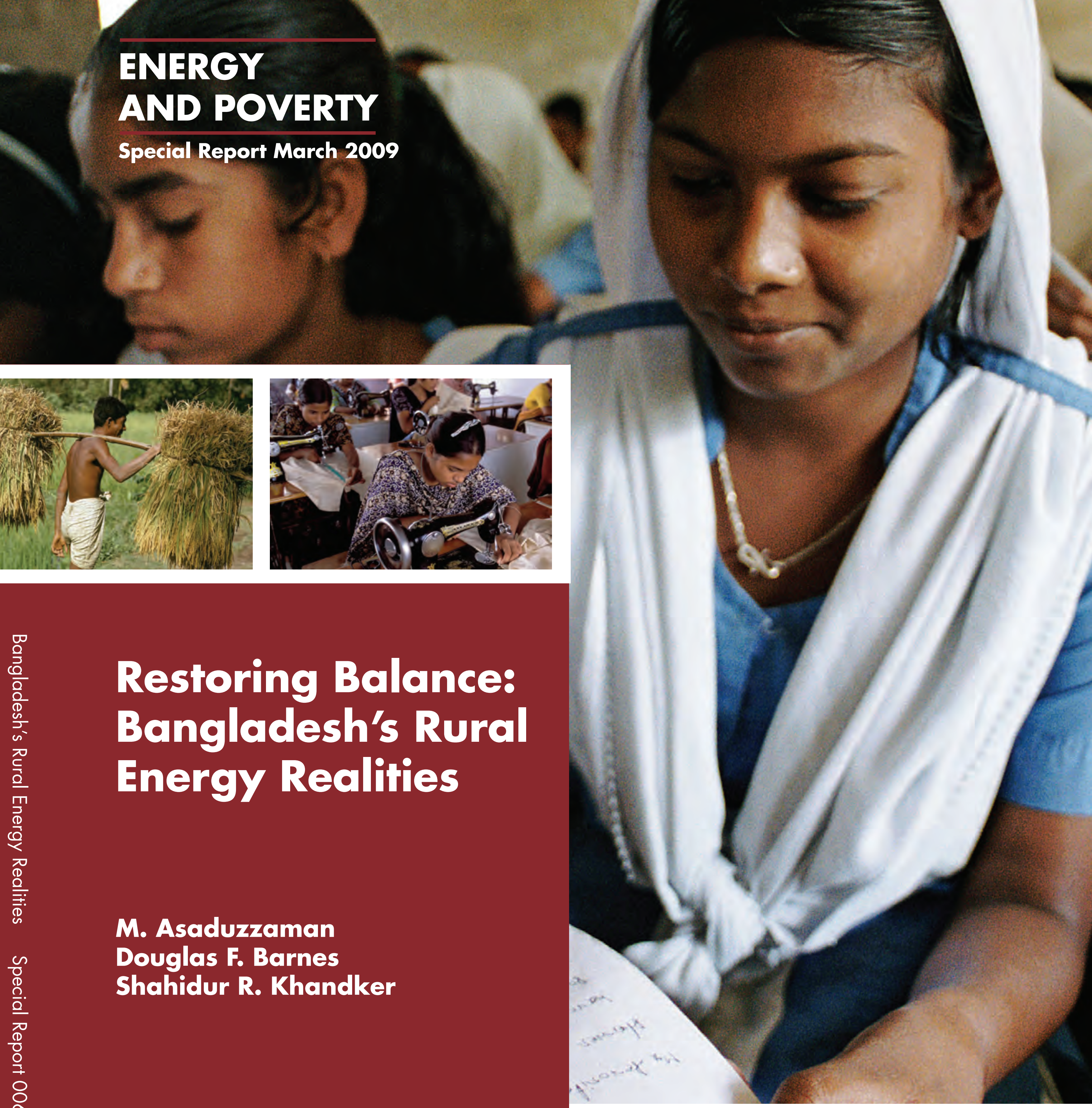

ENERGY AND POVERTY
Special Report March 2009

Restoring Balance: Bangladesh's Rural Energy Realities

M. Asaduzzaman
Douglas F. Barnes
Shahidur R. Khandker

Bangladesh's Rural Energy Realities Special Report 006/09 March 2009

ESMAP

Energy Sector Management Assistance Program

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Research at the World Bank
Development Research Group

Energy Sector Management Assistance Program

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Abbreviations and Acronyms

ARI	acute respiratory infection
BBS	Bangladesh Bureau of Statistics
BCSIR	Bangladesh Council for Scientific and Industrial Research
BIDS	Bangladesh Institute of Development Studies
BPC	Bangladesh Petroleum Corporation
BPDB	Bangladesh Power Development Board
CNG	compressed natural gas
ERC	Energy Regulatory Commission
ESMAP	Energy Sector Management Assistance Program
EXTOP	World Bank Office of the Publisher
FAO	Food and Agricultural Organization
GOB	Government of Bangladesh
HIES	Household Income and Expenditure Survey
IAP	indoor air pollution
IDCOL	Infrastructure Development Company Limited
IEA	International Energy Agency
IFRD	Institute of Fuel Research and Development
LNG	liquefied natural gas
LPG	liquefied petroleum gas
NGO	Non-governmental organization
PBS	Rural Electric Cooperative (*Palli Bidyut Samity*)
PGCB	Power Grid Company of Bangladesh
PM_{10}	particles with an aerodynamic diameter less than 10 microns
$PM_{2.5}$	particles with an aerodynamic diameter less than 2.5 microns
PV	photovoltaic
REB	Rural Electrification Board
SEDA	Sustainable Energy Development Agency
SHS	solar home systems

Units of Measure

GJ	gigajoule
GWh	gigawatt hour
kg	kilogram
kgoe	kilograms of oil equivalent
klm-hr	kilolumen-hour
kWh	kilowatt-hour
loe	liters of oil equivalent
MCF	thousand cubic feet
MJ	megajoule
MW	megawatt
$\mu g/m^3$	micrograms per cubic meter
W	watt

Currency Equivalents

2004	US $1 = 60 Bangladesh takas
2005	US $1 = 64 Bangladesh takas
2006	US $1 = 68 Bangladesh takas
2007	US $1 = 69 Bangladesh takas
2008	US $1 = 68 Bangladesh takas
2009	US $1 = 69 Bangladesh takas

Energy Conversion Factors

Cooking Fuels and Energy Efficiencies

Fuel Source	Energy Content (MJ per unit)	Cooking Stove Efficiency (%)	Efficient Cooking Energy (MJ per unit)
Electricity (kWh)	3.6	70	2.5
LPG (kg)	45.5	60	27.3
Natural gas (m^3)	38.0	60	22.8
Biogas (60% methane) (m^3)	23.0	60	13.8
Kerosene, pressure (kg)	43.0	55	23.7
Kerosene, wick (kg)	43.0	35	15.1
Charcoal, efficient (kg)	30.0	30	9.0
Charcoal, traditional (kg)	22.5	20	6.0
Bituminous coal (kg)	22.5	25	5.6
Fuelwood, efficient (15% moisture) (kg)	16.0	25	4.0
Fuelwood, traditional (15% moisture) (kg)	16.0	15	2.4
Crop residues (5% moisture) (kg)	13.5	12	1.6
Dung (15% moisture) (kg)	14.5	12	1.7
Leaves and grass (kg)	13.5	12	1.6

Sources: O'Sullivan and Barnes (2006) and various World Bank reports.

Note: Energy content = total energy by energy source; efficient cooking energy = energy absorbed into cooking pans or devices.

Household Lighting Energy in Developing Countries

Lighting Type	Light Output (lumens)	Output Based on Lumens per Watt	
		klm-hr per kgoe	klm-hr per kWh
Non-electric			
Paraffin candle	11.8	2.33	0.20
Kerosene, wick	11.4	1.15	0.10
Kerosene, hurricane	32	1.92	0.16
Kerosene, pressure	2,040	17.53	1.48
Incandescent (watts)			
25	230	109.12	9.20
40	430	127.50	10.75
50	580	137.58	11.60
60	730	144.30	12.17
100	1,280	151.80	12.80
Florescent (watts)			
10	600	711.63	60.00
20	1,200	711.63	60.00
40	1,613	478.27	40.33
Compact florescent			
Philips lamp (15-W)	894	706.88	59.60
Philips lamp (9-W)	369	486.28	41.00
Osram sol lamp (6.14-W)	240	463.60	39.09

Source: O'Sullivan and Barnes (2006).

Battery Electricity

Lighting Type	Power Rating (amps)	Storage Capacity (watt hrs.)	Usable Storage Capacity (watt hrs.)
D Cell (high-quality battery)	0.5	6	4.8
Chinese D Cell	0.2	2	1.6
Car battery (60 amp)	60.0	720	576.0

Source: O'Sullivan and Barnes (2006).

Note: Battery amp hours * 12 = watt hours capacity. 20 percent is lost in charging. A battery can only discharge to 80 percent of capacity (amp hours*12*.8).

Executive Summary

Since the 1990s, Bangladesh—one of the world's poorest countries—has taken large strides toward achieving the Millennium Development Goals (MDGs), having outperformed most low-income countries on a range of social indicators. The country is on target to achieve a two-thirds reduction in infant and child mortality by 2015. Food security has improved significantly, and gender disparity in primary and secondary enrollment has been eliminated. Yet in 2005, nearly 40 percent of the nation's 140 million residents and 44 percent of rural residents were below the poverty line (World Bank 2006).[1]

Bangladesh is one of the world's lowest energy producers. Electricity, critical to economic growth, has reached only about one-third of households, despite the country's successful rural electrification program. With the exception of kerosene, commercial fuels are beyond reach for many. Biomass fuels, collected mainly from the local environment only two decades ago, are fast becoming a marketed commodity as access to local biomass becomes ever more difficult. The stark reality is that many rural residents are dependent on such fuels as agricultural residues, dung, and even leaves and grass for cooking.

Knowledge of rural energy in Bangladesh lags recent developments in energy technologies and policies. Until recently, the potential for renewable energy and the adverse health effects of indoor air pollution (IAP) on women and children were ignored. Research on the structure and efficiency of rural energy markets has also been overlooked. Policy analysis and recommendations for rural energy development, along with their implications for the institutions that implement them, have not been assigned a high priority.

With the exception of rural electrification, most intervention programs have emphasized commercial energy, consumed mainly in urban areas. At the same time, the rural electrification program has continued to expand, a forestry master plan has been approved for implementation, and both the government and donors are supporting efforts to popularize improved biomass stoves. Yet the effectiveness of these initiatives, in terms of people's overall energy-using behavior, remains under the radar screen of many development researchers.

Study Goal

Lack of comprehensive data and analysis and knowledge gaps regarding Bangladesh's current rural energy reality have precluded the development of a strategy for modern and efficient energy use. Against this backdrop, the World Bank Group, through a consultative process, initiated two surveys—one focused on rural households and the other on village microenterprises and rural growth centers—to elicit information on energy-using behavior and characteristics. Subsequently, the Bank commissioned studies on the market structure for energy and the macro-level dimensions of biomass supply and demand.

This study—the first to concentrate on Bangladesh's energy systems and their effects on the lives of rural people—drew on these background studies, as well as other World Bank–financed research on IAP

[1] See Bangladesh Country Brief (www.worldbank.org).

and rural infrastructure, to present a rural energy strategy for the country. The study's broad aim was to identify ways to improve the living standard in rural Bangladesh through better and more efficient use of energy, while creating an environment conducive to growth and poverty reduction.

For any developing country, the crux of a rural energy strategy is to have more and better choices for meeting rural demand for energy through market mechanisms and sound policy. This goes hand in hand with the development of competent implementing institutions, which are critical to the process. Also important are new supply- and demand-side technologies that can be used to raise rural people's welfare and improve productivity to increase growth prospects. Accordingly, the rural energy strategy advocated by this study aims to satisfy the types of demand that increase household welfare and raise rural growth prospects as energy becomes a direct input into the production process.

Benefits of Moving up the Energy Ladder

For Bangladesh to grow and prosper, its rural economy must not be ignored. Focusing solely on urban growth—representative of only about 20 percent of the country's 140 million people—would lead to inequitable social and economic development. Making the benefits of modern energy services available in rural areas can promote decentralized development and growth and help rural residents become more productive, thereby mitigating urban–rural disparities.

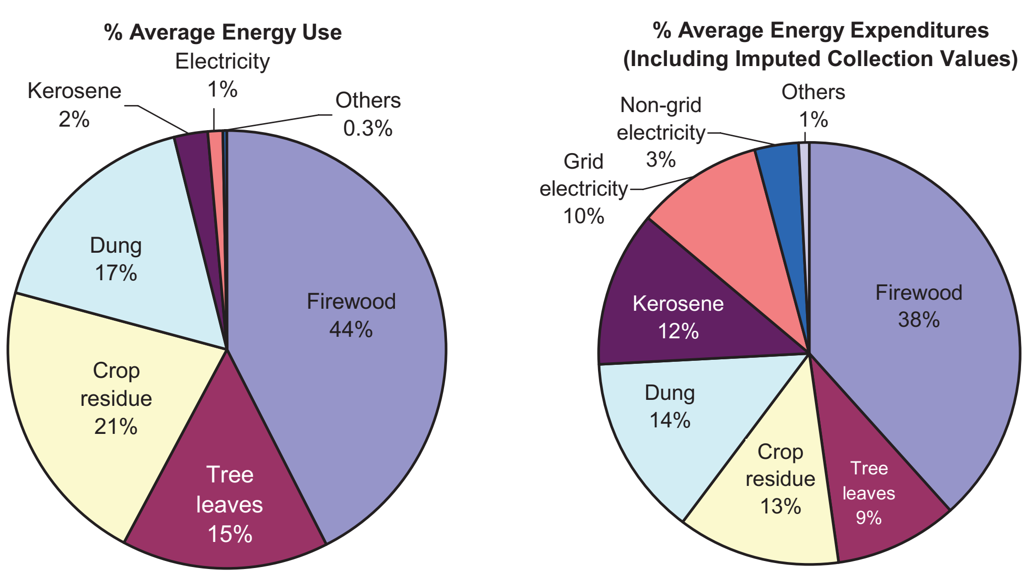
Cooking Energy

Biomass continues to play a critical role in Bangladesh's rural energy balance; today, it is just as important, if not more so, than 25 years ago. Unlike some other South Asian countries, where liquefied petroleum gas (LPG) and other modern fuels have begun to enter the marketplace, rural Bangladesh continues to depend heavily on biomass fuels (fuelwood, cow dung, crop residues, and tree leaves and grass) to meet household cooking needs (see Figure 1).

Some 95 percent of Bangladeshi households collect or purchase biomass energy with which to cook all or part of their meals, mainly using fixed clay stoves. The inherent inefficiency of such stoves, combined with the high moisture content of biomass cooking fuels, results in incomplete combustion, producing IAP. In rural Bangladesh, age-sex composition of households

Figure ES.1

Energy Use and Expenditures in Rural Bangladesh, 2004



Source: BIDS Survey, 2004.

indicates that generally, women and their children suffer greatest exposure. Women also bear the brunt of time spent collecting biomass fuels, accounting for an average of 150 out of 200 household hours per year.

Switching to improved biomass cookstoves and modern cooking fuels can enable rural families, especially women, to improve their quality of life. Because improved stoves require about 25 percent less fuel than traditional ones, using them can similarly reduce the amount of time spent collecting biomass fuels or the money used to purchase them. Cooking with modern petroleum fuels, such as LPG, entails similar welfare gains. In addition to time and cost savings, cooking with cleaner fuels avoids the health risks associated with IAP.

Lighting Energy

In rural Bangladesh, some 70 percent of lighting energy is derived from kerosene, while electricity accounts for most of the other 30 percent. Households with electricity prefer electric lighting to kerosene, but unreliable supply drives them to use kerosene lamps as a backup source in case of power failure.

In terms of cost and kilolumen output, electricity is far superior to kerosene. Electricity's output per unit of energy is 100 times higher than that of kerosene. When one compares households that use kerosene lamps or electric lighting, two trends are obvious. First, the level of lighting increases with income for both kerosene and electricity. Second, the quality of lighting service obtained from electricity is an order of magnitude higher than that from kerosene for all income groups across all regions. For the average household, the number of kilolumens is nearly 80 times higher for those who use mainly electricity, versus kerosene.

The high-quality lighting afforded by electricity has important consequences for Bangladeshi household welfare. A household's electricity consumption for lighting appears to rise steadily as the number of students in the household increases. The study's findings show that total hours of study time are greater in households that use electric lighting than in those that use kerosene lamps, confirming electricity's contribution to human-capital formation. Apart from education, household income also shows a distinct trend in lighting energy use; as incomes rise, households increasingly switch from kerosene- to electricity-based lighting. The potential gain from this transition, as measured by consumer's surplus, is enormous—40 to 45 percent of household income. A separate quantitative analysis shows net positive gains in household income from lighting energy use of similar levels, confirming that lighting has a high value for rural households.

Farming Energy

A third critical energy use for rural Bangladeshi households is farming. The country's potential for increased irrigation, though not as developed as that of other South Asian countries, is significant. The most obvious energy inputs are diesel engines and electric motors for pumping irrigation water. In addition, various small machines, including power tillers, are used increasingly in land preparation, alleviating much of the drudgery associated with such work. This study concluded that farm households that move up the energy ladder enjoy a substantial gain in productivity. For households that use mechanized instead of manual irrigation, farm productivity is 15 to 23 percent higher. Econometric analysis shows that farm income increases as much as 6.3 percent from diesel use and 7.9 percent from electricity use in irrigation.

The study's village survey found that 68 percent of villages used mechanized irrigation methods; of these, 70 percent used diesel power, 10 percent used electricity, and 3 percent used both. One possible reason for farmers not having adopted electric pumps to the extent that they have diesel ones is that 34 percent of villages remain without electricity. Moreover, even in villages with electricity, the potential gain of electricity (7.9 percent) over diesel (6.3 percent) may not suffice to warrant large-scale substitution; that is, both diesel and electric pumps result in similar levels of improved farm productivity. But electricity can be used in tube wells, a common practice in other South Asian countries; while diesel engines are generally limited to surface wells. Thus, in rural Bangladesh, the unrealized potential application of electricity is widespread, presumably for reasons of policy.

Microenterprise Energy and Productivity

Switching to modern energy and the modern use of biomass also contributes to the productivity of rural microenterprises, representing a substantial increase in rural residents' income. The three types of enterprises examined in this study—growth-center, village, and home-based—use a wide array of energy sources. All rural businesses in the growth centers use electricity, either from the grid or local generators; and most have electric lighting. By contrast, not all free-standing village and home-based enterprises have access to electricity; those that do may choose not to use it. Such enterprises depend heavily on biomass energy, mainly for heating and manufacturing needs. Though inconvenient, biomass is the least expensive heating fuel; also, most rural areas lack access to LPG.

Increasingly, Bangladeshi entrepreneurs perceive the health problems associated with traditional fuelwood use, as well as the growing scarcity of local biomass. They also view traditional lighting sources as inefficient and of poor quality, but unreliability of electricity supply forces businesses to depend on kerosene and diesel as backup lighting sources.

Analysis of the relationship between modern energy sources, as defined by the energy ladder concept, indicates that rural businesses that use modern energy generally have more revenue and are more profitable than those that rely on traditional energy sources. Thus, a viable rural energy strategy for Bangladesh must consider the best ways to promote modern energy, as well as the modern use of biomass.

Energy Access

In rural Bangladesh, access to energy is governed by its availability, pricing (both monetary and non-monetary), household income, and other characteristics. One major reason for the prominence of kerosene for lighting is that electricity is not available in all areas. Even where it is available, consumer density is low. Thus, while 66 percent of the villages sampled in this study had a grid connection, only 29 percent of households were connected. Even in the capital division of Dhaka, where one would expect a higher density, less than 50 percent of households adopted electricity, although 80 percent of villages had some type of electricity service available.

If electricity is available, household access is determined by income: the higher the income (approximated by land and non-land assets), the greater the demand. With higher incomes, rural Bangladeshis were found to pursue improved sources of energy and invest in assets that require more energy. Higher-income rural households typically diversify their energy portfolios, moving toward modern energy, which is not only more efficient but also allows household members to invest time and money in more productive activities than biomass energy alone would make possible.

For any energy source, pricing also determines demand. Thus, energy access is not equitable because the source is either priced too high or carries a high opportunity cost (e.g., biomass collection). Inequitable access and level of use may lead to further inequities (e.g., low-income households may pay far higher prices for equivalent lighting services).

Paying More Attention to Rural Energy Services

Rural energy must be viewed as a basic input to the rural economy, in line with its role in rural productivity and income generation. Achieving a supply-and-demand balance is critical at all levels. Given rural residents' heavy reliance on traditional biomass supply, biomass must be used in more efficient ways that mitigate damage to human and global environmental health. Complementing these efforts, more diversified modern energy sources must be made available to fulfill unmet rural household and business demand. To this end, appropriate pricing policies are vital: they must be market-based to ensure that suppliers can sustain the higher cost of rural operations, yet remain affordable to the poor.

Biomass: Increasing Use Efficiency and Supply

Mitigating the ill effects of biomass burning requires both demand- and supply-side solutions adapted to local realities. Biomass demand can be reduced by adopting improved cooking stoves that rural people want and harnessing biogas technology through village-based production and distribution networks. Biomass supply can be increased by planting trees around homes, maintaining and improving local natural resources, and increasing agricultural productivity. Promoting a sustainable supply-demand balance implies the need for policy initiatives that encourage intermediate and end-use efficiency, especially at the household level; increased productivity to keep pace with growing demand; and fuel substitution, where possible.

Rural Electrification: Toward a Pro-poor Approach

Both grid and off-grid electrification programs are critical to the socioeconomic development of rural Bangladesh. As this study shows, electrification translates into substantial gains in household welfare and a higher quality of life. As electricity demand is projected to double over the next nine years, the investment required to generate sufficient capacity to accommodate future demand growth is immense.

If electricity is available, households will pursue its use. But nationwide access to grid electricity is only 40 percent; in rural areas, it is just 30 percent. The Rural Electrification Board (REB), responsible for electrifying rural Bangladesh, is based on the U.S. model of consumer-owned rural electric cooperatives. Today, rural Bangladesh is divided into 70 cooperatives or *Palli Bidyut Samities* (PBSs), benefiting an estimated 7 million households—a remarkable achievement in a country of some 22 million rural households and about 110 million rural residents. Although the PBSs are generally well managed, the program has a nationwide electricity reliability problem. Some 80 percent of rural households report daily outages, while 60 percent report significant power fluctuations. Survey results bring into question the REB's selected coverage approach, suggesting a too-stringent connection policy or other barriers that prohibit many poor households from receiving electricity directly. In addition, most of the PBSs are not yet financially viable.

Given that only 3 percent of Bangladesh's 22 million rural households are gaining access to the national grid each year, it could take several decades to reach the entire rural population because, as the electricity grid expands, it becomes increasingly expensive to serve remote households. Thus, the government and policy makers, along with international donor support, should continue and even increase the successful expansion program financed through the REB. Concurrently, off-grid systems can complement this program to meet the enormous unmet need for electricity. In 2002, the Infrastructure Development Company Limited (IDCOL) was made the country's focal agency for coordinating the off-grid program, the first phase of which has focused on promoting solar photovoltaic (PV) systems. To date, most work has been done by non-governmental organizations (NGOs) specialized in microfinance and microenterprise development. Working with 16 partner organizations, including Grameen Shakti and other NGOs involved in microcredit and solar home systems (SHS), the program has succeeded in installing more than 80,000 systems over a three-year period. It is also important to diversify product lines to micro-grids, which could be connected directly to the national grid system once the PBSs reach more remote communities.

