Sustainable biomass forestry	12	0.3
Improved biomass cookstoves	35	1.0
Grid extension to urban and peri-urban households	**53**	**1.5**
Electricity for rural schools, clinics, community centers	**67**	**1.9**
Capital expenditures	35	1.0
Recurring supply costs	32	0.9
Total costs, all interventions	**443**	**12.7**

Costs of Energy Target 1: Improved cooking fuels
The first intervention, focused on improvement of cooking fuels used by the
poor, involves two components. One component focuses on expanding access
to modern cooking fuels (assumed to be specifically LPG appliances and fuel);
the second component addresses increased biomass availability and cleaner use
of biomass. We have assumed here a goal to reach 50 percent of the country's
population for each component within the next 10 years by 2015. Costs for
both the LPG and biomass components are detailed below.

Table II.2
Data and assumptions supporting intervention cost estimates in Kenya

	Data and assumptions	Notes
Basic geographic and socioeconomic data	Population of Kenya: 35 million Area of Kenya: ~600,000 sq km Average national household size: 5 Per cent of population residing in rural areas: 70% Population, on average, of each rural community: 2,000 Geospatial aggregation factor (rural institutional): 0.30*	*An assumed/estimated value, based on observation and geospatial (GIS and remote sensing) inputs. (See 'disaggregation factor' discussion in Box II.1)
Modern cooking fuels and Improved biomass cooking	**National need for LPG** Current national LPG penetration rate: 5% **LPG appliance and fuel costs** Cost of LPG cookstove and canister: US$50 Cost of LPG fuel: US$750 per tonne **Improved biomass cooking** Cost of initiating sustainable biomass production: US$35 perhousehold Cost of improved cookstove with chimney per household: US$100	These estimates assume that 50% of the need for improved fuels will be met by modern cooking fuel such as LPG. The other 50% will be met by expanding biomass supply and cleaner use of biomass
Electrification of urban and peri-urban households	**Inputs for estimate of system size** % of total population residing in urban areas: 30% Penetration of grid electricity in urban areas: 15% (85% no access) **Inputs for estimate of system cost** Cost per urban/peri-urban connection: US$500	• These projections do not include any infrastructure or power needs for the industrial sector
Access to modern energy (electricity and mechanical power) for all rural community centers	**Inputs for estimate of system size** Rural community centers without electricity: 95% Annual power consumption per electrified center: 5,000 kWh **Inputs for estimate of system cost** Recurring cost of electricity generation: US$0.10 perkWh Line costs, medium voltage: US$15 per m Cost multiplier for transformers: 1.20 (or +20%) **Inputs for off-grid approaches** Cost of mechanical power, per village of 2,000: US$15,000	• Both programs would address 10% of the unserved population each year

Modern cooking fuel

A switch to a modern cooking fuel such as LPG requires a capital expenditure for the hardware, (i.e., cookstoves and canisters) and recurring costs for fuel. The capital expenditure for the hardware for each household is assumed to be US$50. If the number of households that already use modern cooking fuels is 5 percent of the total population, one would need to reach 45 percent of the population in the next 10 years to reach the 50 percent coverage target. This corresponds to 45 percent of the 7 million Kenyan households, or 3.15 million households). So the total cost for canisters and cookstoves over a 10-year period would be the product of 3.15 million households and US$50/household, for a total of US$157.5 million. If 10 percent coverage is achieved each year, the annual cost would be US$16 million.