Household Petroleum Fuels: Toward Equitable Use

For the past 30 years, the Bangladesh Petroleum Corporation (BPC) and its subsidiaries have controlled most aspects of petroleum supply, including its pricing system. Kerosene is priced uniformly across the country, but transport-cost adjustments are made for market distances greater than 40 kilometers from a supply depot. The price difference between rural and urban areas is not great, and the system for containing kerosene within a price range works well throughout the country. By contrast, LPG, which is widely available in urban and peri-urban markets, has largely failed to reach rural households. By switching from biomass to LPG to meet a portion of their cooking needs, rural family members, especially women, could realize large time savings and better health. Finally, piped natural gas (methane) is used mainly by householders in Dhaka and other large towns. But under current pricing policy, households are charged a (subsidized) flat monthly rate, irrespective of the amount of gas consumed. Such a policy leads to abuse and waste and discriminates against households without connections in smaller towns and rural areas.

Importance of Sound Pricing and Subsidy Policies

Promoting more equitable rural access and use of modern energy implies the need for sound pricing policies to increase supply and reliability. It should be noted that the urban areas of Bangladesh are served by a state utility, which is generally considered to be less efficient than the rural cooperatives electricity companies. Even though performing better, the rural electricity policies and service still can be improved. For rural grid electricity, a careful review of the policies of uniform subsidies and similar tariffs for all PBSs is recommended. One potential solution might include mechanisms that give preferential treatment to companies serving poorer regions, such as permitting higher tariffs or providing electricity at lower bulk prices. To date, off-grid electricity schemes have succeeded by providing subsidies through individual projects, allowing prices to float based on the cost of service after subsidies.[2]

As the previous discussion suggests, pricing policies for household petroleum fuels also require careful review. Kerosene, used by most rural households for lighting, is accessible to most consumers at world-market rates, and is available in quantities sufficient for cooking. Thus, its pricing policies require no substantial revision. For LPG, it is recommended that the upfront costs of needed stoves and cylinders be partially subsidized or paid for in installments, which would put LPG within reach of households that otherwise could not afford it. Developing and making available smaller LPG cylinders is occurring in Bangladesh, and should be encouraged even further. This would help extend the reach of LPG into less wealthy markets. In addition, a level playing field should be promoted for all public and private companies that market LPG to encourage innovation and expansion into more remote, underserved areas. With regard to natural gas, it is recommended that the government reverse its flat-rate tariff so that households are charged per unit of consumption and that subsidies, which invariably benefit wealthier households, be removed.

Institutional Challenge: The Way Forward

Rural energy is a complex issue, encompassing a broad and diverse spectrum of resources—from household petroleum fuels to biomass and renewable energy—spanning multiple sectors, including forestry, electricity, and health. To date, the many diverse institutions addressing rural energy issues in Bangladesh have been poorly coordinated. One major recommendation resulting from this study is to develop the long-term institutional capacity to tackle rural energy issues in all their complexity. Such an institution would promote rural energy solutions through its technical assistance, advice to government, and facilitation of grants and loans for worthy projects.

Rural energy's importance to the Bangladesh economy cannot be underestimated, given the world's focus on globalization and market reform. The problems rural people face in obtaining safe, clean, and reliable energy supplies are not minor inconveniences. On the contrary, they represent a significant barrier to rural economic development and improved social well being. A multifaceted approach to solving Bangladesh's rural energy problems is an essential building block to propel the country into the twenty-first century.

The rural energy strategy identified is this: Bangladesh has a comprehensive need for better institutional coordination and attainment of a critical mass of technology and market development. With effective institutional coordination, combined with market development, appropriate subsidy, pricing policies, and government and donor support, current and proposed programs can succeed beyond expectations. The call for action is urgent, not only for rural development, but for the country's equitable and overall economic growth.

[2] Through the World Bank–financed Rural Electrification and Renewable Energy Development Project (RERED), IDCOL has worked with selected local partners to provide rural consumers a 20 percent subsidy for SHS using a microfinancing scheme.

1 Introduction

Bangladesh is one of the world's poorest countries.[3] Nearly 80 percent of the nation's 140 million people reside in rural areas; of these, 20 percent live in extreme poverty. Geographically, many low-lying areas are vulnerable to severe flooding, while other regions are prone to drought, erosion, and soil salinity. Such an unfavorable agricultural landscape, combined with mismanagement of natural resources and increasing population pressure, is pushing many of the rural poor to the brink.

Because Bangladesh is such a poor country, it also is one of the world's lowest energy producers. Total annual energy supply is only about 150 liters of oil equivalent per capita (IEA 2003); in rural areas, conditions are even worse. Compared to other developing countries, Bangladesh uses little modern energy. Despite its successful rural electrification program, close to two-thirds of households remain without electricity and, with the exception of kerosene, commercial fuels are beyond reach for many. Moreover, biomass fuels are becoming increasingly scarce. Collected mainly from the local environment as recently as two decades ago, biofuels are fast becoming a marketed commodity as access to local biomass continues to shrink.[4]

Today, people in rural Bangladesh use a mosaic of energy sources to meet their various domestic and productivity needs. Biomass is still used extensively for cooking, while kerosene is the main lighting source. Electrified households prefer electricity for both lighting and appliance use. Many small businesses, including home-based enterprises, use electricity for lighting, agricultural processing, and other productive activities.

Gradually, the types of energy used in rural areas are improving. Diesel-powered irrigation pumps and agricultural tillers are more common than in the past, when manual and animal powers were the traditional energy sources for cultivation. Grid-based electrification is reaching more rural households at a faster pace. Recent projects in renewable technologies, including solar home systems (SHS), reflect slow, yet significant, progress. In sum, while the traditional biomass system continues to predominate, rural Bangladesh is moving slowly, yet inexorably, toward modern forms of energy and more efficient use of biomass as options for energy supply.

What Is the Knowledge Base?

In the mid-1970s, Bangladesh conducted its first large-scale energy study, which was followed in the early 1980s by a more comprehensive study that included a rural energy component (GOB 1987). Now, more than two decades later, little new information, with the exception of small rural energy surveys, is available. Indeed, knowledge of rural energy in Bangladesh lags recent developments in energy technologies and policies.

Studies on rural electrification and development have been conducted over the past decade; but many new issues remain unexplored. Until recently, the potential for renewable energy and the adverse health effects of indoor air pollution (IAP) on women and children were ignored. Research on the structure and efficiency of rural energy markets has also been

[3] The World Bank estimates that, in 2005, 28 percent of the urban population and 44 percent of rural residents were below the poverty line, with a nationwide poverty rate of 40 percent (World Bank 2006).

[4] In 2005, the FAO Forestry Department reported that only 6.69 percent of Bangladesh's total land area (13.02 million hectares) remained under forest cover.

overlooked. Policy analysis and recommendations for rural energy development, along with their implications for the institutions that implement them, have not been assigned a high priority.

With the exception of rural electrification, most intervention programs have emphasized commercial energy, consumed mainly in urban areas. At the same time, the rural electrification program has continued to expand.[5] A forestry master plan has been approved for implementation, and various community and agroforestry projects have been implemented. The country has renewed its emphasis on tree planting and management as part of activities to mitigate climate change. To curb the health hazards of IAP, both the government and donors are supporting efforts to popularize improved biomass stoves. Yet the effectiveness of these initiatives, in terms of people's overall energy-using behavior, remains under the radar screen of many development researchers.

One of the country's major economic policies is to promote agriculture and rural development. Indeed, food production and consumption are inextricably linked to rural energy. But this reality—recognizing the energy needs for various rural economic and development activities—appears as an afterthought in many government documents. Such policy documents equate energy with electricity, gas, and hydrocarbons.[6] But the main energy uses in rural areas involve fuelwood, cow dung, and crop residue; rural Bangladeshis use these fuels in large quantities to cook their food, heat their homes (in cooler regions), produce bricks in kilns, and make molasses (*gur*) from sugar cane.

Study Goal and Objectives

Lack of comprehensive data and analysis and knowledge gaps regarding Bangladesh's current rural energy status have precluded the development of a strategy for modern and efficient energy use. Against this backdrop, the World Bank, through a consultative process, initiated two surveys—one focused on rural households and the other on village microenterprises and rural growth centers—to elicit information on energy-using behavior and characteristics. Subsequently, the Bank commissioned studies on the market structure for energy and the macro-level dimensions of biomass supply and demand (Openshaw 2004; Khalequzzaman 2005).

This study—the first to concentrate on Bangladesh's energy systems and their effects on the lives of rural people—drew on these background studies, as well as other World Bank–financed research on IAP and rural infrastructure, to present a rural energy strategy for the country. Much of this study's analytical underpinning was based on several background studies. This study also reanalyzed data from earlier research to better understand the benefits of modern energy use for rural households, farm activities, and small businesses.

This study's broad aim was to identify ways to raise the living standard in rural Bangladesh via better and more efficient energy use, while creating an environment conducive to growth and poverty reduction. To this end, the study sought to do the following:

- Describe the rural energy situation for households and small businesses.
- Determine the demand for and benefits of moving up the energy ladder.
- Describe the energy-supply situation and identify bottlenecks to improved supply.
- Recommend policies to help rural regions move toward improved productivity and higher quality of life.

Based on these analyses, the study put forward a set of recommendations as part of a rural energy strategy for Bangladesh.

Principles for a Rural Energy Strategy

The rural energy strategy of any developing country must be guided by basic principles. First, because the

[5] A major study has been conducted on the effects of rural electrification on development (Barkat et al. 2002); at the time of this writing, a monitoring and evaluation study, involving a large survey, was under way.

[6] In various government documents, the energy chapter discusses electric power, gas, coal, and liquefied petroleum gas (LPG); while rural energy is relegated to the forestry section of the agriculture chapter. The National Energy Policy (GOB 1996), a decade-old document, reflects little on the importance of rural energy. Similarly, the government's recent poverty reduction strategy makes little mention of rural energy (GOB 2005).

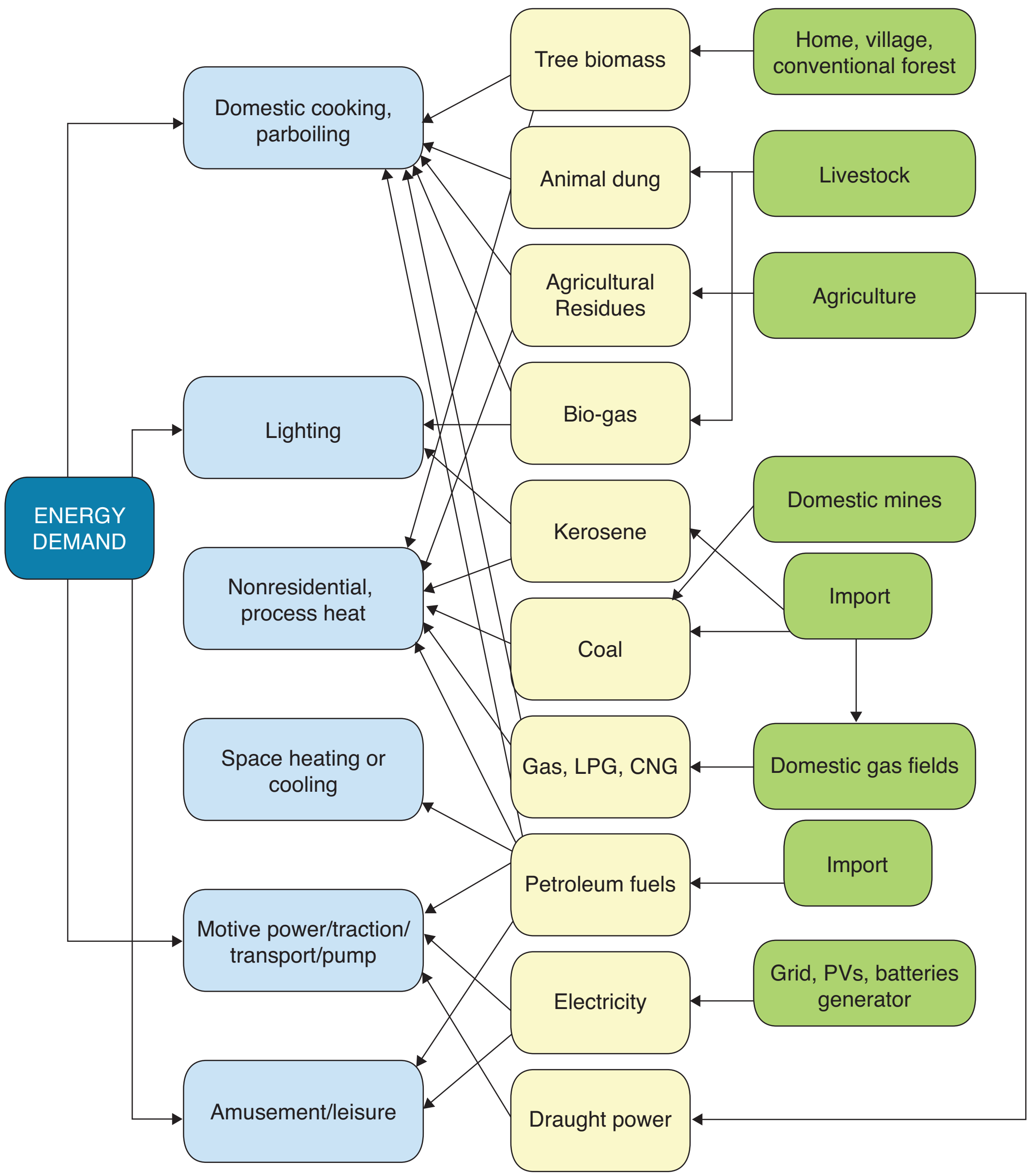
types of energy services that people demand may be obtained from more than one source, issues of cost-effectiveness and satisfying people's preferences arise; not all services may be equally desirable because of their price or aesthetic or practical value. Second, because any particular fuel may have a variety of uses, issues of fuel substitution and complementarity also are important.

Household demand for energy primarily involves cooking, lighting, heating, productive uses, and other end uses. Rural enterprises have a significant demand for non-residential process heat. Both households and rural enterprises require lighting, space cooling and heating, and motive power (among productive activities, crop cultivation generates demand for motive power for irrigation pumps, tillers, and transport) as illustrated in Figure 1.1.

The crux of a rural energy strategy is to have more and better choices for meeting rural demand for energy through the market mechanism and sound policy. This goes hand in hand with the development of competent

Figure 1.1

Types and Sources of Energy Demand



Source: Bangladesh Institute of Development Studies (BIDS) (2005).

implementing institutions, which are critical to the process. Also important are new supply- and demand-side technologies that can be used to raise rural people's welfare and improve productivity to increase growth prospects. Accordingly, the rural energy strategy advocated by this study aims to satisfy the types of demand that increase household welfare and raise rural growth prospects as energy becomes a direct input into the production process (see Box 1.1).

Study Method

This study was based mainly on the results of two large-scale primary surveys, one on rural households and the other on rural growth centers and microenterprises defined in the Bangladesh context as large marketplaces. Because of their importance, these surveys, along with background information, are described in greater detail in this chapter.[7] Furthermore, selected information from the surveys was reanalyzed to address the welfare and growth effects of modern energy use.

The study also drew on reports prepared specifically to assess Bangladesh's biomass and forestry situation, relevant institutions and policies, and delivery mechanisms for several fuel types in rural areas. Various other secondary materials were used, including an earlier World Bank report on IAP in Bangladesh (Dasgupta et al. 2004).

Survey Instruments

This study was based on information from a comprehensive survey, whose objectives were to determine the overall energy-use patterns, potential market for modern energy in rural areas, willingness to pay for electricity services, and barriers to adopting renewable energy.[8] To meet these objectives, and thereby assist in the development of a rural energy strategy, these surveys were conducted:

- *Household survey.* This study determined the socioeconomic characteristics, energy demand and availability, consumer ability and willingness to pay, attitudes toward various energy sources, and perceived benefits of energy.
- *Growth center and microenterprise survey*. This study developed village-level profiles, including characteristics and potential energy demand, and

Box 1.1

What Are the Benefits of Rural Energy?

For Bangladesh to grow and prosper, its rural economy must not be ignored. Focusing solely on urban growth—representative of only about 20 percent of the country's 140 million people—would lead to inequitable social and economic development. Making modern energy services and jobs available in rural areas can help rural residents become more productive, thereby mitigating urban–rural disparities and reducing rural-to-urban migration.

The benefits of rural energy range from increased time savings and farm productivity to improved education, communication, and overall quality of life. For example, electric lights emit more than 100 times the amount of lighting provided by a kerosene lantern or candle, permitting household members—both adults and children—to read and study during evening hours. Electric irrigation pumps make it possible to grow and market crops year-round and raise rural incomes. Electric lighting and motive power can increase the productivity of women-owned microenterprises. Availability of radios and televisions can improve communication and information sharing. Use of well-designed stoves and efficient cooking fuels can reduce IAP and the number of hours that families, especially women and children, spend collecting biomass. Taken together, these benefits can lead to greater rural productivity and a higher quality of life for many of the country's poorest citizens.

Source: Barnes and Floor (1996).

[7] For the basic technical analysis of these surveys, see Asaduzzaman and Latif (2005).
[8] A portable document format (PDF) file of survey modules and questionnaires is available from ESMAP upon request.

assessed the energy used by small- and medium-sized businesses located in village marketplaces, known as growth centers.

- Because 25 years had passed since Bangladesh had conducted such a major rural energy survey, the present one used representative samples of rural households and commercial businesses (see Table A1.1, Annex 1).

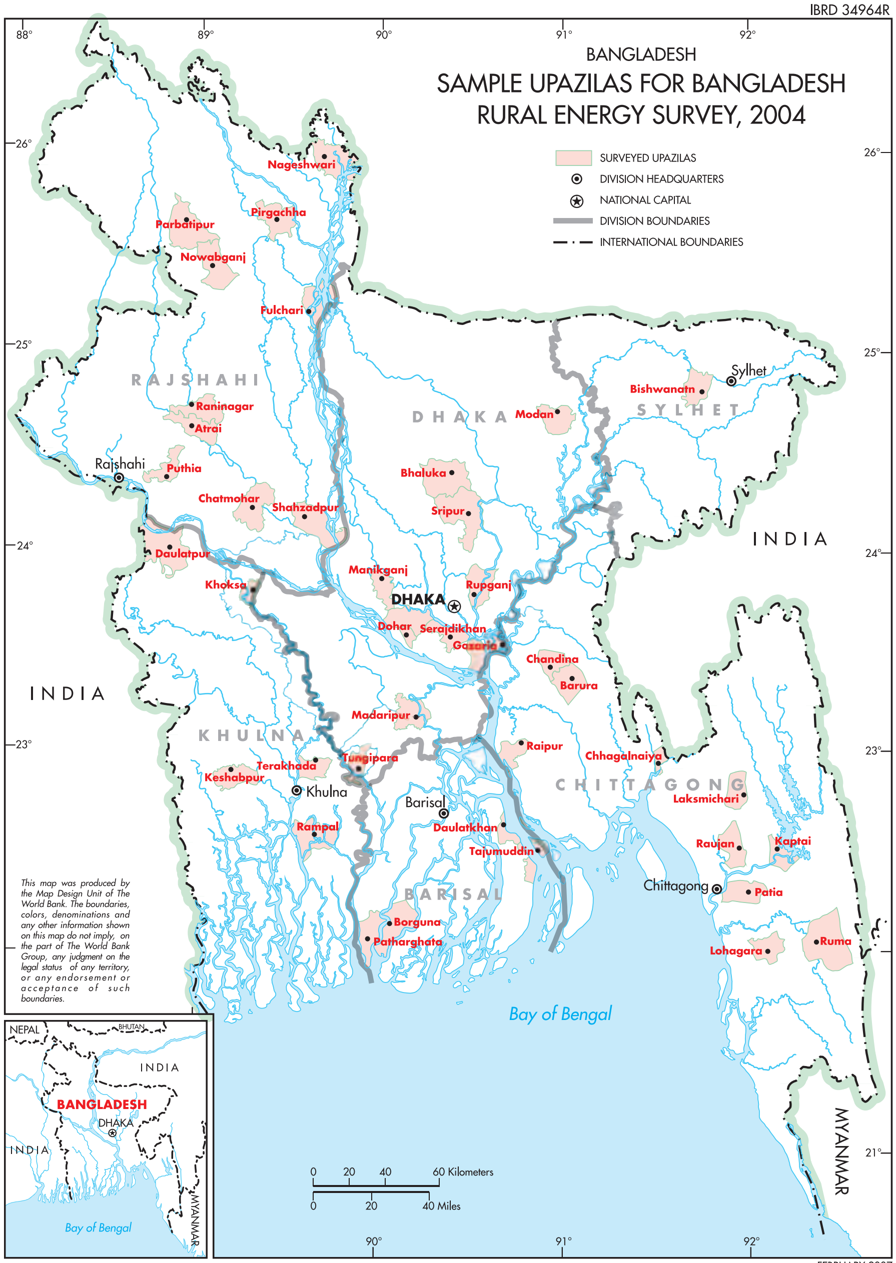
Household Survey

The household survey, conducted in 2004, was based on a cluster sampling strategy. Nationwide, a total of 40 rural subdistricts (known as *upazilas or thanas*) were randomly selected from four older divisions (proportionate to population). This was followed by the random selection of three villages from each subdistrict (see Figure 1.2).

Figure 1.2

Map of Survey Areas in Bangladesh

IBRD 34964R



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Source: This map was prepared by the World Bank Map Design Unit (2008). Shaded areas are sample upazilas (political units) from the Bangladesh Rural Energy Survey (BIDS, 2005).

In order to develop a village sample frame, a census was conducted in each village. This census covered all households; village enterprises based outside the home but not located at the growth center; and all educational, religious, and health institutions. Samples were taken of households, enterprises, and institutions outside the home for further in-depth data collection (see Table 1.1). In addition, a community survey was conducted to identify village characteristics. The resulting sample closely resembled Bangladesh's overall rural population. The survey revealed that about 88 percent of households are headed by men 26 to 45 years of age, nearly 50 percent of whom are illiterate. The average household size is 5. Nearly 55 percent own little or no land (0.5 acres maximum); only 6 to 7 percent own more than 5 acres. About 30 percent of households own little more than their homestead. In 2004, annual household income was roughly US$1,000 (Tk 62,000) or US$200 per person. Some 43 percent of this amount was derived from agricultural sources (e.g., crop cultivation, non-crop agriculture, and agricultural wages), while the remainder was from non-agricultural sources (e.g., processing and trading activities and remittances). All of these figures closely correspond to equivalent figures for rural Bangladesh.

In the case of village-based enterprises, several had more than one distinct business activity because they were owned or operated by households that, when interviewed for the household survey, were found to have home-based enterprises. These 137 enterprises were treated separately.

These rural energy survey results compare favorably with those of the Bangladesh Household Income and Expenditure Survey (HIES), conducted in 2005. For both surveys, the percentage of rural households with electricity was close to 30 percent. There were slight differences in fuel expenditures. According to this rural energy survey, the average annual expenditure for grid electricity was Tk 488 and Tk 608 for kerosene. Results from the 2005 HIES showed that rural households' average annual expenditure for grid electricity was Tk 522 and Tk 566 for kerosene. The results are close, given the different methods used to measure these expenditures. These findings indicate that rural households have increased their electricity consumption while lowering their dependency on kerosene.

Growth Center and Microenterprise Survey

Because most of the country's rural microenterprises are located in growth centers, a separate survey of microenterprises in rural growth centers was conducted to obtain a representative sample of enterprises located outside the home.

Given that no prior information existed on enterprise distribution in the growth centers, a two-phase random sampling technique was adopted. The first phase involved the random selection of 40 subdistricts (from a list of 460 subdistricts, covering six divisions), from which three growth centers (per subdistrict) were chosen. The second phase involved a

Table 1.1

Number of Entities in the Census and Sample by Type and Division

Census Type	Chittagong	Dhaka	Khulna	Rajshahi	Total
Household	5,178	5,928	5,508	5,611	22,225
Business enterprise	342	487	659	394	1,882
Institution	201	223	249	184	857
Total	5,721	6,638	6,416	6,189	24,964
Survey Type					
Household	640	603	548	600	2,391
Home enterprise	31	50	29	27	137
Other enterprise	63	85	136	58	342
Institution	36	38	50	32	156

Source: Asaduzzaman and Latif (2005).

sample survey of business establishments. From each growth center, 15 or more enterprises were randomly selected. The first step in the selection process entailed a census of the enterprises, which provided the sample frame for enterprise selection in each growth center. Because of the small number of growth centers in some subdistricts, the number of growth centers sampled was 115 instead of the 120 targeted for the study. As a result, for several locations, more than the minimum required sample was covered. The total number of enterprises studied from the 115 growth centers was 1,801. Dhaka, Chittagong, and Rajshahi accounted for about 75 percent of regional distribution; while Khulna, Sylhet, and Barisal constituted the remainder (see Table 1.2).

Implications for a Rural Energy Strategy

The two surveys described here represent the first comprehensive attempt to assess the rural energy needs of and benefits for Bangladesh's rural households and microenterprises. Along with a variety of other materials, the surveys provide the analytical underpinnings of this study—the first in 25 years to examine Bangladesh's complex rural energy situation. By covering both households and microenterprises, the study has allowed us to examine rural energy-use patterns and the adequacy of the country's current rural energy policies and institutional framework. The study moves toward broad recommendations that can support a higher quality of life for rural residents and, thus, more equitable economic growth for the country.

Structure of This Report

The structure of this report reflects the directional organization of the study. Chapter 2 presents an overview of the rural energy situation of Bangladeshi households, moving up the energy ladder—from biomass cooking energy to kerosene and electric lighting. Chapter 3 offers an in-depth analysis of household energy demand, examining expenditure patterns for cooking, lighting, and appliance ownership. It presents the results of an econometric analysis to predict how household energy demand is affected by changes in such factors as household income and energy pricing. Chapter 4 provides a descriptive analysis of the household welfare gains that can result from transitioning up the energy ladder, including better health from use of improved biomass stoves and improved education from electric lighting. For farm households, making the switch from manual to diesel- and electric-powered equipment is examined in terms of gains in agricultural productivity. Chapter 5 explores the effects of modern energy on rural production, focusing on the energy-using characteristics of microenterprises and farming. Chapter 6 turns to the current institutional framework for rural energy supply and implications for meeting rural energy demand. It focuses mainly on delivery mechanisms of the biomass, power, oil and gas, and renewable energy (non-biomass) sectors. Finally, Chapter 7 suggests a broad institutional strategy to meet the complex challenges of Bangladesh's current and future rural energy needs.

Table 1.2

Coverage of Growth Centers by Division

	Growth Centers		Shops	
Division	**Total**	**No. Sampled**	**Total in Growth Centers**	**No. Sampled**
Dhaka	531	29	101,256	477
Chittagong	373	25	64,022	403
Rajshahi	543	31	91,592	456
Khulna	274	15	41,685	226
Sylhet	157	3	20,986	48
Barisal	180	12	34,635	191
Bangladesh	2,058	115	354,175	1,801

Source: Data International (2004).

2 Household Energy Use

Unlike South Asian regions where liquefied petroleum gas (LPG) and other modern fuels have entered the marketplace, rural Bangladesh still depends heavily on fuelwood—as well as dung, crop residue, and even tree leaves—for cooking fuel. Indeed, in many areas of the country, biomass energy is in short supply. At the same time, the importance of kerosene, electricity, and LPG is growing. This chapter provides a snapshot of rural Bangladeshi households' energy-use situation, focusing on general consumption patterns and those for the key energy uses of cooking and lighting.

General Consumption Patterns

Nearly all households use both biomass and non-biomass energy (see Table 2.1). A vast majority use biomass sources, including fuelwood, tree leaves, and crop residue. While kerosene is the predominant non-biomass energy source, many households also use grid electricity and dry-cell batteries.

Biomass is used almost exclusively for cooking (see Table 2.2). Fuelwood constitutes 41 percent of total biomass cooking energy. Surprisingly, 39 percent

Table 2.1

Household Distribution of Energy Sources by Division (percent)

	Division				
Energy Source	**Chittagong**	**Dhaka**	**Khulna**	**Rajshahi**	**All Divisions**
Biomass	**98.6**	**99.8**	**100.0**	**99.5**	**99.5**
Fuelwood	95.8	85.1	88.7	67.2	84.3
Tree leaves	61.6	81.4	91.8	72.0	76.1
Crop residue	53.6	81.4	75.4	93.2	75.5
Dung cake/stick	29.5	56.9	64.8	72.3	55.2
Sawdust	0.3	0.7	1.6	0.8	0.8
Non-biomass	**100.0**	**100.0**	**100.0**	**96.5**	**99.1**
Kerosene	98.4	99.0	100.0	91.5	97.2
Grid electricity	38.9	43.8	10.8	20.3	29.0
Dry-cell battery	42.3	39.1	61.3	50.7	48.0
Candle	10.6	2.5	4.4	0.8	4.7
LPG/LNG	1.1	—	—	0.2	0.3
Natural gas	0.9	—	—	—	0.3
Storage cell	0.8	1.3	0.9	—	0.8
Solar PV	—	0.3	1.5	—	0.4

Source: BIDS Survey (2004).

Note: In addition to the main authors, M. Abdul Latif was a contributing coauthor of this chapter.

Table 2.2

Annual Household Consumption (physical quantity)

	Energy Use						
	Heating						
Energy Source	Cooking	Parboiling	Other	Cooling	Lighting	Amusement	All Uses
Biomass (kg)							
Fuelwood	1,064.84	28.60	92.77	—	—	—	1,186.21
Tree leaves	470.67	29.99	0.85	—	—	—	501.51
Crop residue	538.86	164.41	2.72	—	—	—	708.18
Dung cake/ stick	503.68	16.07	4.16	—	—	—	523.90
Sawdust	8.36	0.02	0.02	—	—	—	8.40
Non-biomass							
Kerosene (liter)	1.76	—	0.07	—	27.16	—	28.98
Grid electricity (kWh)	0.25	—	4.00	49.50	80.74	9.34	143.83
Dry-cell battery (piece)	—	—	—	—	—	—	15.01
Candle (piece)	—	—	—	—	15.86	—	15.86
LPG/LNG (liter)	0.05	—	—	—	—	—	0.05
Natural gas (Tk)	9.59	—	—	—	—	—	9.59
Storage cell (kWh)	—	—	—	—	0.14	0.41	0.55

Source: BIDS Survey (2004).

is represented by agricultural residue or leaves and grass, indicating a shortage of fuelwood energy.[9]

Kerosene is used primarily for lighting; grid electricity is another important lighting source. Monthly average consumption of kerosene is 2.25 liters, which barely covers basic lighting services, even considering that households with access to grid electricity use little kerosene for lighting. Batteries, an expensive but extensively used source of electricity, are convenient for powering flashlights, radios, and other consumer electronics. Grid electricity is mostly derived from the cooperatives or PBSs (*Palli Bidyut Samities*), which serve rural areas through the national grid system. Nearly 30 percent of rural households use electricity provided by the PBSs, and the annual percentage continues to climb. This figure compares well with that of the Bangladesh Household Income and Expenditure Survey (HIES), conducted during the same period, which was 30 percent.

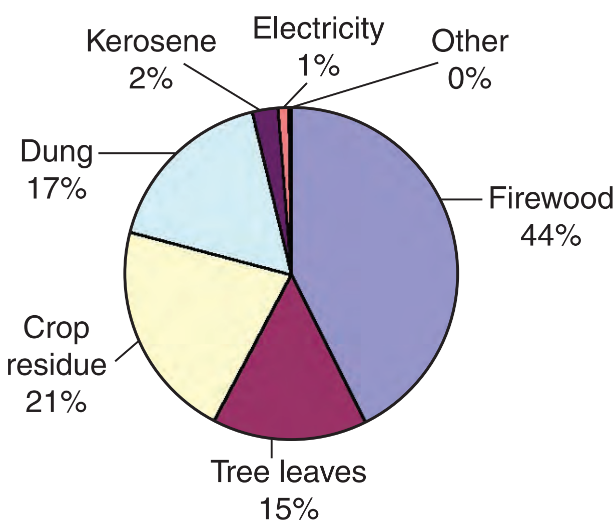
Fuelwood is also the single most important rural energy source in terms of energy unit (kgoe), accounting for some 44 percent of total consumption (see Figure 2.1). Including tree leaves and twigs, the share of tree-based biomass is nearly 60 percent of total household energy. Crop residue (e.g., bagasse, jute sticks, rice hulls, bran; as well as various types of

[9] Such fuels as unprocessed agricultural residue and cow dung are considered inferior to wood for cooking and generally produce higher levels of IAP when burned in traditional stoves.

straw and uprooted plant remains) and animal residue (e.g., cow dung made into round cakes or sticks and dried before burning) constitute other major sources. Not generally used for cooking, modern fuels account for only 3 percent of the energy balance. Because of the significant amount of energy required by cooking and the inefficiency of most rural stoves, the useful or delivered energy is lower than the percentages presented; however, they highlight the importance of biomass for cooking.

Figure 2.1

Rural Household Consumption by Source (percent energy consumption)



Source: BIDS Survey (2004).

Note: The "Electricity" category includes only grid-based electricity. Other types of electricity (solar PV, storage cells, and dry-cell batteries) were either nearly absent or could not be quantified; whatever could be quantified is included in the "Other" category.

Estimated annual energy consumption by rural households is 1,049 kgoe or 8.9 gigajoules (GJ) per person—a vast increase from the 5 GJ per person consumed 25 years ago. Over the same period, the annual growth rate was more than 2.6 percent, higher than the average growth rate in per capita income. Indeed, when only biofuels are considered, growth appears even more remarkable. Leach (1987), using figures based on Islam (1980, 1986), reported that rural households used an estimated 4.2 GJ of biofuels. The corresponding figure for biomass in the current study's household survey is 8.6 GJ per person; this figure translates into an average annual growth rate of 3.2 percent, outstripping even population growth rate.[10] This finding highlights the critical role that biomass continues to play in the rural energy balance; today it is just as important, if not more so, than 25 years ago.

Energy for Cooking

The energy required for basic household cooking—including the parboiling of rice—mirrors, in large part, the country's overall rural energy situation; yet one observes major regional differences (see Table 2.3). For example, in Khulna and Chittagong, regions home to major

Table 2.3

Energy Sources for Cooking and Parboiling of Rice by Division (annual kgoe per household)

	Chittagong		Dhaka		Khulna		Rajshahi		All Divisions	
Energy Source	**C**	**P**	**C**	**P**	**C**	**P**	**C**	**P**	**C**	**P**
Fuelwood	644.8	7.0	365.5	16.7	404.6	9.7	180.5	9.70	400.4	10.7
Tree leaves	120.3	2.6	157.6	12.1	218.0	19.3	116.2	5.40	149.7	9.5
Crop residue	117.4	27.0	159.4	36.9	183.1	114.7	269.4	37.70	171.3	52.3
Dung	79.4	0.8	155.8	7.6	220.6	4.5	251.4	9.20	171.7	5.5
Sawdust	1.4	0	1.0	0	5.8	0	2.8	0.02	2.6	0.01
Kerosene	1.8	0	2.8	0	0.6	0	0.6	0.00	1.4	0
Total	965.0	37.4	842.1	73.4	1,032.7	148.2	820.9	62.00	897.3	78.1

Source: BIDS Survey (2004).

Note: C = cooking; P = parboiling.

[10] The increase may involve advances in survey design instruments with which to measure rural energy use (e.g., previous surveys had more basic questions).

forests, consumption levels are higher. Indeed, nearly 67 percent of Chittagong's cooking energy is derived from fuelwood, indicating that plentiful availability leads to greater use. Not surprisingly, Rajshahi, the division least endowed with forest resources, depends least on tree-based biomass (fuelwood and leaves) for household cooking. In Khulna, where one might expect higher consumption levels, strict forest regulations and restricted access keep consumption lower than in Chittagong, where local residents can more easily access scattered forest patches.

Significant use of biomass energy—especially tree leaves, crop residue, and dung—means that indoor air pollution (IAP) and local biomass shortages are potential problems in rural areas of all four divisions. Since fuelwood is a comparatively more efficient fuel with a higher energy content, the potential for IAP may be somewhat less in Chittagong. The little use made of improved biomass stoves that vent smoke to the outdoors and modern fuels are important related issues, which are discussed in Chapters 3 and 4.

Commercialization of Biomass Energy

A major finding of this study, as mentioned previously, is the increasing commercialization of biomass energy in rural areas. Just two decades ago, most biomass fuels were collected from the local environment. Fuelwood, conventionally derived from rural residents' own production or local collection, is today more likely to be purchased from local markets. Indeed, about 40 percent of all fuelwood is now purchased from local markets; in Dhaka, the proportion is nearly 67 percent (see Table 2.4).

Table 2.4

Distribution of Biomass Supply Sources by Energy Type

	Energy Type (%)			
Supply Source	**Fuelwood**	**Tree Leaves**	**Crop Residue**	**Dung Cake/Stick**
Chittagong				
Own production	14.0	57.8	69.4	82.8
Gathered	61.9	41.2	28.8	3.6
Purchased	24.1	1.1	1.8	13.6
Dhaka				
Own production	6.3	55.5	72.2	23.2
Gathered	26.9	43.9	15.0	9.2
Purchased	66.8	0.6	12.8	67.6
Khulna				
Own production	7.6	55.5	66.6	92.5
Gathered	32.4	40.3	25.7	1.3
Purchased	60.0	4.2	7.8	6.2
Rajshahi				
Own production	7.3	41.0	67.5	25.0
Gathered	55.4	58.9	28.3	17.1
Purchased	37.3	0.1	4.2	57.9
All divisions				
Own production	11.0	52.2	68.5	72.2
Gathered	49.8	46.3	24.7	5.3
Purchased	39.3	1.4	6.8	22.5

Source: BIDS Survey (2004).

Given that fuelwood constitutes the major portion of energy consumption, its increasing commoditization has major implications for energy costs, an issue addressed in Chapter 3. The marketplace is also a major source of other biomass energy supplies, including dung cakes or sticks, particularly in Dhaka and Rajshahi. As Table 2.4 indicates, more than half of tree leaves are still gathered, while most crop residue is derived from residents' own production.

Recent development of rural markets for biomass energy reflects an increase in overall supply; but perhaps more important, a decrease in local supply. The implications for cooking fuels and their increasing scarcity in the local environment suggest the need for policy dialogue on the evolving status of cooking fuels in rural Bangladesh.

Energy for Lighting

In rural Bangladesh, some 70 percent of energy consumed for lighting is derived from kerosene and most of the other 30 percent from electricity (Box 2.1). Nearly 100 percent of households claim to use kerosene lamps. Although households with electricity prefer electric lighting to kerosene, unreliable supply drives them to use kerosene lamps as a backup in case of power failure. While overall energy consumption for lighting is low, regional differences are substantial. For example, rural households in Chittagong use more than twice as much energy as those in Rajshahi (because of differences in kerosene and electricity consumption). In Khulna, nearly 92 percent of lighting is derived from kerosene (see Table 2.5).

A major reason for the prominence of kerosene is that electricity is not available in all areas; even where available, consumer density is low. Thus, while 66 percent of the villages sampled had a grid connection, only 29 percent of households were connected. Even in Dhaka, where one would expect a higher density, less than 50 percent of households adopted electricity, although 80 percent of villages had some type of electricity service available (see Table 2.6).

Box 2.1

Modern Energy Benefits for Rural Families

Making the switch to electric lighting and appliances, petroleum fuels, and improved cooking stoves can enable rural families to raise their incomes and improve their quality of life. In a hot tropical climate such as Bangladesh, the addition of a simple electric fan can significantly improve a rural household's indoor comfort level and ward off insects. Electric lighting offers 100 times more light than traditional kupi or kerosene lamps commonly used in households without electricity. The higher quality of lighting makes it possible for families to pursue reading and other educational activities during evening hours. Cooking with kerosene or LPG, or using improved biomass stoves—still a rare occurrence in rural Bangladesh—can result in fewer hours spent collecting biofuels, less cooking time, and reduced IAP. Chapter 4 considers these benefits in more detail.

Source: Barnes and Floor (1996).

Table 2.5

Energy Sources for Lighting (annual kgoe per household)

Energy Type	Chittagong	Dhaka	Khulna	Rajshahi	All Divisions
Kerosene	27.86	18.64	25.30	17.62	22.38
Grid electricity	11.82	9.70	1.86	3.29	6.86
Candle	2.60	0.09	0.30	0.02	0.79
Solar PV	0	0.04	0.13	0	0.04
Storage cell	0	0.05	0	0	0.01
All	42.28	28.52	27.59	20.94	30.09

Source: BIDS Survey (2004).

Table 2.6

Electrification of Villages and Households by Division

	Grid Connection (%)	
Division	**Villages**	**Households**
Chittagong	78	39
Dhaka	80	44
Khulna	50	11
Rajshahi	53	20
All	66	29

Source: BIDS Survey (2004).

Summing Up

This chapter has raised an important question: Are rural Bangladeshis moving up or down the energy ladder? In terms of household energy use, biomass in all its various forms is of paramount importance. For cooking, fuelwood is the predominant form of biomass used; but it is becoming scarcer than in the past, and a significant portion is being purchased. At the same time, many rural residents are turning to residues, including grass and leaves, to meet their daily cooking needs.

In terms of lighting, kerosene is the main energy source, although most rural households would prefer electric lighting if it were available. Electricity is not used as extensively as it might be, perhaps because of restrictive household connection policies.

The energy-use situation of rural households implies the need for policy initiatives that promote more efficient use of biomass energy, and its increased supply and more efficient use and better pricing of modern energy to increase supply and reliability. To gain a clearer picture of whether rural Bangladeshis are moving up or down the energy ladder, it is critical to examine patterns of energy demand (expenditure and asset ownership), which are the subject of the next chapter.

3 Household Energy Demand

In Bangladesh, access to modern energy is a contentious issue, revolving around the role of energy markets. Although financially motivated rural shopkeepers should want to offer all types of commercial fuels, government policies determine, in part, which modern fuels are marketed in rural areas. A major question is how markets can function to serve rural people. To determine the extent to which modern energy factors in market development, this chapter examines patterns of rural household energy expenditure and asset ownership.

Expenditure Patterns

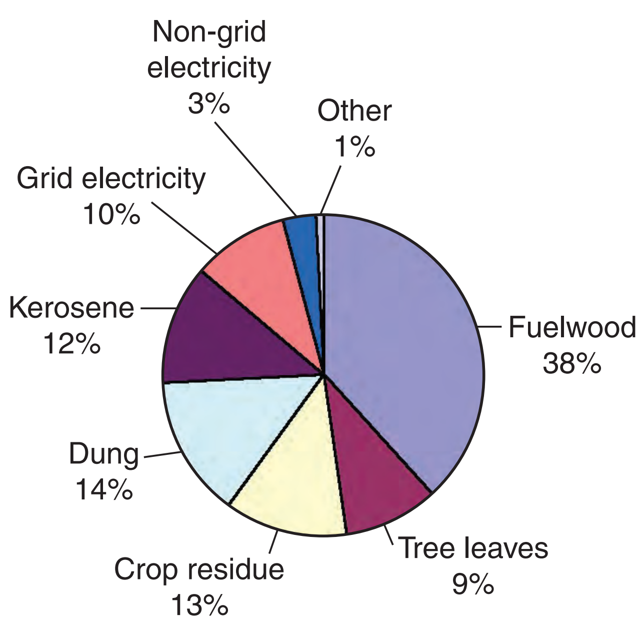
Household energy expenditure depends on many factors, from the availability and pricing of goods and services to household income. The following sections summarize the share of total rural energy expenditure by energy source and household income and region.

By Energy Source

As Figure 3.1 illustrates, rural residents still depend on traditional biomass, particularly fuelwood, to meet most

Figure 3.1

Energy Expenditure Distribution by Energy Source (percent expenditure)



Source: BIDS Survey (2004).

Note: Costs are actual or imputed for each energy source; consumer households must also bear the costs of procurement and supply.

Note: In addition to the main authors, Hussain Samad was a contributing coauthor of this chapter.

Table 3.1

Annual Energy Expenditure by Income and Division (Tk per household)

Income Category (thousands of Tk)	Fuelwood	Tree Leaves	Crop Residue	Cow Dung	Kerosene	Grid Electricity	Non-grid Electricity	Other
< 25	928	419	538	562	440	167	90	18
25–50	1,688	498	582	745	570	304	146	15
50–75	2,455	469	692	711	667	553	190	23
75–100	2,877	500	811	730	706	664	254	42
> 100	3,016	454	779	875	822	1,288	293	194
Division								
Chittagong	3,763	300	352	479	732	761	185	124
Dhaka	1,611	713	823	654	560	710	136	10
Khulna	1,644	612	772	837	661	146	231	20
Rajshahi	685	279	648	922	474	284	140	14
All	1,962	470	641	716	608	488	172	44

Source: BIDS Survey (2004).

Note: The annual energy expenditures include an imputed value for the collection time involved in gathering biomass fuels. The figures for expenditures on electricity and kerosene are reasonably close to those of the Bangladesh Household Income and Expenditure Survey (HIES). According to that 2005 national survey, the annual rural expenditure for kerosene was Tk 566 and Tk 522 for electricity. The results are close, given the different methods used to measure these variables.

of their energy needs. But the importance of commercial fuels far exceeds their basic energy content.

Fuelwood accounts for 44 percent of total household energy use and 38 percent of cost. With regard to the commercial fuels purchased in rural areas, kerosene accounts for only 2 percent of total household energy use but 12 percent of cost, while electricity accounts for just 1 percent in terms of energy content, but 13 percent of cost (10 percent for grid-based electricity and 3 percent for solar PV, storage cells, and dry-cell batteries). The implied differences in fuel and energy prices are discussed later in this chapter.

By Income and Region

In most cases, income level and fuel expenditure exhibit a positive monotonic relationship (see Table 3.1). Even with regard to tree leaves and cow dung, where the pattern is not completely monotonic, higher-income households generally spend more than lower-income ones on energy. Only for the "other" category, which is numerically unimportant, is there no clear pattern.