The fuel component of the cost per household per year is computed assuming that each household would consume 200 kg of LPG per year if LPG were the only source of fuel. At an LPG cost of US$750 per tonne, this would work out to US$150 per household per year. If 10 percent of the 3.15 million households estimated in the prior paragraph are considered to be new consumers each year, we can compute the annual fuel cost for the first year to be the product of the annual cost of US$150 per household and 315,000 (the number of additional households using LPG), resulting in US$47 million. When the entire 10 year span is considered, then this calculation must include both the costs for new customers added with LPG expansion each year as well as the need to serve customers from previous years' expansion. This is done by summing the entire consumption as it grows throughout the 10-year period, then dividing by the 10-year duration of the project. So, for example, in the second year, the cost of serving the original 315,000 households would continue, and another set of households would be added, doubling the second-year cost to US$94 million. In the third year, the cost would be triple that of the first year, and so on. As this pattern continues, this creates a factor of (1 + 2 + 3 + …. + 10 = 55) to characterize the total costs for 10 years. Finally, for simplicity, this total is divided by 10 to give the per year cost for the 10-year span. The result is that a factor of 55/10 = 5.5 will accompany the LPG fuel cost calculation for the first year, giving a final annual cost of US$260 million for LPG fuel expenditures (see Table II.1).

Note that given specific country priorities some portion of the cost of modern cooking fuels would be borne by the consumer.

Improved biomass cooking

The cost associated with initiating sustainable biomass production through agroforestry, woodlots, farm trees, or community forests is assumed to be US$35 per household. This figure was arrived at assuming annual fuelwood consumption per family of 3.5 tonnes and a US$10 per tonne cost of initiating sustainable means of producing the biomass. Assuming that 3.5 million households (i.e., half of the 7 million Kenyan households) are targeted over a 10-year period, we

estimate a total 10-year cost to be US122.5 million. Assuming 10 percent coverage is added each year, the annual cost would be US$12 million.

One way to switch to cleaner biomass use may be the use of biomass cook stoves with means to reduce exposure to smoke, for example through the use of chimneys. This approach is used for costing here, while recognizing that there may be other technologies and practices that may be more suitable depending upon the local cooking practice and the local source of biomass. We assume the cost per household of such an intervention is US$100. So the total 10-year cost of targeting the 3.5 million households is US$350 million. Assuming 10 percent coverage is added each year, the annual cost would be US$35 million (see Table II.1).

Costs of Energy Target 2: Electricity in urban and peri-urban areas

The second intervention requires an estimate of the cost of providing electricity connections to 100 percent of the urban and peri-urban poor. Due to the high population density, degree of aggregation, and proximity to pre-existing electrical grids of the urban population, this calculation is not carried out based on transmission line length (as is the case for rural areas, described in the next section) but instead assumes a flat capital expense for each additional grid connection. We begin with capital expenditures for urban grid electrification first, and follow with recurring costs for power generation.

The first question is determining the number of households that would need to be connected each year. If one takes the current urban electricity penetration rate to be 15 percent, one would need to reach the remaining 85 percent of the urban households over the next 10 years. The number of urban households in Kenya is estimated to be, 2.1 million (obtained as a ratio of the urban population in Kenya, which is about 30 percent of the national population, or about 10.5 million, and average household size which is taken to be 5). So the number of urban households that need to be connected in the next 10 years is 85 percent of 2.1 million, which works out to be 1.8 million households. If each of these connections cost, on average, US$300, the total capital cost is US$534 million. Following the earlier approach of ensuring a 10 percent coverage each year for 10 years, the annual cost would US$53 million. If represented as a per capita cost this target would represent a cost of US$1.53. Note that here the population base that is used to compute the per capita cost is the national population of 35 million.

Costs of Energy Target 3: Modern energy services (mechanical power and electricity) at the community level for all rural communities.

The third target addresses the need for electricity access (through grid extension or through off-grid approaches) to institutions such as schools, clinics and community centers for rural communities. The size of such rural communities is assumed to be, on average, 2,000 people, and the community center is assumed to be a centrally located institution, such as a school, clinic or hospital. Note that both these assumptions would strongly vary across different agroecologies

in a country and also would vary from country to country. The target is to reach 100 percent of the rural population nationally by 2015. The electricity connection could serve any or all of several needs including lighting for a village school; refrigeration of vaccines and other crucial energy needs of a clinic or hospital; power for a central charging point for various small appliances distributed throughout the village; a node of high-wattage power for mechanical or light-manufacturing work; and a telecommunications hub, among others.