Poorer households spend less than wealthier households on energy, but the amount represents a greater percentage of their income. The lowest-income households spend slightly more than Tk 3,000 or 15 percent of their annual income on energy. Higher-income households spend twice as much, but their income is more than four times higher. This pattern is common in other developing countries (World Bank 2002b).

Cooking Energy: Biomass and Its Opportunity Cost

Rural Bangladeshis not only spend a high proportion of their cash income on energy; they also collect substantial amounts of biomass from fields and local forests. The opportunity cost of biomass collection must be considered to understand the nature of this energy cost. In this context, regional differences are likely because of variations in amount of tree cover (e.g., Chittagong and Khulna have major forest lands).

On average, households spend about 200 hours per year collecting biomass fuels (see Table 3.2). Valued at the average agricultural wage derived from the survey for both men and women, the annual value of this work equals about Tk 1,625 per

Table 3.2

Biomass Collection Time by Income and Division (annual hours per household)

Income Category (thousands of Tk)	Biomass Source			
	Fuelwood	Cow Dung	Tree Leaves	Crop Residue
< 25	44.4	38.8	112.2	2.1
25–50	74.5	26.0	120.4	1.3
50–75	75.5	13.9	119.9	1.0
75–100	51.2	15.9	106.5	0.8
> 100	31.9	19.7	98.1	0.7
Division				
Chittagong	152.9	20.7	94.9	1.0
Dhaka	28.4	14.9	116.1	0.8
Khulna	32.2	28.8	143.9	1.6
Rajshahi	20.4	34.6	106.3	1.8
All	60.6	24.6	114.3	1.3

Source: BIDS Survey (2004).

family. When added to the energy expenses of the poorest households, expenditures increase about 50 percent.

Collection time is evenly divided between gathering tree leaves and collecting fuelwood and cow dung. Crop residue involves little time overall, since it is generally collected as part of farm work. By contrast, residue collection is seasonal and thus periodically time intensive. For all types of biomass, the relationship between collection time and income is generally negative. One also observes substantial regional variations. For example, in forested areas of Chittagong, households spend much time collecting fuelwood; but in tree-deficient Rajshahi, more time is spent gathering tree leaves and cow dung.

Women devote an average of 150 hours per year collecting biomass, disproportionately more time than men or children spend (see Figure 3.2).[11] Children play a small role (probably collecting biomass from nearby the house). Previous studies appear to have overestimated the burden of fuel collection by children, which findings from other recent studies on energy and time use confirm (World Bank 2002a).

Lighting Energy

Most rural Bangladeshis use kerosene as their primary lighting source. Some 70 percent of lighting energy is derived from kerosene, even though the quality of lighting service from electricity is an order of magnitude higher across all income groups and regions. In terms of pricing, kerosene varies little across income quintiles or regions. But for electricity, from which about 30 percent of lighting energy is derived, prices fall steadily as household incomes rise. Other factors that influence electricity pricing include connection type and regional variations.

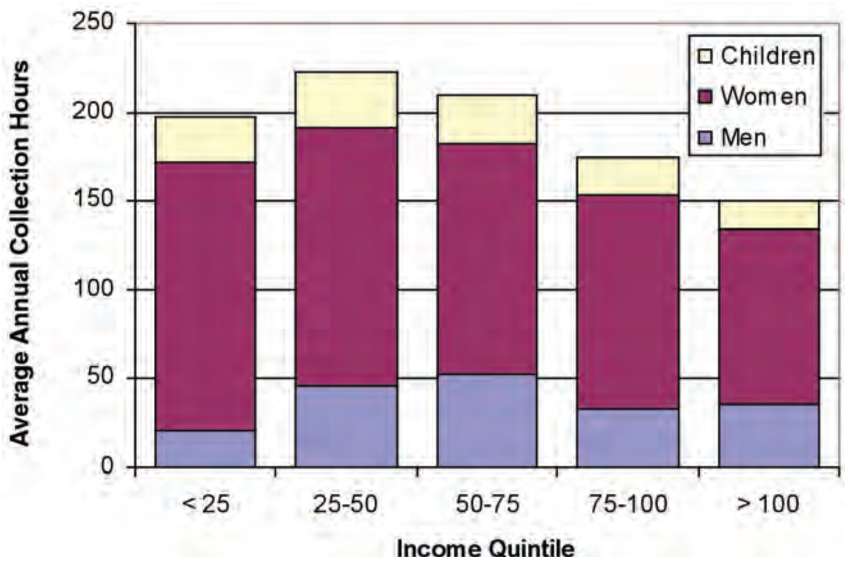
Electricity Connection and Consumption

Electricity connection and consumption rates are influenced by a variety of factors, among which income level and regional differences (discussed next) figure prominently. A third factor (not discussed in this section) is proximity to the electricity supply line. Although one might expect that consumption of significant supplies may be beyond the reach of poor households, it may be that poor consumers living nearby the grid are being excluded from the potential

[11] Much of women's time is spent collecting tree leaves and grass; in terms of fuelwood collection, men's time is at least as important as that of women.

Figure 3.2

Household Biomass Collection Time by Income Quintile (thousands of Tk per year)



Source: BIDS Survey (2004).

Table 3.3

Household Electrification Connection Rate and Consumption by Income Quintile

Annual Income (thousands of Tk)	Connection Rate (%)	Household Consumption (kWh)*
< 25	15.0	32
25–50	23.2	76
50–75	33.7	167
75–100	38.2	180
> 100	54.2	455
All quintiles	29.0	144

Source: BIDS Survey (2004).

Note: The survey showed that the overall monthly electricity use for households with electricity is 41 kWh, which is close to the 38-kWh figure from the records of the Rural Electrification Board.

* Household use = annual consumption per household for all survey respondents.

development benefits of basic electricity services. Thus, the question is whether certain policies exclude poor households from connecting to the grid.

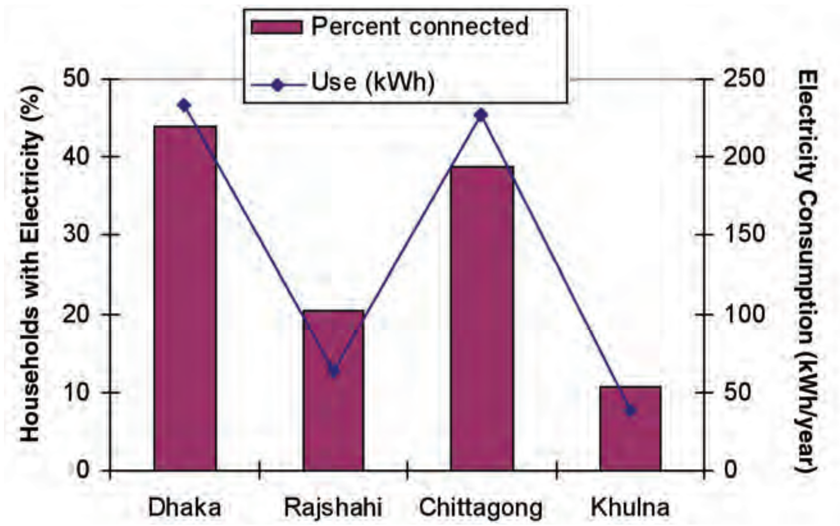
Income Disparities

When other variables are held constant, the probability of having a household grid connection has been found to increase monotonically as income levels rise (Asaduzzaman and Latif 2005). For example, compared to the lowest income quintile (less than Tk 25,000), the next higher group (Tk 25,000–50,000) is 50 percent more likely to have an electricity connection (see Table 3.3). Thus, for poorer households, the high cost of obtaining a grid connection may be prohibitive. When connection and consumption disparities by income quintile are compared, one sees that disparity by income is higher for consumption because households without a connection are included in the consumption calculation.

When this study considered the independent influence of income, results showed that the highest

Figure 3.3

Regional Variation in Electrification



Source: BIDS Survey (2004).

income quintile (more than Tk 100,000) was four times more likely than the lowest (less than Tk 25,000) to have electricity, and the likelihood increased with income.

Regional Variations

Electricity connection and consumption rates also vary significantly by region. As Figure 3.3 illustrates, Dhaka and Chittagong have far higher percentages of households with electricity connections and, consequently, kilowatt-hours of consumption. Khulna exhibits the lowest percentage of connections and kilowatt-hours used.

Kerosene versus Electricity

Although 70 percent of lighting energy is derived from kerosene and only 30 percent from electricity, in terms of cost and kilolumen output, electricity is far superior to kerosene. Electricity's output per unit of energy is 100 times higher than that of kerosene.[12]

Trends

When one compares households that use kerosene lamps or electric lighting, two trends are obvious. First, level of lighting increases with income for both kerosene and electricity. Second, the quality of lighting service obtained from electricity is an order of magnitude higher than that from kerosene for all income groups across all regions. For the average household, the number of kilolumens is nearly 80 times higher for those who use mainly electricity, versus kerosene (see Table 3.4).

The survey findings show that welfare gains from access to electric lighting are extremely high. Chapter 4 analyzes these benefits in more detail.

Price Differences

Prices paid for kerosene and electric lighting services differ markedly. For kerosene, prices for quantities used are fairly uniform, at Tk 20 to 21 per liter, with little variation across income quintiles or regions (see Table 3.5). When prices paid by level of lighting use are considered, households in the middle quintile (Tk 50,000–75,000) pay the lowest price per unit and poorest households (less than Tk 25,000) pay the highest price. But for electricity, prices fall steadily as household incomes rise. The price paid by the highest income quintile is less than half that paid by the lowest. By region, households in Dhaka and Chittagong pay the least amount.

Because households with electricity enjoy a much higher quality of lighting than those that use kerosene

[12] Efficiency of appliances (kerosene kupis and hurricane lamps or electric bulbs and tubes) determines the ultimate lighting use rate, which, in turn, determines the quantity of fuel used.

Table 3.4

Comparison of Kerosene and Electric Lighting Services

Income Quintile (thousands of Tk/year)	Kerosene lamps (klm-hr/month)	Electric lights (klm-hr/month)
< 25	2.99	130.30
25–50	4.00	218.22
50–75	4.71	353.11
75–100	4.97	329.73
> 100	5.86	509.32
Division		
Chittagong	4.34	441.31
Dhaka	3.44	297.67
Khulna	4.46	209.57
Rajshahi	4.81	202.40
All	4.26	324.97

Source: BIDS Survey (2004).

Table 3.5

Annual Price of Lighting by Income Quintile and Division

Income Quintile (thousands of Tk)	Kerosene (Tk/liter)	Kerosene (Tk/klm-hr)	Electricity (Tk/klm-hr)	Relative Price of klm-hr (K:E)
< 25	21.2	46.1	0.71	64
25–50	21.1	39.1	0.54	72
50–75	20.9	27.7	0.43	64
75–100	20.9	35.5	0.40	88
> 100	20.9	30.5	0.33	92
Division				
Chittagong	20.3	22.7	0.41	55
Dhaka	21.5	46.2	0.36	128
Khulna	20.9	43.0	0.61	70
Rajshahi	21.5	30.1	0.75	40
All	21.0	34.9	0.47	74

Source: BIDS Survey (2004).

lamps, kerosene-using households would need to pay 74 times the amount paid by households with electricity to attain the same illumination (see Table 3.5). This ratio rises as households move up the income ladder; that is, higher-income households pay a lower price for electric lighting than do poorer ones.

Price Variations of Electric Lighting

In rural Bangladesh, about 75 percent of household connections are obtained directly from the PBSs; about 21 percent are from neighbors connected to the PBSs, while the remaining 4 percent are mainly from the Power Development Board (see Table A1.28, Annex 1). The average prices for kilowatt-hours and kilolumen-hours are therefore estimated by the type of connection and level of income (see Table 3.6).

For PBS connections, the same monotonic and negative relationship with income is clearly discernible for price by kilowatt-hour and kilolumen-hour. The same is generally true for connections from neighbors. (Because the "other" category of connection sources has few observations, the results are probably not meaningful.) More interestingly, PBS-connected households pay the highest price for each income class, but the difference narrows substantially as incomes rise. When divisional pricing is considered, Khulna and Rajshahi households are found to pay higher prices in nearly all cases. The increase in takas paid per kilowatt-hour is probably caused by a large first block for households in the PBSs, combined with fixed charges on electricity bills; as the amount of electricity increases, the price per kilowatt-hour decreases because fixed charges are averages across total kilowatt-hours used. Also, the marginal cost of a kilowatt-hour is less than the price charged to neighbors. But the profits taken by those who sell electricity to their neighbors appear negative.[13] Such findings call for more in-depth analysis of formal and informal pricing of PBS connection arrangements.

Asset Ownership Patterns

Cooking, lighting, and non-lighting electric appliances all have important implications for rural well being. Biomass cookstoves, for example, are closely tied to levels of indoor air pollution (IAP) and negative effects on human health. The superior lighting quality of electric lamps is closely tied to evening study and educational improvements. Electric fans provide indoor space cooling, while radios and televisions offer communication and entertainment. Thus, it is important to understand typical rural household ownership patterns of such appliances.

Cookstoves and Health Implications

Across all regional divisions, fixed clay cookstoves are used for burning all types of biomass.[14] In the more highly developed division of Dhaka, nearly 7 percent of households use kerosene stoves. On average, households own two clay stoves (see Table 3.7). In

Table 3.6

Price of Electric Lighting by Income, Connection Type, and Division

Income Quintile (thousands of Tk)	Electricity Price (Tk/kWh)			Electricity Price (Tk/klm-hr)			Average Price	
	PBS	PBS-N	Other	PBS	PBS-N	Other	Tk/kWh	Tk/klm-hr
< 25	9.2	5.8	4.1	0.87	0.48	0.34	7.7	0.71
25–50	7.2	4.7	2.9	0.63	0.40	0.23	6.3	0.54
50–75	5.4	4.1	4.6	0.47	0.36	0.28	5.0	0.43
75–100	5.1	5.4	1.7	0.40	0.46	0.14	5.1	0.40
> 100	4.3	3.4	3.2	0.34	0.28	0.23	4.2	0.33
Division								
Chittagong	5.4	4.4	3.8	0.44	0.36	0.26	5.1	0.41
Dhaka	4.7	4.5	2.8	0.35	0.38	0.21	4.6	0.36
Khulna	7.2	4.3	3.5	0.69	0.41	0.28	6.4	0.61
Rajshahi	8.1	5.4	—	0.79	0.50	—	7.7	0.75
All	5.9	4.6	3.7	0.50	0.39	0.26	5.5	0.47

Source: BIDS Survey (2004).

Note: PBS-N = indirect connection to the PBS via neighbor (N). The PBS-Ns are estimates based on appliance ownership, as no bills are available and electricity is often based on fixed rates.

[13] Households that sell electricity to their neighbors cannot accurately determine the amount of such use. The neighbor buyers, who do not have meters, usually pay a fixed monthly amount based on a rough estimate of load, which they underestimate or under-report to the household sellers. The actual load is determined by the wattage and hours of use of all electric appliances and lightbulbs, which is difficult for the sellers to compute.

[14] In such locations as Sylhet District, sun-drying, rather than parboiling, is used to process paddy before milling.

Table 3.7

Household Ownership of Cooking Stoves by Type (number per 100 households)

	Division				
Stove Type	**Chittagong**	**Dhaka**	**Khulna**	**Rajshahi**	**Total**
Clay (fixed)	182.8	200.0	174.8	172.3	182.7
Clay (portable)	3.9	33.2	12.6	32.8	20.5
Kerosene	0.8	7.1	1.3	1.0	2.5
Gas	1.3	0.1	—	—	0.4
Electric heater	1.7	0.3	—	0.2	0.2
Total	190.5	240.7	188.7	206.3	206.3

Source: BIDS Survey (2004).

Table 3.8

Average Effective Cooking Hours by Income Quintile

Income Quintile (thousands of Tk)	Total Cooking Hours
< 25	4.2
25–50	5.9
50–75	7.0
75–100	8.0
> 100	9.2
Average	6.4

Source: BIDS Survey (2004).

Dhaka and Rajshahi, about 33 percent of households own portable stoves, which may be used for cooking outdoors. A few households also use kerosene stoves, while gas and electric stoves are rare. Average cooking time is three to four hours per day using fixed stoves and about two hours a day using portable ones.

The average clay stove, whether fixed or portable, is used two to three hours daily. However, when total effective hours (number of stoves times number of hours of operation) are considered, wealthier households are found to cook for longer periods of time than poorer ones (see Table 3.8).

As discussed in Chapter 4, IAP is a major health risk for women and children. It may present an even more serious hazard for wealthier households, given their longer cooking hours. At the same time, poorer households, who cook only once or twice a day, often end up eating cold meals more frequently than wealthier households, who cook two to three meals per day. In short, the net effect of IAP on human health and nutrition is difficult to predict.

Lighting Appliances

Kerosene Lamps

Bangladeshi households use two major types of kerosene appliances: kupis and hurricane lamps. Typically, kupis are uncovered lamps with a single handmade wick made of discarded fabric. Hurricane lamps, which have a glass chimney and thicker (often purchased) wicks, provide brighter light than kupis. In addition to these types, pressurized kerosene lamps, called petromaxes or hachaks, provide even brighter light.

Kupi ownership is virtually universal, while hurricane lamps are owned by far fewer households (see Table 3.9). Poor residents tend to rely more on kupis, which emit little light. The proportion of households who own hurricane lamps is similar across divisions, probably indicating their function as backup lighting for households with electricity.

Electric Lamps

Virtually all households with electricity have electric lamps (using 60-W incandescent bulbs), fluorescent tubes, and compact fluorescent lamps. The number of households using more efficient fluorescent lamps is less than those using incandescent bulbs. In fact, ownership of fluorescent lamps is limited almost exclusively to the two highest income quintiles (see Table 3.10). Rural Bangladesh has virtually no compact fluorescent lamps. These patterns are understandable, given the large price differentials between an incandescent bulb and

Table 3.9

Household Ownership of Lighting Appliances by Electrification Status (number per 100 households)

Household Status by Division	Appliance Type					
	Kupi/cherag	Hurricane/ Lantern	Petromax	Light Bulb	Tube Light	Charger (with torch)
Households with electricity						
Chittagong	212.4	95.6	—	414.5	77.9	19.3
Dhaka	153.0	80.3	1.1	310.6	36.7	—
Khulna	161.0	81.4	—	308.5	20.3	1.7
Rajshahi	162.3	77.0	1.6	315.6	18.9	0.8
All	176.7	85.3	0.7	348.6	47.0	7.2
Households without electricity						
Chittagong	210.2	98.2	—	—	—	0.5
Dhaka	162.5	89.7	0.6	—	2.9	—
Khulna	196.7	84.7	0.4	—	6.7	—
Rajshahi	160.5	90.2	0.8	—	—	—
All	182.8	90.3	0.5	—	2.5	0.1
All households						
Chittagong	211.1	97.2	—	161.3	30.3	7.8
Dhaka	158.4	85.6	0.8	136.0	17.7	—
Khulna	192.9	84.3	0.4	33.2	8.2	0.2
Rajshahi	160.8	87.5	1.0	64.2	3.8	0.2
All	181.0	88.9	0.5	101.2	15.4	2.2

Source: BIDS Survey (2004).

Table 3.10

Electric Lighting by Income and Division

Income Quintile (thousands of Tk)	Households with Electric Lighting (%)	Total Wattage/ Household	% Using Bulbs	No. Bulbs/ Household	Bulb Wattage	% Using Fluorescent Lamps	No. Compact Fluorescent Lamps	Compact Fluorescent Lamp Wattage
< 25	15.0	16	14.8	0.3	16	0.6	0.01	0.5
25–50	23.2	35	23.1	0.6	33	2.7	0.04	1.4
50–75	33.7	69	33.7	1.1	62	9.2	0.16	6.1
75–100	38.2	79	38.7	1.4	69	12.4	0.31	10.0
> 100	54.2	156	53.9	2.7	137	24.3	0.55	20.0
Division								
Chittagong	38.9	94	38.8	1.6	84	13.8	0.29	10.6
Dhaka	43.8	86	43.4	1.4	79	9.6	0.17	6.4
Khulna	10.8	17	10.9	0.3	15	2.9	0.08	2.0
Rajshahi	20.3	27	20.3	0.6	25	2.0	0.04	1.4
Average	29.0	58	28.9	1.0	52	7.3	0.15	5.2

Source: BIDS Survey (2004).

fluorescent tube or compact fluorescent lamps using similar wattage.

Ownership of electric lamps thus depends on both the rate of rural electrification and household income. The number of lighting watts per household also increases by income level. The wealthiest quintile has electric lights with a total of 156 watts per household, nearly 10 times more than the poorest quintile. In divisions with low rates of electricity use, the average number of watts per household is typically low, generally reflecting the respective region's rate of rural electrification.

Non-lighting Electric Appliances

Given Bangladesh's hot tropical climate, it is not surprising that the most frequently observed non-lighting appliance in households with electricity is the fan (see Table 3.11). Two out of three households own at least one electric fan. One out of three households owns a television set. Ownership of fans, radios, and television sets is highly correlated with income level. With few exceptions, fans are found only in households with electricity. Some households without electricity own and operate battery-powered radios and television sets.

Demand for Other Energy: Quantitative Analysis

The cross-sectional analysis from the previous sections suggests that factors such as income and landholding determine the patterns and types of energy used by rural households. Additional variables that may influence household energy demand include community infrastructure and consumer prices. Together, such factors affect energy demand for both household consumption and production. For example, both income and prices influence farmers' selection of fuels and irrigation pumps. From a policy perspective, it is critical to determine the relative importance of these factors, given the competing demand for alternative sources of energy and its quality. The question for researchers is this: What are the direction and magnitude of these factors' effects on demand for various types of energy?

To answer this question, we conducted an econometric analysis to predict how household energy demand is affected by changes in the various factors. A tobit regression was run to account for households having zero values for one or more types of energy demand. The variables used as influencing factors were gender of household head, age, maximum level of education in the household, household income (proxied by land and non-land assets), community prices for major energy sources and consumer goods, and community infrastructure variables.[15] Table 3.12 provides summary statistics of energy demand and selected influencing variables of policy relevance, while Table 3.13 presents the effects of selected variables on energy demand.

Table 3.11

Ownership of Non-lighting Electric Appliances by Income Quintile

Income Quintile (thousands of Tk)	% Connected	Electric Fans		Television Sets		Radios/Tape Recorders	
		% Ownership	Mean Number Owned	% Ownership	Mean Number Owned	% Ownership	Mean Number Owned
< 25	15.0	40.0	0.53	16.0	0.16	17.3	0.17
25–50	23.2	52.4	0.75	23.6	0.24	26.0	0.26
50–75	33.7	61.0	1.07	36.4	0.36	37.0	0.38
75–100	38.2	71.1	1.42	49.4	0.49	43.4	0.45
> 100	54.2	73.0	1.87	59.2	0.62	50.0	0.55
All quintiles	29.0	60.4	1.16	37.6	0.38	35.6	0.37

Source: BIDS Survey (2004).

[15] Only those influencing variables considered most important are reported here; see Table A2.1 (Annex 2) for the complete regression output.