Initially, the cost estimate is based on grid extension. In remote and sparsely populated areas, off-grid approaches are likely to be more cost-effective, nevertheless the grid-based costs provide a bound of sorts for such estimates. The cost estimate is obtained as follows.

Unlike urban areas, where a cost estimate for each additional grid connection can be adequately estimated by a single flat fee, in less-dense, rural areas, the costs of wire, transformers, and other features of the electrical grid itself are the dominant cost. Hence, one must estimate the distances between each community center. A computation that assumes a perfectly uniform distribution of all rural community centers in Kenya would simply divide the total area of the nation (600,000 square kilometers) by the total number of all rural community centers in the country (estimated to be 12,250) and then taking the square root of the result (see Box II.1), giving nearly 7 kilometers. Note that the number of rural community centers was arrived at by dividing the rural population (70 percent of Kenya's total population of 35 million, or 21.4 million people) by 2,000 (the estimated size of a rural community).

This distance of 7 kilometers between community centers, however, does not account for the tendency of settlement patterns to avoid some terrains (deserts, especially) and concentrate people in clusters. To resolve this issue, a key assumption for this calculation is made, specifying the institutional 'disaggregation factor' (also described in Box II.1). This factor for Kenya is taken to be 0.30; when multiplied by 7 (the assumed distance between rural community centers) results in a more realistic 2.1 kilometers between each rural community. Next, the number of rural institutions requiring grid electrification is estimated by multiplying the number of rural community centers computed above, 12,250, by the percentage lacking access to electrification (95 percent). This gives 11,600 rural community centers requiring electricity.

These results—11,600 rural electrification points that are, on average, 2.1 km apart—becomes the basis for computation of capital expenditure related to transmission and distribution—the largest single fraction of the total costs. Multiplied together, they give the total length of medium voltage (MV) line required for transmission, or 24,400 km. At US$10,000 per km of MV line, this cost is US$244 million. Transformer costs are computed by simply using a multiplier cost of 20 percent raising this total network cost to US$293 million. Also, there is a cost of roughly US$5,000 per community center connection, multiplied by the number of connections (11,600) giving a connection cost of US$58 million.

When these two costs—the total network cost and total connection cost—are summed, the result is the total capital expenditure for grid expansion for Kenya amounts to approximately US$350 million. With an assumed 10 percent coverage per year, the annual cost would be US$35 million (see Table II.1), or US$30,000 per community center.

The main recurring cost is for purchasing power. Note that the framework for generation costs is that these costs would be paid to the electricity-generating entity in a transparent and explicit fashion. The investment cost of creating the generation capacity is included here as part of the per kWh cost of electricity. If each institution is assumed to consume about 5,000 kWh of electricity per year at a cost of US$0.10 per kWh, then a single institution's consumption would cost US$500 for the first year. This figure would vary with the source of power among others. Where electricity is predominantly produced from liquid fuels the cost per kWh would be much higher. For all 11,600 institutions covered by the initial year of grid expansion, this amounts to US$5.8 million. As was the case with recurring costs for LPG fuel presented above, when the entire 10-year span is considered, the fuel generation cost must include both the costs for new customers added each year and the costs of serving customers from previous years' expansion. This requires that the first-year power generation costs again include a factor of 5.5, giving a final value of US$32 million for power generation expenditures.

In the above analysis the cost of creating electricity access to each rural community was estimated to be about US$30,000 (US$350 million divided by 11,600 rural communities). In remote and sparsely populated areas, it may be more cost-effective to provide off-grid access to community facilities such as clinics, schools and community centers. The actual technologies would depend upon available local resources (solar, wind, biomass, micro-hydro, diesel generators) and the anticipated demands and loads. For example, the need for mechanical power—for grinding, water pumping, and many other potential applications at the village level—could be estimated from the known costs for a multifunctional platform, US$15,000; this amount would provide, for example, a diesel engine with one or more related tools that would provide a range of services for a typical community of 2,000 persons. Appliances needed at clinics/schools may require additional costs. For estimating purposes, it is assumed that the total cost of off-grid electricity will be within or near about the US$30,000 per community figure for grid extension.

Summary of national and per capita costs for interventions

All of the costs computed above are summarized in Table II.1. These are expressed first in terms of the entire costs for national interventions annually and then in per capita annual terms. For macro-economic reasons and for cross-sectoral comparisons, the per capita values are computed simply by dividing the aggregate cost of the national interventions by the national population of Kenya (35 million).

An important component of these estimates is a geographic 'disaggregation factor,' which provides an estimate of the degree to which the rural population is spread sparsely over the landscape, or concentrated in town centers or other clusters. This factor is explained in more detail in Box II.1. This factor, between 0 and 1, indicates the degree to which the length of a network connecting features on the landscape—in this case community centers or houses —is smaller than the network length if all features were evenly spaced. A value of one indicates that all features are uniformly spaced and hence the network length is the maximum possible, while a value close to zero indicates that all features are clustered tightly together and hence the network length is small; both extremes are, obviously, not seen in real geographies. The network length scales with the mean distance between features.

A variety of cultural, geographic, biophysical, and economic reasons lead to variation in geographic disaggregation. In looking at rural community centers as the features of interest, as in Kenya, some important contributing factors are the large arid or semi-arid regions of the country, rivers, topography, concentration in urban centers, and other factors leading to aggregation, which contribute to a lower value. For the purposes of the cost estimates, this factor is used to compute inter-community distances in a part of Western Kenya near Lake Victoria. The disaggregation factors used for this estimate is 0.30, indicating that the inter-community distance in rural Western Kenya tends to be approximately one third what one would predict by simply averaging their distribution evenly over the entire land area. This value is approximate, but has been ground-truthed and compared with distances typically found in satellite-sensed imagery and GIS data.

Box II.1
The geographic disaggregation factor

If one has data describing the actual distance between reference points on a landscape (people, buildings, town centers, etc.), then the average distance between each item, $\bar{a}$, is simply the sum of each distance, d, divided by the total number of points, N:

$$\frac{\sum d_n}{N} = \bar{a}$$

If, however, one assumes that all reference points are spread evenly over the landscape, and the distance between them, a, is maximized, the formula becomes the square root of the area of the country divided by the number of points:

$$\sqrt{\frac{A}{N}} = a$$

The ratio of these two numbers—the actual average distance between points ($\bar{a}$) divided by the maximum average distance between points (a)—expresses the degree to which points are dispersed or aggregated across the landscape, which is referred to here as the disaggregation factor, f, which will range between 0 and 1:

$$\frac{\bar{a}}{a} = f \qquad ; \qquad 0 < f \le 1$$

The factor is an expression of the ratio of the actual spacing of features versus their maximum possible spacing. The closer this value is to 1, the more disaggregated are the points over the landscape. An example of a relatively disaggregated landscape would be a pattern of consistently sized farms with households placed more or less centrally on each farm. Settlement patterns of roughly this type can be seen in geographies as diverse as the American Midwest (which is sparsely settled, on average) to Western Kenya (which is relatively densely settled). The opposite situation, where f is close to zero, refers to a highly aggregated landscape. The settlement patterns of a country such as Australia, with its population highly concentrated in coastal areas, is one example. Mountainous island nations or communities, which have populations clustered in coastal lowlands, are another example of a highly aggregated landscape. Again, the value of f has no necessary relationship to average population density. A landscape can be very sparsely settled, on average, and still have a high degree of aggregation if settlements, buildings, and people are concentrated. On the other hand, a landscape can be very densely settled, on average, but still have a high disaggregation factor, close to 1, if the features are uniformly spread over the landscape.