Table 3.12

Summary Statistics of Outcomes and Important Explanatory Variables of Household Energy Demand Regressions

Variable Type	Mean	Standard Deviation
Household energy demand		
Fuelwood (kg/month)	98.86	104.57
Kerosene (liter/month)	2.41	1.94
Diesel (liter/month)	1.80	11.18
Electricity (kWh/month)	25.72	252.29
Explanatory		
Maximum education of household adults (years)	5.02	4.17
Household assets		
Land (acres)	1.25	2.22
Non-land (Tk 10,000)	1.68	5.55
Village price		
Fuelwood (Tk/kg)	1.65	0.68
Kerosene (Tk/liter)	22.94	2.73
Diesel (Tk/liter)	23.19	2.61
Electricity (Tk/kWh)	2.85	0.40
If village has electricity	0.66	0.47

Source: BIDS Survey (2004).

Table 3.13

Estimates of Household Energy Demand

	Household Demand (monthly)			
Explanatory Variable	Fuelwood (kg/month)	Kerosene (liter/month)	Diesel (liter/month)	Electricity (kWh/month)
Household				
Maximum education of adult males (years)	1.46**	0.020*	0.001	1.49
Maximum education of adult females (years)	0.76	0.020	–0.001	2.38
Land assets (acres)	1.91**	0.080**	0.020**	3.71
Non-land assets (Tk 10,000)	1.55**	0.020**	0.020**	2.65**
Village price				
Fuelwood (Tk/kg)	–34.73**	0.320**	–0.003	–0.12
Kerosene (Tk/liter)	5.95**	–0.009	0.002	0.53
Diesel (Tk/liter)	–8.81**	–0.110**	0.001	–0.41
If village has electricity	14.21**	–0.600**	–0.020	32.78**

Source: BIDS Survey (2004).

* = significance level of 10 percent; ** = significance level of 5 percent or stronger. Figures represent changes in energy demand for fuelwood, kerosene, diesel, and electricity caused by unit changes in the explanatory variables.

The study results support the assumption that an increase in income increases the demand for energy. Indeed, with higher incomes, rural Bangladeshis were found to pursue improved sources of energy and invest in assets that require more energy. Household income, apportioned by landholding and non-land assets, influences the demand for fuelwood and diesel, but non-land assets matter most in demand for electricity. It should be noted that income flow can be influenced by electricity consumption, where electricity use is viewed as an input in production. By contrast, assets are stocks that do not change over the short term but only over the long run. Therefore, we use assets rather than income to estimate the effect of household income proxies on energy use. For example, an increase of 1 acre in landholding increases household consumption of fuelwood by 1.91 kg per month and kerosene consumption by 0.08 liters per month. An additional Tk 10,000 of non-land assets increases household electricity consumption 2.65 kWh per month.

As incomes increase, rural households typically diversify their energy portfolios, moving toward modern energy, which is not only more efficient but also allows household members to invest time and money in more productive activities than biomass energy alone would make possible. The study findings confirm that education reflects rural people's preference for improved sources of energy. For example, an additional year of education for household adult males increases electricity consumption by nearly 1.46 kWh per month. Chapter 4 discusses in more detail the benefits of the transition to modern energy services (e.g., from biomass to kerosene or kerosene to electricity) on overall household welfare and productivity.

The price of an energy source has a direct effect on its own consumption and a cross-effect on the demand for alternative energy sources, depending on whether they are substitutes. For example, a price increase in fuelwood leads to decreased demand for it (direct effect) and increased demand for kerosene (positive cross-effect). A similar positive cross-effect is observed with regard to fuelwood demand when the price of kerosene rises. These phenomena clearly suggest that, for rural households, fuelwood and kerosene are substitutes.

The presence of electricity also increases fuelwood demand. That fuelwood is considered a good fuel for cooking in Bangladesh supports the notion that villages with electricity are more affluent than those without electricity. These measures have an overall village-level income effect on the demand for alternative energy sources. In addition, availability of electricity results in reducing villagewide energy prices, which affords households more to spend on energy generally, including fuelwood. But demand for kerosene declines with village electrification, which signals the substitution effect of users switching from kerosene to electricity (mostly for lighting).

Summing Up

In rural Bangladesh, access to energy is governed not only by its availability, but also by its pricing (monetary and non-monetary), household income, and other characteristics. Household demand for energy is sensitive to both price and income. If electricity is available, household access is determined by income; the higher the income (proxied by land and non-land assets), the greater the demand. For any energy source, pricing also determines demand. Thus, energy access is not equitable because the source is either priced too high or carries a high opportunity cost (e.g., biomass collection). Inequitable access and level of use may lead to further inequities (e.g., low-income households may pay far higher prices for equivalent lighting services). By exploiting price sensitivity, policy makers can play a role in influencing demand (e.g., by withdrawing the price subsidy for an energy source whose demand is insensitive to price or, conversely, introducing a price subsidy for a source whose demand is negatively sensitive to price). The next chapter demonstrates the loss to household welfare that can result from such inequities and the important gains that moving up the energy ladder makes possible.

4 Household Gains from Energy Use

Across the developing world, rural residents have benefited from switching to electricity and other forms of modern energy. Productivity gains in agriculture and business have increased household welfare directly, while skills development and improved education have contributed indirectly to a higher quality of life.

This chapter first considers the gains in Bangladeshi household welfare and farm productivity that result from moving up the energy ladder. Given Bangladesh's heavy reliance on biomass cooking energy, the health risk of indoor air pollution (IAP) is analyzed, and potential mitigation measures are considered. Next, the direct and indirect benefits of energy use on household income and consumption are presented within the context of the energy ladder typology.

Biomass Cooking: From Traditional to Modern Energy

Some 95 percent of Bangladeshi households collect or purchase biomass energy to cook all or part of their meals, mainly using fixed clay stoves. Although biomass is freely available or inexpensive, the inherent inefficiency of stoves, combined with the high moisture content of biomass cooking fuels, results in incomplete combustion, which produces excessive smoke.

Indoor Air Pollution from Traditional Stoves: Empirical Evidence

Long-term exposure to smoke and small particulates has long been considered an environmental health risk. Although there are many ways to measure exposure to smoke, the most common method involves the measurement of small particulates. Small particulates are a heath concern because they have an impact deep in the lungs and are a major cause of respiratory illness. The most general measurements of particulate matter are called PM, with a number afterwards that represents the aerodynamic diameter of the particle. For example, PM_{10} refers to fine particulate matter with an aerodynamic diameter smaller than 10 micrograms (μg). $PM_{2.5}$ has an aerodynamic diameter smaller than 2.5 μg. The exposure levels recommended by health and environmental agencies generally refer to the number of particulates of a certain diameter per cubic meter of air. The most recent standards of the World Health Organization for PM_{10} are 20 $\mu g/m^3$ of air annual mean exposure levels and 50 $\mu g/m^3$ 24-hour mean exposure levels (WHO 2006). For $PM_{2.5}$, the recommended levels are 10 $\mu g/m^3$ annual mean exposure levels and 25 $\mu g/m^3$ 24-hour mean exposure levels. For Bangladesh, the standard for annual recommended average for PM_{10} is 50 $\mu g/m^3$.

Worldwide evidence indicates that women and their children bear the brunt of indoor air pollution (IAP). Moreover, poorer households, compared to wealthier ones, bear the heavier burden. In rural Bangladesh, age–sex composition of households indicates that generally women and children suffer greatest exposure. Adult men are the least exposed because they spend more time outside the home. Solid particulates, especially those with diameters smaller than 10 microns (PM_{10}) are released into the air; and, if inhaled for prolonged periods, can lead to various diseases, loss of health, and early morbidity.

Note: In addition to the main authors, Hussain Samad and Susmita Dasgupta were contributing coauthors of this chapter.

Table 4.1

Mean Daily Hours in Household Location by Age Group*

	Female			Male			Female–Male		
Age Group	Cooking Area	Living Area	Outdoors	Cooking Area	Living Area	Outdoors	Cooking Area	Living Area	Outdoors
0–1	1.12	20.04	3.01	1.11	19.29	3.57	–0.01	–0.75	0.56
2–5	1.08	18.44	4.52	0.93	18.13	4.97	–0.15	–0.31	0.45
6–8	1.01	16.40	6.61	0.48	16.41	7.17	–0.52	0.01	0.56
9–12	1.32	15.55	7.19	0.31	15.61	8.06	–1.01	0.06	0.87
13–19	2.38	15.71	5.97	0.28	14.33	9.41	–2.10	–1.38	3.44
20–60	3.75	16.05	4.27	0.19	13.07	10.79	–3.56	–2.98	6.52
> 60	1.48	19.76	2.93	0.17	16.56	7.37	–1.31	–3.20	4.45

Source: Dasgupta et al. (2004).

* For seven regions in Bangladesh.

Finer particles ($PM_{2.5}$) are even more damaging. This section discusses various aspects of IAP caused by incomplete biomass combustion.

Both male and female children spend many hours indoors in the cooking space or adjacent living area until 6 to 8 years of age, when gender-based patterns begin to diverge (see Table 4.1). Adolescent males begin to spend more time outdoors, while adolescent females move in the opposite direction, spending more time in indoor cooking and living areas. Women 20 to 60 years of age spend nearly 4 hours per day cooking, nearly 16 hours in the household living area, and the remaining hours outdoors. For those above 60 years of age, the patterns are somewhat reversed.

Evidence suggests that pollution levels in living areas adjacent to the kitchen are broadly similar. Except for a few hours in the early morning and early afternoon, PM_{10} concentrations in kitchen and living areas remain far above 100 µg/m^3, the Indian standard for air pollution load. Ambient concentration, for the most part, remains below the Indian standard, except during early evening hours (see Figure 4.1).

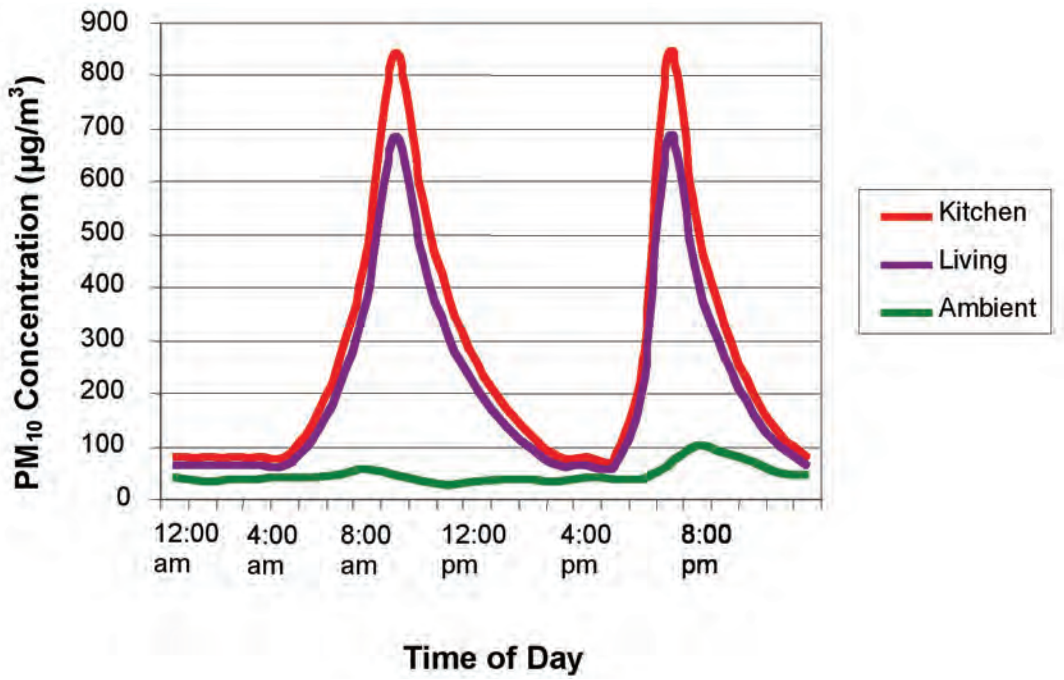
As Dasgupta et al. (2004) have estimated, both males and females are exposed to solid particulate pollution far above accepted standards for all ages, except for males 20 to 60 years of age, whose exposure level is little above the standard pollution concentration (see Figure 4.2); but they, too, are at risk for respiratory and other diseases. Exposure levels and their consequences may be tempered by various socioeconomic factors, including education and income, which influence awareness, fuel choice, mitigation measures, and general living environment.

Among Bangladeshi children, acute respiratory infection (ARI) remains a major cause of morbidity and mortality. A 2004 survey reported that 21 percent of rural children 1 to 5 years of age suffered from ARI.[16] This study's household survey indicates a broadly similar picture. However, the survey data are imprecise. Because they only reported whether working days were lost in the prior month due to specific diseases, the reported incidence of children's diseases may have been lower. In addition, the specific

[16] The 2004 survey was conducted by the National Institute of Population Research and Training (NIPORT), Mitra and Associates and Measure/DSH+.

Figure 4.1

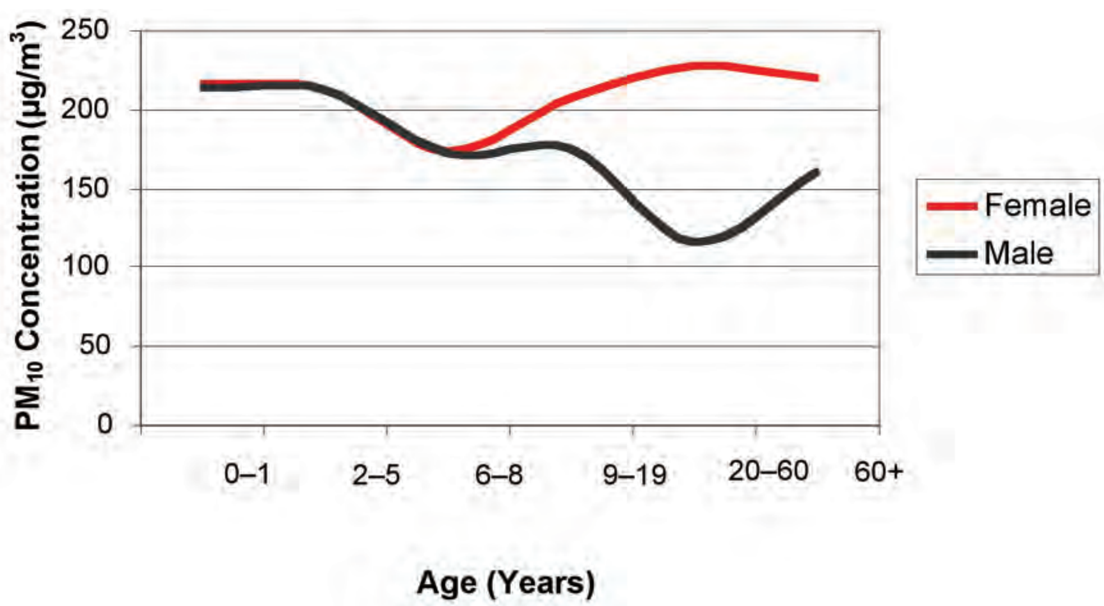
PM_{10} Concentration by Time of Day and Household Location



Source: Dasgupta et al. (2004).

Figure 4.2

PM_{10} Concentration by Age Group and Gender



Source: Dasgupta et al. (2004).

symptoms or diseases reported by household heads were subject to bias. Because symptoms were not always well clarified, it is difficult to know whether respiratory problems were present.[17]

Despite these information gaps, the findings are instructive. Overall, 10 to 11 percent of men and women experienced respiratory problems and diseases. About 24 percent of male children and 20 percent of female children in the 0 to 5 age group suffered from such diseases. For children and adolescents 10 to 19 years of age, about 8 percent of both genders were affected. For adults 20 to 60 years of age, the proportions were 9 percent for men and 10 percent for women. Thus, there was little difference by sex, but young children suffered more than adolescents and adults.

Evidence from rural Bangladesh indicates that IAP varies by fuel type, cooking location, kitchen ventilation characteristics, and other factors; furthermore, non-fuel factors may be as important as fuel characteristics (Dasgupta et al. 2004). The extent and duration of particulates in the kitchen, as well as the amount of smoke that leaks into other living spaces or the outdoors, may depend on kitchen location and ventilation, as well as the porous quality of materials used to construct kitchen roofing and walls. This survey revealed wide variation in household-specific ventilation characteristics. Regression of 24-hour PM_{10} concentration on fuel use and a large set of variables that describe household cooking and ventilation practices suggest that ventilation factors play a larger role than fuel choice. Two construction materials, mud walls and thatch roofs, significantly affect PM_{10} concentration.[18] If the cooking location is indoors, the sealing effect of mud walls increases PM_{10} concentration significantly.

After controlling for stove locations, construction materials, and opening of doors and windows after cooking, the PM_{10} effects of biomass fuels (dung, fuelwood, twigs and tree branches, dung, rice husks, and straw) are indistinguishable. Relative to these fuels, which are taken as the baseline, use of kerosene subtracts about 90 µg/m^3, LPG or LNG subtracts 103 µg/m^3, and piped natural gas 136 µg/m^3 from indoor PM_{10} concentration. Figure 4.3 presents the interactive effect of critical pollution factors by computing mean PM_{10} concentrations for groups that distinguish between clean (kerosene and natural gas) and biomass fuels, inside and outside (detached or open-air) cooking, and mud-wall and other construction materials. For statistical comparison of means, the benchmark is the mean living-space PM_{10} concentration for households with biomass fuels, inside cooking, and non–mudwall construction (acronym BIOL). The mean concentration for these households is 223 µg/m^3.

Pitt, Rosenzweig, and Hassan (2005), working with Bangladesh data, show that such exposures may not be random. Their findings show that cooking is done mostly by women. But those women in poorer health are more involved in cooking, possibly because they have little chance to switch to cleaner fuels or because the task falls onto those who otherwise cannot contribute to more productive activities. Among mothers, those with young children are less involved in cooking than others, indicating that cooks exposed to IAP are conscious of its hazards and avoid them as much as possible. Yet, because fuel-substitution possibilities are extremely limited or costly, the adjustments are insufficient.

This study has detected dangerously high levels of pollution in rural Bangladeshi households. Concentrations of respirable airborne particulates (PM_{10}) 300 µg/m^3 or greater are common, implying widespread exposure to a serious health hazard. Within households, individuals' exposure is related to concentrations of pollution in indoor locations during the daily round of activities. The estimates reveal high levels of exposure for children and adolescents of both sexes, with children under five years of age at increased risk. Among prime-aged adults, men have half the exposure of women (whose exposure is similar to that of children and adolescents). Elderly men also have significantly lower exposure than elderly women.

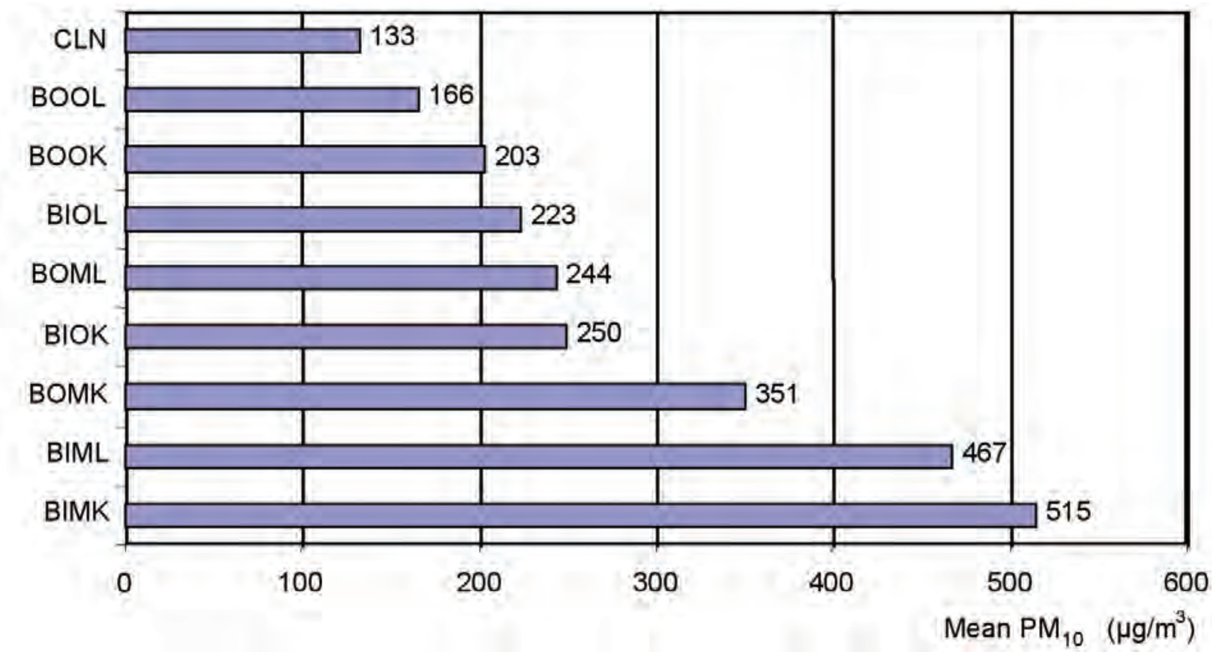
Predictably, fuel choice affects indoor pollution levels. Kerosene and natural gas are significantly

[17] Colds, coughing, breathing problems, tuberculosis, headaches, eye problems, chest pains, and fever were compiled to give a broad idea of the respiratory problems associated with IAP.

[18] In most localities of rural Bangladesh, the soil has low sand content, and mud walls and floors are frequently recoated to prevent cracking. The effective mud seal permits little ventilation, compared to other common construction materials (e.g., thatch or corrugated iron).

Figure 4.3

Pollution Factors and PM_{10} Concentrations



Fuel	Cooking	Location	Building Material	Space
CLN	Clean			
BOOL	Biomass	Outside	Other	Living room
BOOK	Biomass	Outside	Other	Kitchen
BIOL	Biomass	Inside	Other	Living room
BOML	Biomass	Outside	Mud	Living room
BIOK	Biomass	Inside	Other	Kitchen
BOMK	Biomass	Outside	Mud	Kitchen
BIML	Biomass	Inside	Mud	Living room
BIMK	Biomass	Inside	Mud	Kitchen

Source: Dasgupta et al. (2004).

cleaner than biomass fuels. But econometric results strongly suggest that certain household characteristics—construction materials, space configurations, cooking locations, and use of doors and windows—matter as much or perhaps more than fuel choice in determining PM_{10} concentrations. In some biomass-burning households, concentrations are scarcely higher than in those using natural gas.

Across households, family income and adult education levels (particularly that of women) significantly affect choices of cooking fuels, cooking locations, construction materials, and ventilation practices. As a result, the poorest, least-educated households have twice the pollution levels of higher-income households with highly educated adults. The exposure of young children and poorly educated women in poor households is quadruple that of men in higher-income households organized by more highly educated women.

Possible Gains from Cooking with Modern Stoves

Use of improved stoves and more modern forms of cooking energy has several classes of benefits, some of which are private and others public. This section considers mainly the private benefits, which are fairly self-evident. Because improved stoves require less fuel, using them reduces either the time spent collecting biomass fuels or the money spent to purchase them. Cooking with modern fuels involves cash expenses, but also entails many benefits.

In most rural economies, biomass fuels are collected from the local environment; thus, the benefits mainly involve the reduction in collection time for household members, especially women. As reported in Chapter 3, annual biomass-collection time for rural households in Bangladesh totals about 200 hours (150 of which are contributed by women). This means that using an improved stove saves about 25 percent of both fuel and collection time, representing a significant annual savings. For those that purchase biomass fuels, the benefits are similar to, but more straightforward than, time savings. If 25 percent less fuel is used for the same amount of cooking, then avoided expenses equals a 25 percent monetary gain. Similar potential gains can result from using modern fuels, such as LPG, for cooking.