Appendix III : Providing Energy Services for the MDGs: Assessing Needs and Planning for Scaling Up

The core recommendation of the UN Millennium Project is to put the MDGs at the center of national and international national development strategies through a series of specific and practical efforts by developing countries themselves and their development partners. The Project's recommended strategy begins at the country level. Every country that suffers from extreme poverty—including middle-income countries with pockets of extreme poverty—should be encouraged and supported to adopt an MDG-based national development strategy, building on existing strategies. The MDG-based national development strategy should set a serious 10-year timetable to 2015, with policies, governance strategies, and public investment plans. In order to achieve the MDGs, countries need to take the 2015 targets and time horizon seriously. This implies a major a shift in thinking and language: from planning around a marginal expansion of social services and infrastructure to planning around a long-term investment strategy to achieve the MDGs. The world thus needs to change its discussions from a focus on 'accelerating progress towards the Goals' to 'achieving the Goals.'
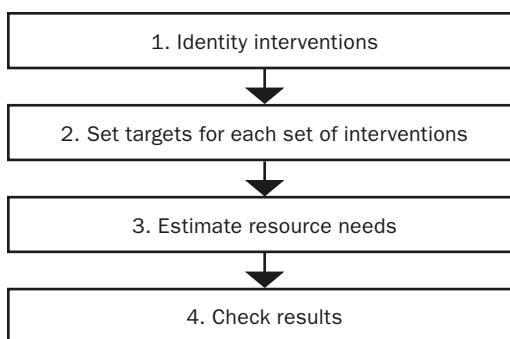
As a first step toward developing MDG-based national development strategies, countries will need to work backwards from the MDG outcome targets to concretize the operational set and scale of public interventions—including human resources, infrastructure, and financial resources—needed as inputs in order to achieve the Goals by 2015. We call this quantification of required investments the 'MDG needs assessment.'

Needs assessments quantify the human resources, infrastructure, and financial resources required to meet the MDGs between now and 2015. These interventions will need to be accompanied by policies that enable rapid and equitable scaling up of services and infrastructure needed to reach the MDGs. Reaching the MDGs requires a broad set of interrelated actions that can be divided into nine areas of activity—termed 'investment clusters':

1. Rural development—increasing food output and rural incomes
2. Urban development—promoting jobs, upgrading slums, and developing alternatives to new slum formation
3. Health systems—ensuring universal access to essential health services
4. Education—ensuring universal primary education and expanded post-primary and higher education,
5. Gender equality—investing to overcome pervasive gender bias
6. Environment—investing in improved resource management
7. Science, technology and innovation—building national capacities
8. Cross-national infrastructure—trade integration and government co-operation
9. Public sector management.

Investments in improved energy services are critical for supporting each of the clusters identified above. The UN Millennium Project is therefore recommending to explicitly include investments in energy services. Energy services can be thought of as forming an integral part of rural and urban development strategies. Alternately, a needs assessment could treat energy as a separate investment cluster in itself.

The UN Millennium Project has divided the needs assessment into four analytical steps to answer the question "What investments are needed to achieve the MDGs?"

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│           1. Identity interventions             │
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│    2. Set targets for each set of interventions │
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│           3. Estimate resource needs            │
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│               4. Check results                  │
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Presented below are some suggested interventions, targets, calculations, and sample results that may be useful for countries as they conduct a national energy needs assessment.

Step 1: Develop list of interventions

Rural energy interventions may include:

- interventions to support the use of modern cooking fuels (such as LPG and kerosene) and modern cooking devices (such as stoves and canisters);
- interventions to reduce the adverse health impacts from cooking with biomass (improved ventilation, chimneys, smoke hoods, and behavioral change interventions);
- interventions to increase sustainable biomass production (agroforestry, woodlots or community forestry, area closures, etc.);
- interventions to increase the access of rural communities to reliable electricity and mechanical power, including: electrification for rural social services such as schools, hospitals, and clinics (through grid extension, diesel generators, mini-grids, etc.);
- interventions to facilitate community-level access to electricity and mechanical power—for cooperatives, small businesses, and community centers—through support for electrification, fuel, and mechanical devices; and

- interventions to facilitate the use of electricity in rural communities that are not connected to the grid, through low-cost technologies such as batteries.