It is not as straightforward to estimate the private health benefits of using improved stoves and modern cooking fuels (e.g., avoided eye irritation and illnesses or early deaths caused by exposure to high levels of IAP and improved cleanliness of the home). Most households are well aware of the benefits of eliminating smoke from their kitchens and other rooms. Household members, especially women, know the drudgery involved in keeping pans and walls free of the extensive carbon produced by traditional stoves. Assuming the same level of service and ease of use, households should, at least theoretically, be willing to pay more for a stove that involves less eye and throat irritation and less cleaning of pots and pans. However, the health and avoided death benefits are more difficult to grasp.[19]

Despite these difficulties, the World Health Organization is making efforts to quantify some of the public and private benefits of using improved stoves or substituting petroleum for biomass cooking fuels (Hutton and Rehfuess 2006; Hutton et al. 2006; WHO 2006). These studies develop economic valuation methods to evaluate time savings involving fuel collection and cooking, avoided health costs, and environmental benefits, among others. For a typical household in South Asia, the benefits of switching exclusively to improved stoves or from biomass energy to LPG or kerosene total about US$30 per year. Some of the best new-generation models, lasting 5 to 10 years, cost about US$50. Thus, households that use such stoves can expect a positive return on investment within two years.

The benefits of improved stoves, with certain caveats, significantly outweigh the costs, at least in theory. Unfortunately, the rural reality tells a much different story. If rural households perceived that even a fraction of the benefits developed under the national program were true, the program would not require significant subsides. Rural residents would be willing to purchase such stoves at their retail cost. But improved stoves must be designed to deliver a range of cooking services that people want: fuel efficiency, reduction in IAP, ability to cook a wide array of food preparations, cooking convenience, and even attractiveness in the kitchen or room. Given the history of low adoption rates, it is clear that past government subsidies used to promote the program have been problematic.

Despite the effectiveness of improved stoves to reduce indoor cooking smoke, programs from around the world reveal a wide range of successes and failures. Obviously, if a household decides to revert to a traditional stove or uses an improved stove that develops cracks and leaks, the desired improvements in cooking efficiency and reduced IAP will not be achieved. In addition, even after a household adopts an improved stove, indoor pollution levels remain significantly higher than those advocated by international development organizations, such as the World Health Organization and environmental agencies. Clearly, Bangladesh requires more options with regard to the types of improved stoves promoted and potential use of modern cooking fuels.

From Kerosene to Electric Lighting

The high-quality lighting afforded by electricity has important consequences for Bangladeshi household welfare. This study applied the concept

[19] Health evidence is just reaching the point where people are realizing the long-term health consequences of IAP.

Table 4.2

Annual Energy Use by Number of Students in Household

Students in Household (no.)	Lighting		Domestic Uses	
	Kerosene (liter)	Grid Electricity (kWh)	Kerosene (liter)	Grid Electricity (kWh)
0	23	52	25	92
1–2	28	84	30	153
3–4	34	121	36	209
> 4	37	232	40	415
Average	27	81	29	144

Source: BIDS Survey (2004).

of consumer's surplus to measure the welfare gains for lighting resulting from transitioning from less efficient kerosene-using devices to those using electricity to obtain the same amount of benefit (Annex 3). Similar measurements could be made for other services (e.g., entertainment), which were beyond the scope of this study.

Gains in Education

Mounting global evidence suggests that rural electrification is closely tied to higher income and improved education. Various studies have confirmed the link between rural electrification and education, suggesting that children's school attendance improves as households adopt electricity (Kulkarni, Barnes, and Parodi 2007). Many rural surveys have found that children study better when the high-quality lighting made possible by electricity is available (World Bank 2002b). A recent study on rural electrification and development in Bangladesh indicates that households with electricity have higher literacy rates and increased school enrollment than those without electricity (Barkat et al. 2002).

Evidence from this study suggests that the number of school-going students in rural Bangladeshi households influences the amount of electricity consumed (Asaduzzaman and Latif 2005). If the number of students in a family household increases by one, annual electricity consumption grows by about 51 kWh. This change is large, given that average annual household consumption is 114 kWh for domestic uses and 81 kWh for lighting. Indeed, compared to electric lighting, use of kerosene lamps varies considerably less by number of students (see Table 4.2).

Table 4.3

Study Time by Household Electrification Status (average number of hours)

Student Study Time	Household Status	
	With Electricity	Without Electricity
Daily	2.72	2.13
Evening	1.32	0.96

Source: BIDS Survey (2004).

The most plausible explanation for such increases in electricity use is that schoolchildren use electric lights to extend their study time. According to the survey, students in households with electricity study longer (see Table 4.3).

Total hours of study time (both daily and evening-hour) are greater in households that use electric lighting versus those without electricity, which use kerosene lamps. Clearly, electricity contributes to human-capital formation, leading to a longer-term increase in productivity.

Moving to Better Lighting: Consumer's Surplus

In rural Bangladesh, the most common household lighting appliances are kerosene-using kupi and hurricane lamps and electricity-using incandescent bulbs, fluorescent tubes, and compact fluorescent lamps. In this study, households were categorized into three groups: (1) those that light only with kupi lamps, (2) those with hurricane lamps that may or may not own a kupi lamp but do not have electricity, and (3) those with electricity that sometimes use an electric lamp and may or may not use any type of kerosene lamp. The gains in consumer's surplus were estimated for the transition from the kupi- to the hurricane-based system, and from the hurricane- to the electricity-based system.

To understand the results of the estimates of welfare gains, it is necessary to observe the distribution of households by their lamp-holding characteristics. This study's findings indicate that kupi-based households are concentrated more among poorer households (see Table 4.4). Hurricane lamp holdings are far more common than kupis, and patterns across income classes are not clearly discernible. Households with electric lamps are about 29 percent of households, reflecting those that have electricity; and their proportion increases with income.

One conservative measure of the improvement in consumer welfare is avoided expenditures from switching from kerosene to electricity for lighting. Although this is a rather rudimentary measure, it is interesting to compare kerosene expenditures for households with and without electricity. Because households without electricity spend more on kerosene, some fuel substitution occurs (see Table 4.5). Generally, households with electricity spend 200 to 500 takas less per year on kerosene. Although this avoided expenditure is an interesting benefit, it severely underestimates the true benefits because households with electricity have significantly more light compared to those with kerosene lamps.

A better way to measure the welfare gains of switching from kerosene to electricity involves a concept called consumer's surplus, which is based on a demand survey for lighting (see Annex 3). The gain in welfare, as measured by consumer's surplus, is substantial for the average consumer switching from any of the kerosene lamps to electric lights (see Table 4.6). The estimated benefit is 40 to 45 percent of household income (a substantial gain in terms of Bangladeshi takas). The reason is the inherent efficiency of electric lamps. The price of each kilolumen-hour from incandescent bulbs or

Table 4.4

Households by Lighting System and Income

Income Quintile (thousands of Tk/year)	Type of Home Lighting System (% households)		
	Kupi Only	Hurricane-based	Electricity-based
< 25	41.4	43.6	15.1
25–50	19.5	57.3	23.2
50–75	13.3	53.0	33.7
75–100	10.6	51.2	38.2
> 100	5.0	40.6	54.4
Average	20.1	50.8	29.0

Source: BIDS Survey (2004).

Table 4.5

Household Expenditure by Electrification Status on Kerosene and Other Energy Sources, by Income Group (Tk per year)

Income Category (thousands of Tk)	Households without Electricity		Households with Electricity	
	Kerosene Expenditure	Other Energy Expenditure	Kerosene Expenditure	Other Energy Expenditure
< 25	467.8	2,466.0	281.9	3,054.7
25–50	645.9	3,613.8	319.2	3,865.4
50–75	794.4	4,715.2	415.6	4,179.2
75–100	883.6	5,886.1	418.8	4,095.9
> 100	1,133.8	5,944.9	559.9	5,270.3
All	688.9	3,905.0	408.8	4,227.2

Source: BIDS Survey (2004).

Table 4.6

Welfare Gains from Switching Lighting Systems

Income Group (thousands of Tk/year)	System Transition		
	Kupi Only to Hurricane-based	Hurricane- to Electricity-based	Kupi Only to Electricity-based
< 25	56 (4.0)	838 (59.4)	894 (63.5)
25–50	67 (2.2)	1,333 (43.4)	1,401 (45.6)
50–75	83 (1.7)	2,243 (44.0)	2,326 (45.6)
75–100	58 (0.8)	2,156 (29.8)	2,214 (30.6)
> 100	80 (0.5)	3,197 (20.9)	3,276 (21.4)
Average	72 (1.4)	2,057 (40.1)	2,129 (41.5)

Source: BIDS Survey (2004).

Note: Left-hand figures represent takas per month; right-hand figures in parentheses are ratios of the gains in consumer's surplus to the relevant group's average monthly income.

fluorescent tubes is only about 1.43 percent of the cost of comparable lighting service from kerosene lamps (see Table 3.5).

Interestingly, when consumers are divided into income classes, the relative income gains are higher for poorer groups. But as expected, because of the higher density of lamps found in wealthier households, their absolute gains are two to three times higher than those of poorer groups. These findings have major rural energy policy implications for Bangladesh.

From Manual to Mechanized Farming

This study hypothesized that using modern energy for farming ultimately leads to gains in agricultural productivity. According to the United Nations Millennium Project: "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" (United Nations 2005). One should interpret the gains discussed here with caution, however, as more intensive data is needed to conduct an appropriate analysis.[20,21]

Improved Productivity

Bangladesh's agriculture is characterized by three rice-cropping seasons (Chapter 5). From the viewpoint of energy inputs, the most important is the dry season, when irrigated winter rice (*boro*) is grown; boro rice accounts for roughly 50 percent of rice production. The other is the partly wet/partly dry season, when *aman* rice, which may require supplementary irrigation, is grown. In all cropping seasons, both bullocks and power tillers are used for land preparation. As a result, four basic types of energy-using technology are classified by energy-use importance in production: low tillage–low irrigation, low tillage–high irrigation, high tillage–low irrigation, and high tillage–high

[20] Farmers accounted for 61 percent of the survey sample; they were involved in some form of cultivation during the 12 months preceding the survey.

[21] For example, while data on crops grown and output, including by-products, have been requested from respondents on a disaggregated level, cost figures have been taken on an aggregated level. In such cases, total costs of fertilizer purchase may be accurate overall; but aggregate information on labor costs may have a significant margin of error. Unfortunately, collection of labor-related data is a detailed exercise; thus, gross, rather than net, returns have sometimes been used. Furthermore, labor use, which usually differs by tenure arrangement, adds to the complexity in determining net returns.

Table 4.7

Farm Household Distribution by Tillage/Irrigation Technologies

Energy Technology Combinations	Rice Cropping Season (%)			
	Aus	Aman	Boro	Overall
Low tillage–Low irrigation	98.1	93.1	41.9	39.4
Low tillage–High irrigation	1.3	4.9	56.3	58.2
High tillage–Low irrigation	0.5	1.4	0.4	2.4*
High tillage–High irrigation	0.1	0.5	1.4	*

Source: BIDS Survey (2004).

* Indicates merger of these two groups.

irrigation (see Table 4.7). Low irrigation is defined as the absence of irrigation or manual irrigation, while high irrigation refers to use of mechanized (diesel or electric) pumps. Low tillage is defined as the use of bullocks in land preparation, while high tillage refers to the use of power tillers or tractors.

Modern energy use is particularly relevant during the boro season and, to a considerable extent, in the aman season. Rural Bangladesh has only two major combinations of energy technology: low tillage–low irrigation and low tillage–high irrigation. Empirically, it is the difference between the first two categories that indicates the productivity-raising effect of modern energy, particularly during the boro season and in paddy cultivation, which accounts for most farmed land.

The study found productivity differences by energy type for boro and aman paddy for owned land cultivated by the sample respondents (see Table 4.8). Farm productivity is significantly higher during the boro and aman seasons (22 percent and 17 percent, respectively). Thus, as is commonly known, irrigation provides a significant improvement in productivity.

Table 4.8

Gross Productivity of Paddy by Tillage/Irrigation (Tk/decimal)

Energy Technology Ladder	Rice Cropping Season	
	Boro	Aman
Low tillage–Low irrigation	118[a,b]	84[a,b]
Low tillage–High irrigation	145[a]	96[a]
High tillage–Irrigation (low and high)	140[b]	68[b,a]

Source: BIDS Survey (2004).

Note: 1 decimal = 50 square yards; comparisons are for the same crop (within same column) between technology levels.

[a] Figures differ at 1 percent significance level.

[b] Figures differ at 5 percent significance level.

Distribution of Irrigation Gains by Land Ownership

Although likely to have higher energy use, larger farms generally have lower land productivity than smaller ones. To purge the confounding influence of such factors on land yield, this study conducted a regression analysis for the average gross yield of boro paddy land. Results of the analysis suggest that, on average, when the influence of such factors as education of household head, size of owned land, and regional variations are accounted for, up to 15 percent improvement in productivity can be attributed to switching from low tillage–low irrigation to the higher irrigation scenario. In absolute terms, the figure totals nearly Tk 1,800 per acre. For aman paddy, by contrast, estimated improvements are substantially smaller or may not be clearly discernible because irrigation may be supplemental, depending on rainfall level in a particular location or farmer's land conditions.

In reality, the gains may be even more substantial and inequitably distributed. Table 4.9 illustrates the issue for boro paddy production. Both sets of observed and estimated yield figures for low-energy technology users exhibit the classic pattern of negative size–productivity relationship. But the observed yields

Table 4.9

Paddy Productivity in Boro Season by Land Ownership (gross value in Tk/decimal)

Land Ownership (decimal)*	Technology			
	Observed		Estimated	
	Low-energy	High-energy	Low-energy	High-energy
1–49	164	147 (–10)	140	149 (6)
50–249	141	145 (3)	123	144 (17)
250–500	96	146 (52)	99	138 (39)
> 500	80	141 (76)	89	130 (46)
Average	118	145 (23)	107	141 (32)

Source: BIDS Survey (2004).

Note: Figures in parentheses represent percentage change over the low-energy situation.

* 1 decimal = 50 square yards.

for high-energy technology users are similar for every land-ownership class. The change in land productivity from energy use is likely masked by the influence of other factors. Although both observed and estimated yields fall with rising land ownership, the one high in energy use declines at a slower rate than the one low in use, indicating increasingly greater gains from higher farm technology (energy) use. The percentage differences in estimated yields for high energy use are somewhat less than those for the observed figures, but the patterns are similar. Furthermore, the average gain is 32 percent (Tk 3,400), nearly double that suggested initially by the regression equation.

The conclusion is that farm households that move up the energy ladder enjoy a substantial gain in productivity and can provide irrigation or purchase irrigation water for their farms. About 50 percent of the average gain in transitioning from lower- to higher-energy technology is derived from switching to more intensive irrigation using mechanized (diesel or electric) irrigation pumps, with complementary factors accounting for the other 50 percent.

Overall Income Gains: Moving Up the Energy Ladder

Thus far, this chapter has examined some of the gains derived from using more modern energy for the specific areas of lighting, cooking, and irrigation. This section examines more general income gains that can be derived from moving up the energy ladder, many of which overlap with those already described. In short, the gains described in this section are a more general indicator of the value of the changes that result from improved cooking and living standards made possible by better ways of using energy.

Cross-sectional Correlations of Electricity Use and Income

This study survey measured household income separately for business and wage-related activities. More specifically, there are four measures of income, including agriculture (farm-production activities), non-agriculture (entrepreneurial activities), agricultural wage labor, and non-agricultural wage labor. This section examines income levels for households with and without electricity, while the next one explores income gains from using more modern energy, controlling for many other factors.

Overall, households with electricity have significantly higher incomes than those without electricity (see Table 4.10). This is generally true with regard to income from non-agricultural activities, except in divisions where irrigation is more prevalent, notably Rajshahi. In other divisions, the relationship may be reversed. Regarding agricultural wage labor, the relationship is counterintuitive, as it relates negatively to household electrification. Finally,

Table 4.10

Household Income Differentials by Electrification Status (Tk per year)

Income Source	Electricity Connection	Division				All Divisions
		Chittagong	Dhaka	Khulna	Rajshahi	
Agriculture	No	31,776[a]	17,348	20,395[b]	19,751[a]	22,227
	Yes	21,251[a]	20,169	28,898[b]	35,418[a]	23,980
Non-agriculture	No	23,443[a]	24,729[a]	18,706[a]	13,538[a]	19,545[a]
	Yes	78,455[a]	58,236[a]	43,747[a]	29,504[a]	59,208[a]
Agricultural wage labor	No	4,821[a]	3,086[a]	4,606[a]	6,439[a]	4,868[a]
	Yes	2,240[a]	1,775[a]	1,168[a]	2,883[a]	2,085[a]
Non-agricultural wage labor	No	3,865	5,972	2,969	2,430	3,624
	Yes	2,915	6,472	4,569	2,490	4,334
Total	No	63,906[a]	51,135[a]	46,677[a]	42,159[a]	50,264[a]
	Yes	104,860[a]	86,652[a]	78,383[a]	70,296[a]	89,607[a]

Source: BIDS Survey (2004).

[a] Differences are statistically significant at 1 percent level or less.

[b] Differences are statistically significant at 5 percent level.

non-agricultural wage labor is shown to have little relevance to electrification. Thus, it is mainly income from non-agricultural activities that has the most stable relationship with electrification. Given the low use of electricity for irrigation in Bangladesh, this is not an unexpected finding.

Electricity is not the only modern energy source used in agriculture. The main fuel used for irrigation in Bangladesh is diesel. As discussed previously, rural households can gain substantially by moving up the energy ladder—whether switching from kerosene kupis to electric lamps, manual irrigation to electric pumpsets, or inefficient biomass stoves to improved models using cleaner-burning fuels. Similarly, farm productivity gains from switching to mechanized irrigation are estimated at 17 to 22 percent for any cropping season.

Net Gains after Controlling for Other Variables

It should be noted that correlation does not signify causality, and the tables presented thus far do not control for many factors. To quantify the effects of energy use on household income or consumption while controlling for other important factors, a regression technique is most appropriate. In this section, the results are presented only for the energy and outcome variables. The detailed models used for this analysis can be found in Annex 2.

For this analysis, we divided household energy use into two relevant categories: (1) non-lighting and (2) lighting. Both types can be used for consumption and income generation. We further categorized energy use by major sources, namely, biomass, kerosene/diesel, and electricity. Thus, the main outcome variables for the study are both farm and non-farm income (see Table 4.11). Perhaps surprisingly, in rural Bangladesh, non-farm income is higher than farm income. In addition to income, household consumption is considered an outcome.[22]

The study estimates the benefits of various forms of energy, especially modern energy, on household consumption (net of energy consumption) and income obtained from both farm and non-farm production.

[22] Household energy expenditure is excluded from this consumption figure.

Table 4.11

Summary Statistics of Outcomes and Energy Use Variables of Household Welfare Regressions

Variable	Mean	Standard Deviation
Outcome (Tk/month)		
Consumption	3,581	2,449
Farm income	2,229	2,702
Non-farm income	2,889	4,997
Total income	5,118	5,950
Monthly energy use		
Non-lighting (kgoe)	95.7	70.7
Lighting (klm-hr)	115.6	267.7
Biomass (kgoe)	90.1	65.7
Kerosene/diesel (kgoe)	3.5	9.5
Electricity (kWh)	25.7	252.3

Source: BIDS Survey (2004).

Table 4.12 shows the effects of energy use on household consumption and income by types of use (lighting and non-lighting) and source (biomass, kerosene/diesel, and electricity).[23] The findings are interesting and in line with what one would expect from both farm and non-farm households moving up the energy ladder.

To a certain extent, the findings reflect the efficiency with which a fuel is used. Biomass energy is generally burned in inefficient stoves, ovens, or boilers. Kerosene and diesel use generally has energy efficiency ratios of about one-third. At the end-use point, electricity is a very efficient form of energy. One would expect its effect to be higher than that of other fuels on both expenditure (consumption) and income. The results confirm that electricity has the highest level of impact on both energy expenditures and the equivalent measure of income.

As might be expected, lighting energy has a greater effect on non-farm income than farm income. Conversely, non-lighting energy has a greater effect on farm income than non-farm income. Thus, lighting is more important for non-farm income, while non-lighting energy, such as diesel, is more important for farm income. After all, diesel can be used for irrigation, which, as noted previously, is strongly correlated with farm productivity.

The effects of different types of energy consumption (biomass, kerosene/diesel, and electricity) are even more interesting. Biomass energy is the fuel most commonly used by households in Bangladesh. An increase of 1 kgoe of biomass energy increases monthly household income by about Tk 8, most of which can be attributed to farm income. Moving up the energy ladder yields greater income gains. Use of kerosene or diesel fuel significantly raises farm income, likely resulting from diesel-powered irrigation. Use of 1 kgoe (about 1 liter of fuel) increases farm income by approximately Tk 149, significantly higher than its cost. Of all fuels, electricity has the greatest effect; 1 kWh contributes to raising non-farm income by Tk 4.7 and total income by almost Tk 16, which is equivalent to more than Tk 185 for 1 kgoe, a gain of more than 20 times that achieved from biomass use. Much of the non-farm income gain from electricity use can be attributed to lighting, the most

[23] Tables A2.2 and A2.3 (Annex 2) present complete regression results. These are marginal gains, which differ from the gross average gains calculated earlier.

common rural use of electricity. But one should not discount electricity's importance to farm income in rural Bangladesh, despite its limited use in irrigation.

Income and other welfare gains are indicators of improved energy use by rural households.[24] Given that biomass is used only for cooking, kerosene for both cooking and lighting, and electricity for lighting only, one can infer that household welfare would increase significantly by switching from biomass to kerosene for cooking and from kerosene to electricity for lighting. As previously discussed, real improvement in household income and consumption can be achieved by switching from biomass to kerosene or from kerosene to electricity. The evidence is fairly conclusive that switching to modern energy sources can increase a household's income and consumption both directly and indirectly. Increased income leads to greater consumption and more diversified investment, which, in turn, creates more income and household welfare.

Summing Up

This chapter has demonstrated that moving up the energy ladder can contribute significantly to rural income growth. Large welfare gains result when households switch from kerosene to electric lighting. Land productivity and agricultural income increase when farm households switch from manual to mechanized tillage and irrigation.

The indirect link between electrification and education is also positive. Households with electricity have higher levels of education, although the causal direction is unclear. Children who live in households with electricity appear to study longer, thereby laying the foundation for longer-term, human-capital formation. Since mainly the poor lack electricity, a major concern is that children in poor households miss out on the educational benefits that electricity affords.

Another concern is IAP, caused by the incomplete combustion of biomass for cooking and heating. Although the effects are not yet clearly understood, switching to cleaner-burning fuels, if affordable, and using improved stove designs, can mitigate the health risk to rural households.

Modern energy's returns to household welfare and farm productivity are substantial, even after controlling for such factors as education, assets, and household location. Switching to modern energy and the modern use of biomass also contributes to the productivity of rural industries and microenterprises, the subject of the next chapter.