Urban energy interventions may include:
- interventions to support the use of modern cooking fuels (such as LPG and kerosene) and modern cooking devices (such as stoves and canisters);
- interventions to reduce the adverse health impacts from cooking with biomass (improved ventilation, chimneys, smoke hoods, and behavioral change interventions);
- interventions to ensure access to reliable electricity and mechanical power for urban areas (through grid extension, lifeline rates, etc.);
- financing mechanisms to spread out first costs of electricity connection, fuel supply and devices, etc.; and
- bill collection and monitoring interventions (such as smart cards and personnel).

Step 2: Specify targets for each set of interventions
Each country needs to identify its output targets for energy services that link to the broader objective of meeting the MDGs. The UN Millennium Project proposes the following output targets that countries can adapt and expand to suit their own needs:

Suggested targets for rural areas:
- enable the use of modern fuels and devices for 50 percent of those who at present use traditional biomass for cooking,
- reach other users of traditional biomass with efforts to develop and adopt the use of improved cookstoves, measures to reduce the adverse health impacts from cooking with biomass, and measures to increase sustainable biomass production, and
- provide access to modern energy services at the community level for all rural communities (in the form of electricity and mechanical power). This entails (1) reaching 100 percent access to electricity for all schools, clinics, hospitals, and community health centers, (2) reaching rural cooperatives, small businesses, and other community centers with adequate sources of electricity and mechanical power, and (3) the ability to meet basic household level electricity needs through community-level battery charging stations

Suggested targets for urban areas:
- ensure reliable access to modern energy services (including electricity services and improved fuels and devices) in the urban and peri-urban areas, including access for all households and schools, hospitals, clinics, and community health centers.

Step 3: Estimate resource needs

The UN Millennium Project has created needs-assessment tools (in most cases, spreadsheet-based models) to estimate the costs of delivering the interventions described above.

Each set of spreadsheets needs to be tailored to account for locally specific interventions in each country.

In most cases, needs can be estimated using simple multiplication. Examples include:

Multiplication by coverage of population:
[Population size] × [percentage of population reached] × [amount of intervention per person or household] × [unit cost of intervention] every year with rising coverage—and scaled up over the 10-year period to meet targets.

Multiplication by infrastructure units (e.g., km of medium- or high-voltage line):
[Total infrastructure units] × [percentage of total reached each year] × [unit cost of intervention]—scaled up over the 10-year period to meet targets.

Overhead:
[Total needs in investment area per year] × [percentage overhead]

Consumption targets per household or institution are a key input to this sort of calculation. Table III.1 presents recent UN Millennium Project estimates of the amounts of modern fuel needed in a variety of situations.

Table III.1		**Modern cooking fuel needed annually**
Estimates of MDG-compatible modern cooking fuel consumption levels	Household	1 GJ 'into the pot'
	School (lunch, 500 children)	2,500 kg LPG or equivalent
	Hospital	10,000 kg LPG or equivalent
Source: authors' estimates	Clinic/health post	200 to 1,000 kg LPG or equivalent

Table III.2 presents recent UN Millennium Project estimates of electricity consumption levels that households and key public institutions need.

The needs assessment should cover the period between the starting year (e.g., 2005) and 2015. Total resources calculated for the full time period will then need to

	Lighting/electrification
Households	75 kWh / 15 kWh[a]
School	2,000 kWh
Hospital	50,000 kWh
Clinic/health post	2,000 to 8,000 kWh

[a] 75 kWh is sufficient to provide reading light in one room for 4 hours each day. Households that receive electricity through batteries charged at local schools will only be able to access enough electricity to cover minimal household lighting needs (15 kWh).

be divided into annual increments, depending on the scale up path of the investments. This path will be determined by national priorities as well as by immediate capacity constraints. It will also be important to reassess and update unit costs as the interventions are implemented, as they may go up or down with increasing coverage.

The energy needs assessment tool, for example, calculates resource needs for energy interventions that reach rural and urban households as well as institutions that provide essential social services.

The needs assessment tool requires the following inputs:

- current and target coverage for MDG-compatible cooking, space heating, and mechanical power,
- minimum cooking fuel and electricity consumption requirements to meet the MDGs,
- complementary infrastructure and services necessary for delivering interventions (such as grid extension, fuel delivery, and cookstoves), and
- unit costs for each intervention.

Using these inputs, the spreadsheets allow the user to calculate:

- number of households and social service institutions with access to MDG-compatible energy services,
- physical infrastructure and fuel inputs needed to achieve the targets,
- resources needed for upgrading and maintenance, and
- per capita and total costs of providing interventions.

Step 4: Check results

With any needs assessment, the results should be carefully reviewed to make sure that they are accurate and adequate to reach the MDGs. This report attempts rough estimates of the costs of meeting a set of energy-related MDG-based targets in East Africa, with Kenya as an example. This is with the view to understanding both the absolute cost of the entire set of goals, as well as the relative cost of each.

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Acronyms

AFREPREN	African Energy Policy Research Network
ALRI	acute lower respiratory infection
ARI	acute respiratory infection
CDM	Clean Development Mechanism
CIER	Regional Integration Energy Commission
CIESIN	Center for International Earth Science Information Network
CIS	Commonwealth of Independent States
COPD	chronic obstructive pulmonary disease
DFID	Department for International Development (UK)
DME	dimethyl ether
$PPP	purchasing power parity dollars
ESMAP	UNDP/World Bank Energy Sector Management Assistance Programme
FAO	Food and Agriculture Organization of the United Nations
GDP	gross domestic product
GHG	greenhouse gas
GIS	geographic information system
GJ	gigajoule
GNESD	Global Network on Energy for Sustainable Development
HDI	Human Development Index
IBGE	Instituto Brasileiro de Geografia e Estatísticas
ICT	information and communication technology
IEA	International Energy Agency
IFAD	International Fund for Agricultural Development
IEEE	Institute of Electrical and Electronics Engineers
IIMA	Indian Institute of Management Ahmedabad
JPOI	Johannesburg Plan of Implementation

kgoe	kilograms of oil equivalent
KITE	Kumasi Institute of Technology and Environment (Ghana)
kWh	kilowatt hour
LDC	Least-Developed Country
LPG	Liquefied Petroleum Gas
LV	low voltage
MDG	Millennium Development Goal
MFP	multifunctional platform
MV	medium voltage
NEPAD	New Partnership for Africa's Development
NGO	non-governmental organization
ODA	official development assistance
OECD	Organisation for Economic Co-operation and Development
PRSP	Poverty Reduction Strategy Paper
PV	photovoltaic
SAPP	Southern Africa Power Pool
SEI	Stockholm Environmental Institute
Sida	Swedish International Development Agency
SME	small and medium-sized enterprise
STEG	Tunisia Electricity and Gas Company
SWER	single wire earth return
TANESCO	Tanzania National Electric Utility
TWh	Tetrawatt hours
UECCO	Urambo Electric Consumers Cooperative Society
UNAIDS	Joint United Nations Programme on HIV/AIDS
UNDESA	United Nations Department for Economic and Social Affairs
UNECA	United Nations Economic Commission for Africa
UNIFEM	United Nations Development Fund for Women
UNDP	United Nations Development Programme
UNIDO	United Nations Industrial Development Organization
WAGP	West Africa Gas Pipeline
WAPP	West Africa Power Pool
WHO	World Health Organization
WSSD	World Summit on Sustainable Development