Table 4.12

Estimates of Household Welfare (Tk per month)

Monthly Energy Use	Consumption	Farm Income	Non-farm Income	Total Income
Model 1				
Non-lighting (kgoe)	4.89**	9.61**	3.80	11.20**
Lighting (klm-hr)	4.32**	–0.19	9.68**	9.39**
Model 2				
Biomass (kgoe)	3.43**	13.32**	–10.37	8.18**
Kerosene/diesel (kgoe)	–18.00	149.07*	–151.61	–54.59
Electricity (kWh)	7.43**	–2.17	4.72**	15.73**

Source: BIDS Survey (2004).

Note: Figures represent changes in outcome (consumption and income) due to one unit change in energy use.

* = significance level of 10 percent.

** = significance level of 5 percent or stronger.

[24] The consumer or producer's surplus approach used to calculate consumption gain does not represent a real increase in household or farm income; rather, it estimates potential gain; that is, the savings a household could realize by switching from a lower-tier energy source to a higher one (Annex 3).

5 Energy Consumption and Rural Production

Around the globe, microenterprises have demonstrated their ability to facilitate economic growth and development. China's development of small- and medium-sized enterprises, for example, has contributed to the country's rapid economic advance. Such programs have been complemented by rural electrification and other rural infrastructure investments. Indeed, without the underpinnings of electricity and other development inputs, rural microenterprises would struggle. But simply introducing modern energy into the rural economy is unlikely to produce an economic miracle. Substantial evidence suggests that other supporting conditions are needed for businesses to grow and flourish. Under the right conditions, long-term growth can be sustained.

This chapter charts the course of modern energy use in Bangladesh's rural microenterprises, exploring their energy-use characteristics and the effects of energy consumption on business growth and development. The rich data set collected by this study—including information on enterprise type, assets, and employment—reflects the need to conduct separate surveys on rural household and growth-center microenterprises. A brief section on energy and farming highlights the importance of irrigation for productivity.

Enterprise Types and Distribution

Bangladesh's rural enterprises can be grouped into three location-based categories: growth center, village, and home. The survey findings reveal, perhaps surprisingly, that most home-based businesses center on manufacturing, while village and growth center industries are involved more in trading. On closer examination, the reasons are clear. Many home businesses are run by women involved in such production activities as basket weaving and sewing. Outside the home, village enterprises, run mostly by men, are involved in store operations selling goods and services (see Table 5.1).

Table 5.1

Microenterprise Distribution by Location and Activity Type

	Microenterprise Type									
	Agriculture and Food		Manufacturing		Trading		Services and Other		All	
Location	No.	%	No.	%	No.	%	No.	%	No.	%
Home	5	3.6	73	53.3	36	26.3	23	16.8	137	100
Village	63	18.4	12	3.5	208	60.8	59	17.3	342	100
Growth center	197	10.9	191	10.6	1,116	62.0	297	16.5	1,801	100
All	265	11.6	276	12.1	1,360	59.6	379	16.7	2,280	100

Source: BIDS Survey (2004).

Note: In addition to the main authors, Rashid Faruqee and Hussain Samad were contributing coauthors of this chapter.

Growth-Center Microenterprises

Bangladesh has formally classified some 2,078 growth centers (large-sized markets).[25] This study focused on rural enterprises randomly selected from 115 formal growth centers across 40 subdistricts (*upazilas*). Eighty percent of the selected growth centers were located 15 kilometers or more from the nearest district headquarters, while subdistrict centers were also situated at a considerable distance (about 15 percent of growth and upazila centers were indistinguishable). Most growth centers had access to roads in fair condition.

Concentration of enterprises varied greatly by growth center. Some centers had no more than 15 enterprises, while others had as many as 808. All enterprises in the centers surveyed were self-standing (none included household-based enterprises). Seventy-five percent of the selected growth centers had been recently established, as evidenced by enterprise distribution by age of the growth centers. None of those established within one year of the survey involved manufacturing. Those established 5 to 10 years earlier had the highest concentration of such enterprises.

The study found that, compared to other rural areas, growth centers enjoyed more extensive access to electricity. Nearly 94 percent of those studied had electricity; 76 percent obtained a connection from the rural cooperatives or PBSs (*Palli Bidyut Samities*), and 18 percent from the Bangladesh Power Development Board. Although only 38 percent had phone connections, nearly 67 percent had access to mobile phones.

Types and Distribution

Growth-center microenterprises typically focused on retail services. Trade and business (food and non-food) predominated, together comprising 61 percent of enterprises; these were followed by services (27 percent) and manufacturing (10 percent). About 38 percent of rural enterprises were linked to agriculture, mostly in the retail business. There was little regional variation (see Table 5.2).

In the trade and business (food) category, groceries and general stores predominated, followed by tobacco (*biri*), betel quid (*paan*), and beetle nut shops. In the trade and business (non-food) category, the main establishments were traders of pharmaceutical and medical goods; cosmetics and toiletries; and textiles, clothing, hosiery, footwear, and leather goods. In the services category, tea stalls, restaurants, tailor shops, and beauty salons were the major businesses. The manufacturing category mainly included non-grain processing (e.g., jewelry, wood furniture, sawmills, and wood-processing units). Unlike other South Asian countries, where rice mills are common, Bangladesh

Table 5.2

Distribution of Growth-Center Microenterprises by Region

	Establishments by Region									
	Chittagong		Dhaka		Khulna		Rajshahi		Total	
Enterprise Type	No.	%	No.	%	No.	%	No.	%	No.	%
Trade and business (food)	153	33	160	33	142	34	145	31	600	33
Trade and business (non-food)	116	25	139	29	118	28	143	31	516	28
Services	128	28	120	25	123	29	123	26	494	27
Manufacturing	54	11	58	12	34	8	45	9	191	10

Source: Data International Survey (2002).

[25] The Government of Bangladesh, through its Engineering Department and local government, maintains a regularly updated list of rural growth centers.

mills rice either in households or using mobile threshing machines.

The survey results compare favorably with those of other recent studies. For example, the National Private-sector Microenterprise Survey, conducted in 2003, revealed a similar pattern of micro-, small-, and medium-sized enterprises. It showed that 27 percent of enterprises (excluding fisheries) were agriculture-based;[26] while 14 percent were in manufacturing, compared to 11 percent in this survey. Since the 2003 survey included medium-sized enterprises, trade and services sectors combined represented only about 50 percent of enterprises, while they predominated in this survey.

This survey showed that 95 percent of rural enterprises have sole owner operators, while 5 percent are partner owned. Current owners initiated most of the businesses, signifying their recent establishment. Similarly, the 2003 survey found that 94 percent of enterprises had sole owners, of which 90 percent were owner operated.

This survey's findings revealed that all establishments are owned and operated by men. The average operating day is 12 hours; unlike agricultural activities, there is no peak business season. Rural microenterprises are small, run primarily by owners (with an average of two employees). Even the size of manufacturing establishments is small (averaging only four employees). Similarly, the 2003 survey revealed an average of 3.3 workers for all types of rural enterprises. This survey shows that women are an extremely small percentage of employees (1.5 percent); by contrast, the 2003 survey reported that women represented about 9 percent of the work force.

The value of enterprise assets is limited. Only one in six owns the land on which the operation was established. Nearly 67 percent have no assets; that is, the total value of assets, on average, is roughly equivalent to the annual revenue of the enterprise.

Although the rural-enterprise composition of growth centers may not be representative of enterprises nationwide,[27] it is nonetheless helpful to compare current findings with earlier data on Bangladesh and other countries. For example, Islam (2001) notes that eateries and tea stalls dominated earlier commercial activities in Bangladesh. This survey shows that such activities remain significant, but others have emerged, reflecting a diversification of business operations.

Energy Use

Analysis of energy-consumption patterns in Bangladesh's growth centers underscores the need to consider the context of energy-services delivery and the relative efficiency of the energy sources used. The survey confirms that firms use multiple energy sources, depending on their specific business needs (see Table 5.3).

Nearly all firms use some form of electricity, mainly for lighting. If owners cannot access electricity from the cooperatives or national grid, they generate their own or purchase it from small firms. Because electricity is used more efficiently than other energy sources, its consumption appears lower (9 percent). Kerosene and diesel are major sources of backup lighting during power outages, while candles are also used.

One surprising finding is that only 6 percent of firms—111 out of 1,801 enterprises—use biomass energy, mainly for heat and steam. Charcoal is used by only 4 percent of firms to meet similar needs (see Table 5.4).

Modern energy sources are used mainly for lighting and heating (including the preparation of food for sale). Non-lighting uses include manufacturing and catering services and powering of small appliances. Use in drive-shaft power for productive purposes is not yet widespread.

Energy Costs

For most growth-center microenterprises, energy is a significant but not major cost, averaging less than 5 percent of total operating expenses (from less than

[26] If fisheries had been included, agriculture would have comprised 32 percent, compared to 38 percent in the current survey.

[27] Limiting business coverage to the growth centers means that many common, larger-sized enterprises (e.g., brick kilns, cold storage, fisheries, poultry, and hand looms), some of which are energy intensive, are not captured.

Table 5.3

Distribution of Energy Sources by Activity Type

		User Microenterprises (%)				
Energy Source	Users (no. of firms)	Trade and Business (food)	Trade and Business (non-food)	Services	Manufacturing	All*
Biomass	111	3.8	0.2	15.6	5.2	6.2
Charcoal	73	0.0	0.4	6.3	20.9	4.0
Candle	1,034	58.2	64.1	52.6	49.2	57.4
Kerosene/diesel	986	59.8	39.7	59.9	66.0	54.7
Dry cell	196	11.2	13.6	8.9	7.8	10.9
Storage cell	57	2.5	4.3	4.0	0.0	3.2
Captive electricity	343	19.5	21.7	18.0	13.1	19.0
Grid electricity	1,472	79.0	86.6	79.6	82.7	81.7
Miscellaneous	56	3.2	4.1	2.0	1.6	3.1
None	26	2.7	0.8	1.0	0.5	1.4
Total	1,801	600.0	516.0	494.0	191.0	NA

Source: Data International Survey (2002).

* Sum of percentages is more than 100 because enterprises use multiple energy sources.

Table 5.4

Major Energy Sources by Use Type

	Microenterprises that Use Fuels		Use as Major Lighting Source		Use as Major Non-lighting Source	
Energy source	No. of Users	% of Total Respondents	No. of Users	% of Energy Users	No. of Users	% of Energy Users
Biomass	111	6	0	0	71	63
Charcoal	73	4	0	0	47	64
Candle	1,034	57	66	6	—	—
Kerosene/diesel	986	54	352	35	180	18
Generator electricity	343	19	122	35	0	0
Grid electricity	1,472	81	1,120	76	208	14

Source: Data International Survey (2002).

2 percent in the food trade to about 10 percent for services) (see Table 5.5). As already illustrated, not all firms use all sources of energy for lighting and non-lighting purposes. If such a distinction is made, the proportion of energy costs rises appreciably, particularly for non-lighting uses.

Although energy comprises a comparatively lesser share of total expenses, energy costs vary by energy intensity of the business. For example, retail shops incur small lighting costs, while diesel- or electricity-powered heavy machinery shops must budget more for energy. Explaining such cost

Table 5.5

Energy as a Percentage of Total Costs by Activity Type

		Microenterprise Type (%)				
Energy Source	**No. of Firms**	**Trade (food)**	**Trade (non-food)**	**Services**	**Manufacturing**	**All Firms**
Biomass*	110	3.9	1.8	5.3	4.3	4.9
Charcoal	71	0	16.2	11.0	1.9	5.8
Candle	1,034	0.2	0.3	0.7	1.0	0.5
Kerosene/diesel	985	1.0	1.3	4.7	2.6	2.4
Dry cell	180	0.1	0.2	0.8	0.1	0.2
Storage cell	57	0.3	0.8	1.9	0	1.1
Generator electricity	343	0.6	0.7	4.5	1.7	1.7
Grid electricity	1,472	0.8	1.4	5.4	6.1	2.8
All sources	1,775	1.7	2.3	10.1	8.3	4.9

Source: Data International Survey (2002).

* Biomass sources include fuelwood, sawdust, tree residue, straw, rice husk, jute sticks, bagasse, and other crop residue, animal dung, and briquette.

variations requires examining the level and effects of relative energy pricing for various fuels used by rural enterprises.

Energy cost is relative to what businesses pay for it. Predictably, based on standard energy units, the price of electricity is higher than that of all other energy types, mainly because of the higher value of the energy services provided. Measured by energy content, biomass is the cheapest source, while electricity is the most expensive. Although the price of charcoal is low, its use is specialized (e.g., making jewelry and tobacco [*biri*]). Conversely, for lighting services (measured in kilolumen-hours), electricity is the cheapest source (Tk 0.003 per klm-hr versus Tk 1.4 for kerosene and Tk 41.3 for candles). Indeed, for the same lighting service, kerosene is about 45 times costlier than grid-based electricity (see Table 5.6).

To summarize, patterns of energy choice are, in large part, determined by the relative fuel price for the desired end use. For heating, biomass is the least expensive fuel. For lighting, grid electricity is by far the cheapest source. Thus, it is not surprising that most rural microenterprises switch to grid electricity when it becomes available in their respective communities and otherwise generate their own electricity or purchase it locally from small generator firms.

Entrepreneurial Attitudes

The study survey asked business owners and operators a variety of energy-related attitudinal questions. Findings show that business entrepreneurs consider electricity the best source of lighting, but also perceive that reliability of supply is a significant problem. Few respondents consider kerosene superior to electricity for lighting. Most agree that electricity provides better illumination than kerosene and makes reading easier. They also perceive that grid electricity is superior to batteries for powering television (see Table 5.7).

Entrepreneurs perceive irregular electricity supply and voltage fluctuations as a negative use factor. Some 67 percent of respondents are convinced that PBS power distribution and management quality have declined in recent years. Indeed, nearly 75 percent consider fatal accidents as a disadvantage of use. About 67 percent view electricity as expensive,

Table 5.6

Price per Unit of Energy for Non-lighting Business Use

Energy Source	Unit of Energy	No. of Users	Enterprise Type (Tk/unit)				All Enterprises
			Trade (food)	Trade (non-food)	Services	Manufacturing	
Biomass*	kgoe	71	3.1	1.3	3.3	3.9	3.3
	klm-hr	0	—	—	—	—	—
Charcoal	kgoe	47	—	3.5	4.2	4.9	4.6
	klm-hr	0	—	—	—	—	—
Kerosene/diesel	kgoe	180	22.6	23.0	22.3	23.5	22.7
	klm-hr	301	1.3	1.0	1.4	1.5	1.4
Grid electricity	kgoe	208	55.9	86.4	66.1	53.4	66.3
	klm-hr	1,173	0.04	0.02	0.03	0.03	.03
Candles	klm-hr	72	48.2	41.8	39.2	37.9	41.3

Source: Data International Survey (2002).

* Biomass sources are fuelwood, sawdust, tree residue, straw, rice husk, jute sticks, bagasse, and other crop residue, animal dung, and briquette.

Table 5.7

Perceived Advantages and Disadvantages of Electricity Use

Survey Statement	Response Choices (%)				
	Strongly Agree	Agree	Indifferent/Neutral	Strongly Disagree	Disagree
Electricity provides better illumination than kerosene oil (*n* = 1,801)	70.7	28.9	0.1	0.2	0.0
Reading is easier with electric lamp than kerosene lamp (*n* = 1,801)	64.4	34.8	0.8	0.1	0.0
It is [more] advantageous to run TV by electricity than battery (*n* = 1,766)	60.9	35.1	3.5	0.2	0.3

Source: Data International Survey (2002).

and most consider it an unattractive option for cooking, probably because of its high cost compared to biomass fuel. However, nearly all respondents agree that the advantages of using electricity far outweigh the disadvantages.

Enterprises without electricity were asked several questions related to the costs and benefits of electricity use. There was no consensus on the cost of obtaining a business connection: About 50 percent did not consider prevailing rates exorbitant, 30 percent thought they were too high, and about 19 percent were indifferent. This finding is consistent with respondents' reactions to a similar statement on affordability of connection. About 59 percent of non-users said that, if they were to obtain access, the monthly payments would not be too high; about 44 percent perceived it as unaffordable. In short, despite the overwhelming perception regarding net

Table 5.8

Perceived Advantages and Disadvantages of Fuelwood Use

Survey Statement	Response Choices (%)				
	Strongly Agree	Agree	Indifferent/Neutral	Strongly Disagree	Disagree
Fuelwood is readily available to collect (*n* = 1,801)	31.2	33.3	0.3	17.9	17.3
Fuelwood can be obtained free of cost from own trees (*n* = 1,801)	30.3	32.6	2.3	15.1	19.8
Fuelwood creates smoke that creates breathing problems (*n* = 1,801)	40.1	45.1	5.1	4.3	5.3
Cooking with fuelwood creates health hazards (*n* = 1,750)	25.0	33.4	10.5	16.6	14.5
Fuelwood is very expensive for cooking (*n* = 1,798)	28.3	32.5	1.6	15.3	22.3

Source: Data International Survey (2002).

gains, most respondents believed the advantages of electricity outweighed the problems.

With regard to fuelwood, the opinions expressed varied markedly, reflecting the widespread problem of deforestation and thus uneven resource availability. Because of scarcity and moderate shortages, about 50 percent considered fuelwood expensive. At the same time, many rural entrepreneurs perceived fuelwood as a readily available resource. More than 90 percent expressed concern with regard to deforestation. Rural entrepreneurs preferred fuelwood to straw, dung, and other biofuels, which were used sparingly. But about 85 percent of respondents were aware that the smoke emitted from fuelwood could cause respiratory problems, and some 50 percent agreed that it may cause other health problems (see Table 5.8).

Respondents' opinions differed on the use of kerosene and liquefied petroleum gas (LPG). Kerosene, although readily available, was viewed as a health hazard. Rural entrepreneurs perceived its price as relatively high, but were unclear why. More than 55 percent considered LPG a good source of cooking energy. About 38 percent considered LPG as very expensive, but few respondents were current users, reflecting the perception of high price versus actual cost. Many answers to LPG-related questions were indifferent, suggesting that most respondents were unaware of the fuel (see Table 5.9).

The picture that emerges from this survey is that most growth-center microenterprises in rural Bangladesh are not energy intensive. They consist mainly of small retail stores and shops, with some manufacturing. The main energy use is lighting, for which virtually all businesses use electricity. If a particular growth center does not yet have electricity, business owners organize their supplies, either by buying their own generator or purchasing small amounts from a local firm. Small agricultural industries and restaurants that require energy for heat rely mainly on biomass or kerosene.

Home and Village Enterprises

The survey showed that many rural microenterprises are located outside the growth centers. Out of 2,400 households, 137 had home-based enterprises; in

Table 5.9

Perceived Advantages and Disadvantages of Kerosene Use

Survey Statement	Response Choices (%)				
	Strongly Agree	Agree	Indifferent/Neutral	Strongly Disagree	Disagree
Cooking with kerosene is easy (*n* = 1,801)	17.2	24.5	4.1	30.6	23.6
Kerosene is not expensive for lighting (*n* = 1,801)	14.1	21.6	2.2	38.6	23.4
Kerosene is very expensive for cooking (*n* = 1,801)	59.6	30.5	3.8	3.4	2.6
Cooking with kerosene creates health hazards (*n* = 1,801)	46.8	35.7	11.2	3.1	3.2

Source: Data International Survey (2002).

Table 5.10

Microenterprise Distribution by Location and Length of Operation

Years in Operation	Home-based		Village-based		Total	
	No.	%	No.	%	No.	%
< 1	11	8.1	58	17.2	69	14.2
1–3	26	19.3	91	27.0	117	24.8
3–5	14	10.4	48	14.2	62	13.1
5–10	29	21.5	75	22.3	104	22.0
> 10	55	40.7	65	19.3	120	25.4
Total	135	100.0	337	100.0	472	100.0

Source: BIDS Survey (2004).

addition, 342 village-based enterprises were located outside rural households.

Types and Distribution

As already mentioned, most home-based businesses are women run and involve manufacturing (basket weaving and sewing), while village industries, run mainly by men, focus more on trading (selling of goods and services). The age of home and village microenterprises is spread over a number of years. More than 25 percent have been in operation for a decade or longer, although interesting differences are evident between categories. For example, about 40 percent of home-based enterprises are more than 10 years old, twice the proportion of village-based ones. Few home-based enterprises have been in operation for one year or less, while more than 17 percent of village enterprises have been recently established (see Table 5.10). Home-based manufacturing enterprises likely involve handicraft activities carried down by families over generations.

Some 50 percent of home- and village-based microenterprises are run by only one person, although

Table 5.11

Microenterprise Distribution by Number of Employees and Location

Workers in Peak Periods (no.)	Home		Village		All Firms	
	No.	%	No.	%	No.	%
1	40	30.7	182	58.3	222	50.2
2	41	31.5	93	29.6	134	30.3
3–5	43	33.0	34	10.9	77	17.4
> 5	6	4.0	3	0.9	9	2.0
Total	130	100	312	100	442	100

Source: BIDS Survey (2004).

differences between categories are apparent. During peak periods of operation, about 31 percent of home enterprises employ only one person, compared to some 58 percent of village enterprises. In fact, home enterprises are more evenly distributed in terms of size of operation (proxied by number of workers during peak periods). This finding reinforces the distinction between manufacturing centered mainly in home enterprises and trading in village-based ones (see Table 5.11).

Energy Use and Costs

The survey findings show that more than 70 percent of home enterprises and virtually all village enterprises—most of which operate during extended evening hours—use energy for lighting. Beyond lighting, however, these small handicraft and retail firms use little energy. About 67 percent of home enterprises and 64 percent of village ones use no energy for non-lighting purposes. Some report using no energy types for either lighting or non-lighting purposes, implying that their businesses involve manual labor and operate mainly during the daytime.

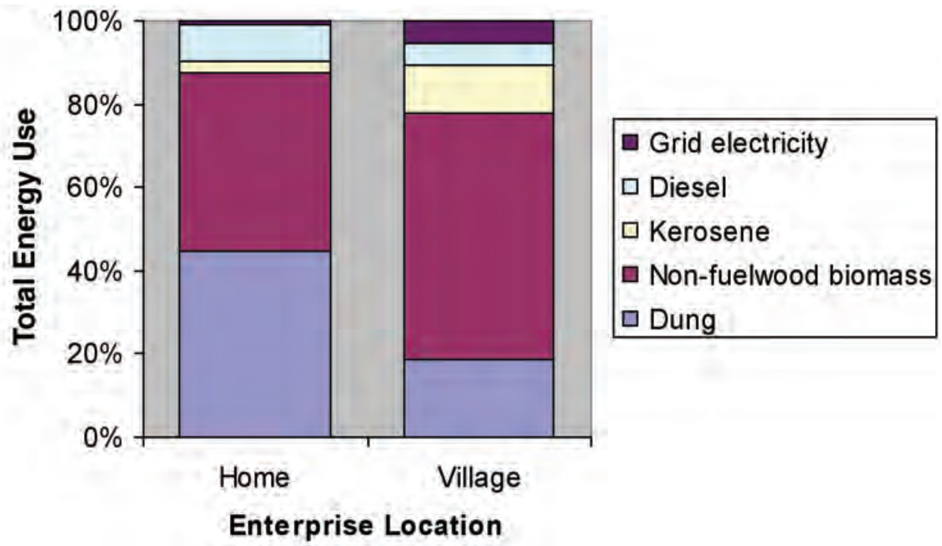
Compared to village enterprises, home-based businesses use significantly less energy; on average, home enterprises consume 332 kgoe per year, compared to 608 kgoe for village-based ones (including non-users). Predictably, home businesses depend more on biomass than do village enterprises. But surprisingly, within the biomass portion of the energy basket, home enterprises depend more on fuelwood, while village enterprises use non-fuelwood biomass; cow dung accounts for 8 percent of village enterprises' energy basket, compared to only 1 percent for home enterprises. Similarly, village enterprises derive 49 percent of their energy from crop residue, compared to only 26 percent for home enterprises (see Figure 5.1). A major reason is that manufacturing businesses, mostly home-based, require better heat control and are thus more likely to use superior forms of biomass. A portion of the needed resources may be collected from the owner's homestead, implying an easier supply for home-based, versus village, enterprises.