The Millennium Development Goals

Goal 1: Eradicate extreme poverty and hunger
Target 1: Halve, between 1990 and 2015, the proportion of people whose income is less than $1 a day
Target 2: Halve, between 1990 and 2015, the proportion of people who suffer from hunger

Goal 2: Achieve universal primary education
Target 3: Ensure that, by 2015, children everywhere, boys and girls alike, will be able to complete a full course of primary schooling

Goal 3: Promote gender equality and empower women
Target 4: Eliminate gender disparity in primary and secondary education, preferably by 2005, and in all levels of education no later than 2015

Goal 4: Reduce child mortality
Target 5: Reduce by two-thirds, between 1990 and 2015, the under-five mortality rate

Goal 5: Improve maternal health
Target 6: Reduce by three-quarters, between 1990 and 2015, the maternal mortality ratio

Goal 6: Combat HIV/AIDS, malaria and other diseases
Target 7: Have halted by 2015 and begun to reverse the spread of HIV/AIDS
Target 8: Have halted by 2015 and begun to reverse the incidence of malaria and other major diseases

Goal 7: Ensure environmental sustainability
Target 9: Integrate the principles of sustainable development into country policies and programs and reverse the loss of environmental resources
Target 10: Halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation
Target 11: Have achieved by 2020 a significant improvement in the lives of at least 100 million slum dwellers

Goal 8: Develop a global partnership for development
Target 12: Develop further an open, rule-based, predictable, nondiscriminatory trading and financial system (includes a commitment to good governance, development, and poverty reduction—both nationally and internationally)
Target 13: Address the special needs of the Least Developed Countries (includes tariff- and quota-free access for Least Developed Countries' exports, enhanced program of debt relief for heavily indebted poor countries [HIPCs] and cancellation of official bilateral debt, and more generous official development assistance for countries committed to poverty reduction)
Target 14: Address the special needs of landlocked developing countries and small island developing states (through the Program of Action for the Sustainable Development of Small Island Developing States and 22nd General Assembly provisions)
Target 15: Deal comprehensively with the debt problems of developing countries through national and international measures in order to make debt sustainable in the long term. Some of the indicators are monitored separately for the least developed countries, Africa, landlocked developing countries, and small island developing states
Target 16: In cooperation with developing countries, develop and implement strategies for decent and productive work for youth
Target 17: In cooperation with pharmaceutical companies, provide access to affordable essential drugs in developing countries
Target 18: In cooperation with the private sector, make available the benefits of new technologies, especially information and communications technologies

The Millennium Development Goals are the world's shared targets for dramatically reducing extreme poverty in its many dimensions – income poverty, hunger, disease, exclusion, lack of infrastructure and shelter – while promoting gender equality, education, health, and environmental sustainability, all by 2015. These bold Goals can be met in all parts of the world if nations follow through on their commitments to work together to meet them. While the Goals do not include any concrete energy targets, they will not be met unless access to improved energy services is increased.

The UN Millennium Project was commissioned by UN Secretary-General Kofi Annan to develop a practical plan of action to meet the Millennium Development Goals. An independent advisory body directed by Professor Jeffrey D. Sachs, the UN Millennium Project presented its findings and recommendations to the UN Secretary-General in January 2005, laid out in Investing in Development and in the 13 reports of the UN Millennium Project Task Forces. These reports underscore the importance of energy services for achieving the Goals.

 "Energy Services for the Millennium Development Goals" has been co-authored by ESMAP, UNDP, the UN Millennium Project, and the World Bank to outline practical strategies for providing the energy services needed to meet the Goals by 2015. The report draws on the findings of a working group on energy comprising experts from governments, academia, international organizations, and civil society, which was led by Prof. Vijay Modi of Columbia University.

The report first describes the energy services and associated coverage targets that need to be met to achieve the Millennium Development Goals. It then outlines the operational challenges that the world's poorest countries face in providing these services and lays out a set of practical recommendations for how these energy challenges can be met. In doing so, the report outlines how countries can increase access to energy services as part of their MDG based poverty reduction strategies.