Findings also reveal differences in other portions of the energy basket. With regard to liquid fuels, home enterprises use more diesel than kerosene; conversely, village enterprises use more kerosene than diesel. Home enterprises, on average, consume only about 6 kgoe of kerosene, compared to nearly 68 kgoe for village enterprises. With regard to electricity, village enterprises use more than 30 kgoe, compared to only 3.9 kgoe for home enterprises (see Figure 5.1). Clearly, trade-oriented village enterprises require more lighting services than do home-based businesses.

Given that non-lighting energy use predominates in home and village-based enterprises—as evidenced by the critical role biomass plays in the energy balance of both—it is of interest to compare the output and costs of energy sources for non-lighting and lighting uses (see Table 5.12). On average, village enterprises consume more energy per enterprise for non-lighting

Figure 5.1

Comparison of Energy Use Structure by Enterprise Location



Source: BIDS Survey (2004).

Table 5.12

Comparison of Energy Output and Cost by Use and Location

	Home				Village			
	Lighting		Non-lighting		Lighting		Non-lighting	
Energy Source	Amount (klm-hr/ year)	Price (Tk/klm-hr)	Amount (kgoe/ year)	Price (Tk/kgoe)	Amount (klm-hr/ year)	Price (Tk/klm-hr)	Amount (kgoe/ year)	Price (Tk/kgoe)
Biomass	0.00	—	317.5	4.34	0	—	546.2	3.68
Candle	0.32	43.33	0	—	1.1	54.68	0	—
Kerosene or diesel	23.40	79.15	40.7	29.11	37.7	17.11	95.1	32.08
Grid electricity	461.50	0.77	14.2	185.62	2,877.0	0.27	16.0	55.52
All sources	474.20	17.92	372.4	27.21	2,915.8	10.50	657.2	29.20

Source: BIDS Survey (2004).

purposes than do home enterprises (657 versus 372 kgoe per year). Indeed, for each enterprise type, village enterprises consume higher levels of energy. Furthermore, the lighting services consumed by village enterprises are more than six times that of home-based enterprises, suggesting the importance of lighting for village businesses and the small size of home enterprises, some of which lack access to electricity.

The price of energy per kilograms of oil equivalent varies markedly by fuel source. For non-lighting uses, biomass is by far the least expensive source, which accounts for its dominance as a heating fuel. Because village enterprises are larger than home-based ones, they use significantly more biomass energy for non-lighting uses.

The price for lighting is similar to the results presented for rural households in Chapter 3. For home enterprises, the average price of electric lighting is Tk 0.27 per klm-hr and more than Tk 40 per klm-hr for candles and kerosene; findings show similar prices for village-based enterprises. Given the wide disparity in the price of lighting, it is not surprising that businesses use more electricity when they need lighting; electric lights are used primarily, with kerosene lamps and candles as backup sources.

The benefits of switching to a higher-tier source along the energy ladder extend beyond profitability, particularly for lighting services. The cost of one unit of lighting service from electricity is far cheaper than that from kerosene. For home and village-based enterprises, the respective costs of electric lighting are Tk 0.77 and 0.27 per klm-hr. The corresponding costs for kerosene lighting are Tk 30.40 and 17.11 (nearly 40 and 63 times greater). Clearly, a major reason for the higher profitability of electricity-based enterprises involves such cost differences for lighting.

Enterprise Energy Demand and Profitability: A Quantitative Analysis

Rural microenterprises, like rural households, are influenced by a range of enterprise- and community-level factors when selecting from among alternate energy sources. Their choices, in turn, eventually affect the enterprise outcome; that is, revenue and profit. Enterprise factors may include years that a business has been in operation, assets, and types of activities; community factors may include prices of alternate energy sources and infrastructure variables. Table 5.13 provides summary statistics of energy variables and selected influencing variables, while Table 5.14 presents regression results of energy demand.[28]

An enterprise's non-land assets have a significant positive effect on consumption of biomass (fuelwood), diesel fuel, and electricity. Although the price of fuelwood has no effect on any type of energy source, the prices of diesel and electricity significantly affect energy demand. The price of diesel positively affects electricity consumption, thereby showing that diesel and electricity are substitutes in enterprise consumption. If this statement is true, however, a higher electricity price should lead to greater diesel consumption. But results show a negative effect, which is possible if the negative income effect caused by the

Table 5.13

Summary Statistics of Outcomes and Explanatory Variables of Enterprise Energy Demand Regressions

Variable	Mean
Enterprise energy demand	
Fuelwood (kg/month)	73.25
Kerosene (liter/month)	164.72
Diesel (liter/month)	60.39
Electricity (kWh/month)	218.58
Explanatory	
Enterprise assets	
Land (acres)	26.34
Non-land (Tk 10,000)	1.25
Village/growth center price	
Fuelwood (Tk/kg)	1.36
Kerosene (Tk/liter)	19.71
Diesel (Tk/liter)	21.39
Electricity (Tk/kWh)	4.50
If the village/growth center has electricity	0.89

Sources: Data International Survey (2002) and BIDS Survey (2004).

higher price of electricity outweighs the positive relative price effect of electricity on demand for diesel. Thus, diesel and electricity remain substitutes in energy use by rural enterprises. The demand for kerosene, which appears unaffected by these factors, is included here for completeness (see Table 5.14).

Given the demand for alternate types of energy in non-farm production, one can estimate the effects of energy use on enterprise revenue and profit. Energy use is expressed in taka value adjusted by village and growth-center price indices. Table 5.15 provides summary statistics and Table 5.16 regression results.[29] As Table 5.16 shows, energy consumption positively affects enterprise profit. One taka worth of energy consumption increases enterprise profit by more than half a taka. When the effect is differentiated by energy source, one discovers that kerosene/diesel consumption has no effect on either profit or

[28] Table A2.4 (see Annex 2) presents the complete regression for energy demand.
[29] Tables A2.5 and A2.6 (see Annex 2) provide complete regressions.

Table 5.14

Estimates of Enterprise Energy Demand (*N* = 2,290)

	Energy Demand (monthly)			
Explanatory Variable	**Fuelwood**	**Kerosene**	**Diesel**	**Electricity**
Enterprise assets				
Land (acres)	−0.15**	0.04	−0.04*	0.11
Non-land (Tk 10,000)	3.99**	1.14	6.12**	25.51**
Village/growth center price				
Fuelwood (Tk/kg)	5.25	1.17	0.93	−10.46
Kerosene (Tk/liter)	11.43*	−1.03	−3.76	−14.56
Diesel (Tk/liter)	−4.79	−11.17	3.29	23.38*
Electricity (Tk/kWh)	−6.07	−15.87	−13.26*	25.68
If village/growth center has electricity	10.47	−26.91	−18.19**	418.72**

Source: Data International Survey (2002) and BIDS Survey (2004).

Note: * = significance level of 10 percent; ** = significance level of 5 percent or stronger.
Figures represent changes in energy demand caused by unit changes in explanatory variables.

Table 5.15

Summary Statistics of Outcomes and Energy Use Variables of Enterprise Profitability Regressions (*N* = 2,290)

Variable (Tk/year)	**Mean**
Outcome	
Revenue	555,817.6
Profit	72,590.8
Energy	
Total use*	6,674.82
Biomass	1,129.62
Kerosene	2,701.26
Electricity	2,622.92

Source: Data International Survey (2002).

* Includes the cost of miscellaneous sources, in addition to the three major ones.

Table 5.16

Effects of 1 Tk Increased Energy Use on Enterprise Outcome (annual Tk per enterprise) (*N* = 2,290)

Energy Source (Tk/yr)[a]	**Revenue**	**Profit**
Model 1		
Total energy use	0.86	0.55**
Model 2		
Energy use		
Biomass	5.72*	1.22**
Kerosene	−3.82	−0.27
Electricity	4.11	1.35**

Source: Data International Survey (2002).

Note: * = significance level of 10 percent; ** = significance level of 5 percent or stronger. Figures represent changes in outcome (consumption and income) caused by unit changes in explanatory variables.

[a] Total energy cost used in Model 1 is slightly higher than the sum of individual energy costs used in Model 2 because it includes other miscellaneous sources.

revenue, but biomass and electricity have a significant positive effect, especially on profit. One taka spent on biomass consumption increases profit by Tk 1.22; a similar amount spent on electricity increases it by Tk 1.35. Thus, the effect is slightly higher for electricity than for biomass as an energy source in enterprise income generation; that is, enterprises would gain by switching from biomass and diesel to electricity as an energy source in production.

The conclusion is that use of either high-quality biomass or purchased electricity dramatically affects the profitability of rural Bangladeshi enterprises. To reiterate, biomass is usually the least expensive fuel and is used primarily for heating, while electricity is used for lighting and other purposes. Thus, energy source matters in the profitability of rural businesses.

Energy for Farming

Farming is a critical energy use for rural households. The country's potential for increased irrigation, though not as developed as that of other South Asian countries, is significant. The most obvious energy inputs are diesel engines and electric motors for pumping irrigation water. In addition, a variety of small machines, including power tillers, are used increasingly in land preparation, alleviating much of the drudgery associated with such work.

Farming Stages and Energy Inputs

As discussed in Chapter 4, Bangladesh is characterized by three rice-cropping seasons: (1) *aus* (rainfed summer rice planted in March–April), (2) *aman* (rice planted in July–September and harvested in November–December), and (3) *boro* (irrigated winter rice planted in December–February and harvested in April–June).[30] Aus requires little energy for tillage (except bullock power) and irrigation; boro necessitates energy for both tillage and irrigation, and aman falls in between.

The major rice-farming stages involve land preparation, irrigation, harvesting, and transport to market.[31] During land preparation, bullock-driven ploughs or power tillers/tractors are used. While bullock power may be quantified, Bangladesh has little relevant data available. Power tillers/tractors require petroleum fuel (mainly diesel).

Irrigation, the next major stage, overlaps with land preparation; that is, when rice is transplanted, the land must be thoroughly flooded and puddled. Irrigation is also required at later stages of rice-growing. The capacity to irrigate land is limited to manual implements (e.g., swing baskets and hand tube wells). Mechanized methods that depend on modern energy use far costlier, but more efficient, equipment for large tracts. The three basic equipment pieces are low-lift pumps for surface water irrigation, surface tube wells (including deep-set shallow tube wells), and deep tube wells. These may be run with either a diesel- or electricity-operated motor. Low-lift pumps are owned either privately or collectively. Surface tube wells are privately owned; while deep tube wells are usually owned collectively (for reasons of higher cost, as well as custom).

After irrigation are harvesting and transport. Most harvesting is done manually. Threshing, traditionally done manually, depends more on diesel- or electricity-powered machines. Husking increasingly uses machines that run on diesel and occasionally kerosene. Crops may be transported to market by bullock or by using mechanized methods that depend on petroleum fuels.

Land Tillage Methods

Over the past decade, acreage under mechanized tillage has risen significantly. In 1996, 4.2 million acres—20 to 25 percent of the country's cultivated land—was tilled using diesel- or petroleum-powered tillers or tractors. When the 2004 household survey was conducted, that proportion had risen to more than 66 percent, although regional variations were substantial (see Table 5.17).[32]

Although use of power tillers and tractors is common, ownership is not. In the study sample, only 35 farmers owned mechanized tillage equipment, while 1,068 rented it; another 186 households rented draft bullocks, while the remainder used their own bullocks.

Irrigation Methods

Mechanized irrigation using modern energy is of growing importance in rural Bangladesh. In 2002–2003, 73 percent of the 11.68 million acres irrigated used mechanized tube wells; another 17 percent used

[30] Details are available from the International Rice Research Institute (www.irri.org/irrc/weeds/closing.asp).
[31] To simplify data collection and analysis, this study emphasized farmers who directly manage their own land. Thus, analysis and discussion on energy use and its characteristics are tentative, as key data may be lacking. More definitive answers call for more in-depth studies.
[32] In 2005, a large-scale survey found that, since 1996, the number of power tillers and tractors had risen from slightly more than 150,000 to 711,000 (BBS 2005).

Table 5.17

Comparison of Tillage Methods by Division

	Division (%)				
Tillage Method	Chittagong	Dhaka	Khulna	Rajshahi	Total
Power tiller/tractor	45.9	75.3	61.5	86.6	66.1
Draft bullock	54.1	24.7	38.5	13.4	33.9

Source: Village censuses (2004).

Table 5.18

Irrigation Method and Energy Type by Division

	Division (%)				
Method or Type	Chittagong	Dhaka	Khulna	Rajshahi	All Divisions
Irrigation					
Mechanized	52.0	78.5	53.4	91.5	68.1
Hand tube well	1.1	1.2	0.9	0.8	1.0
Indigenous method	10.1	15.0	19.8	1.1	11.2
None	36.8	5.3	25.9	6.6	19.7
Energy					
Diesel	50.0	93.3	66.7	76.7	70.4
Electricity	19.2	6.7	—	20.0	10.4
Diesel and electricity	2.6	—	7.4	3.3	3.2
Not applicable	34.2	—	25.9	—	16.0

Source: BIDS Survey (2004).

power pumps, while 3 percent used canals (or in combination with power pumps) and the remainder traditional methods (BBS 2005).

Although most mechanized irrigation equipment is diesel-driven, the percentage division between diesel and electricity is unclear. In 2005, the country had 7.54 million mechanized irrigation sets (including low-lift pumps, shallow tube wells, deep-set shallow tube wells, and deep tube wells) (BBS 2005). According to the Rural Electrification Board, in February 2006, irrigation connections totaled slightly more than 195,000.[33] Even assuming that one connection could serve more than one set (which is seldom the case), electrically driven irrigation sets are uncommon.

The village survey found that 68 percent of villages used mechanized irrigation methods. Of these, 70 percent used diesel power, 10 percent used electricity, and 3 percent used both (see Table 5.18).

Of the 1,459 farm households surveyed, only 62 percent irrigated their land (see Table 5.19). Of these, 97 percent used mechanized means. Only 130, or 9 percent of all respondents, owned mechanized irrigation sets.[34] Ownership of mechanized pumps was concentrated in Rajshahi—77 out of 130 farming households—where 18 percent of such households owned modern irrigation equipment. But in Dhaka, half of non-farmers owned irrigation sets.

[33] Details are available at www.reb.gov.bd.
[34] Several households owned more than one piece of equipment.

Table 5.19

Farmer Irrigation Method by Division

	Division									
	Chittagong		Dhaka		Khulna		Rajshahi		Total	
Method	No.	%	No.	%	No.	%	No.	%	No.	%
Manual	1	0.3	12	3.7	9	2.8	1	0.2	23	1.6
Mechanized	159	40.3	203	63.2	158	48.5	356	85.4	876	60.0
All	160	40.5	215	67.0	167	51.2	357	85.6	899	61.6

Source: BIDS Survey (2004).

Table 5.20

Energy Consumption in Farming (average owner-user households per year)

	Electricity				Diesel			
	Consumption		Cost (Tk)		Consumption		Cost (Tk)	
Equipment Type	Yearly kWh	Households	Yearly	Per kWh	Yearly liters	Households	Yearly	Per liter
Irrigation pump	3,643.47	9	9,762	2.8	347.95	103	7,056	20.5
Power tiller/tractor	—	—	—	—	238.24	35	4,799	20.2
Thresher	—	—	—	—	78.13	17	1,698	20.8

Source: BIDS Survey (2004).

Fuel Choice for Irrigation

As noted previously, mechanized irrigation equipment may be powered by electricity or diesel. According to available information, only 112 of current farm households use their machines for land under their control (i.e., self-cultivated owned land and other land under lease agreement or other form of user rights). Of these, 103 are operated by diesel and 9 by electricity (8 of which are in Rajshahi). It is also noteworthy that about 70 percent of diesel-pump users are in villages without electricity. Average electricity consumption per farm and the costs borne by farmers indicate an expense of nearly Tk 2.8 per kWh, far lower than for domestic purposes (Tk 7.7 per kWh in Rajshahi and Tk 5.5 for all divisions). Average diesel consumption per farm and farmer costs are slightly more than Tk 20 per liter. The cost per liter is similar across types of use, but varies slightly by division (see Table 5.20).

The study found that many farmers used water from mechanized irrigation equipment, whether owned or leased. The percentages were higher for farmers owning pumps, reflecting the active market for purchased irrigation water in rural areas. As expected, Rajshahi had the highest proportion of farmer ownership of irrigation equipment. On average, a farm household required about 348 liters of diesel per year for irrigation, reflecting an annual expense of nearly Tk 7,056. Thus, irrigation is extremely important for farm productivity, as well as profitability from the sale of irrigation water to neighbors.

Clearly, farm households that could benefit from electricity-powered irrigation have not used electricity as extensively as they might, perhaps, in part, because of their remote location. Further research is needed to identify the factors that have prevented farmers from adopting electricity-driven pumps, particularly given the difficulty of moving large diesel pumps between fields and deciding whether government-subsidized electricity for irrigation is a sound policy.

Summing Up

In rural Bangladesh, microenterprise entrepreneurs own and operate a range of businesses, from trade and commercial services to small-scale manufacturing. Although small, these enterprises represent a substantial increase in rural people's incomes. The three types of microenterprises examined in this chapter—growth-center, village, and home-based—use a wide array of energy sources. All rural businesses in the growth centers use electricity, either from the grid or local generators; and most have electric lighting. By contrast, not all free-standing village and home-based enterprises have access to electricity; those that do may choose not to use electricity, even for lighting. Such enterprises depend heavily on biomass energy, mainly for heating and manufacturing needs. Though inconvenient, biomass is the least expensive heating fuel, a major factor in explaining rural businesses' continued reliance on it. Another factor is that most rural areas have little or no access to LPG.[35]

Bangladeshi entrepreneurs perceive that biomass is inexpensive compared to other fuels and that it can be collected from the environment. At the same time, they are aware of the health problems associated with traditional fuelwood use. They also agree that local biomass collection is becoming more difficult. Increasingly, they view traditional lighting sources as inefficient and of poor quality. The lighting analysis confirms that candles and kerosene lamps are many times more expensive than electric lighting.

Microenterprises with electricity enjoy benefits and cost advantages related to lighting and profitability. Indeed, the average cost of electric lighting can be 60 times less expensive than kerosene, the next cheapest source. Unreliability of electricity supply, however, forces businesses to depend on kerosene and diesel as backup lighting sources.

The survey findings indicate scope for improvement in the energy-use patterns of rural Bangladeshi microenterprises.[36] Analysis of the relationship between modern energy sources, as defined by the energy ladder concept, indicates that rural businesses that use modern energy generally have more revenue and are more profitable than those that rely on traditional energy sources. Thus, a viable rural energy strategy for Bangladesh must consider the best ways to promote modern energy, as well as the modern use of biomass. To this end, it is critical to examine the institutional underpinnings of energy distribution, which are the subject of the next chapter.

[35] Generally unavailable in rural areas, LPG uses 60 percent of cooking energy, compared to only 15 percent for traditional biomass stoves.

[36] Although energy for non-lighting use is limited, improvements are possible through the use of charcoal and more efficient kerosene stoves.

6 Institutional Framework for Rural Energy Supply

Promoting better rural energy policies in Bangladesh is inextricably linked to national poverty reduction and rural development. Extending both grid and off-grid electricity systems improves rural livelihoods and enables delivery of critical human services, from clean water and sanitation to health and education. The results of this study demonstrate that access to improved biomass stoves, electric lighting, and mechanized tillage and irrigation creates the enabling conditions for informal and small-enterprise sectors to grow, thereby empowering the poor. [37]

Rural energy must be viewed as a basic input to the rural economy, in line with its role in rural productivity and income generation. Achieving a supply-and-demand balance is critical at all levels.[38] Given rural residents' heavy reliance on traditional biomass energy, an urgent priority must be to increase biomass supply. To achieve a sustainable supply, biomass must be used in more efficient ways that mitigate damage to human and global environmental health. Complementing these efforts, more diversified modern energy sources must be made available to fulfill unmet rural household and business demand. To this end, appropriate pricing policies are vital: They must be market based to ensure that suppliers can sustain the higher cost of rural operations,[39] yet remain affordable to the poor.[40]

Institutional Challenges and Potential

To advance the development goals of poverty reduction and human development, the institutions responsible for delivery of modern energy services must be responsive to the unique needs of rural populations. The inefficiencies associated with Bangladesh's current energy-sector providers, which have shifted financial burden to the government and rural consumers, call for more effective institutional arrangements and coordination. This chapter reviews the current structure of Bangladesh's energy sectors, highlighting past institutional and policy deficiencies and opportunities for building a more integrated approach to meeting current and future rural energy demand.

Biomass Sector

This study suggests that Bangladesh's heavy reliance on the unsustainable use of traditional biomass, especially fuelwood, represents a significant opportunity cost and serious health risk for millions of the rural poor. Compounding their diminished quality of life is the accelerated commercialization of all forms of biomass—including low-quality tree leaves and grass.[41] This section highlights lessons from past and ongoing efforts to improve biomass

Note: In addition to the main authors, M. Iqbal, M. Khaliquzzaman and Grayson Heffner were contributing coauthors of this chapter.

[37] In 2005, Bangladesh's National Strategy for Accelerated Poverty Alleviation set forth eight strategic priorities, most of which imply a role for promoting better energy policies to improve rural access.

[38] At the local level, for example, transportation costs and seasonal irrigation requirements call for a degree of local supply–demand balance or self-reliance.

[39] The government's current pricing of electricity, oil, and gas is far below the cost of supply.

[40] In deciding whether subsidies are required for particular types of energy or end users, policy makers must consider both the social and economic costs and periodically revisit the results as these factors change.

[41] Paradoxically, the rural buying and selling of biomass also creates jobs. Indeed, employment from trading biomass exceeds that from trading substitute fuel products (e.g., kerosene, LPG, and electricity). Thus, in the push to promote modern energy, one must also consider the potential loss to rural employment, which could lead to even greater poverty.

energy efficiency to increase rural productivity and quality of life.

Improved Biomass Stoves

From the late 1980s to 2001, the Institute of Fuel Research and Development promoted improved cookstoves through several donor-supported projects. Although an estimated 400,000 improved stoves were distributed, commercialization failed, in large part, because projects focused on targets and subsidies rather than monitoring. Today the potential market for improved stoves is enormous. Better-designed stoves could save millions of days in lost productivity, decrease early mortality, and save energy. But to succeed, programs must promote stoves that people want. Thus, future institutional support should focus on stove design, manufacture, and testing, as well as training and quality monitoring.

Biogas Production

Basic biogas technology holds special promise for rural Bangladesh. Biogas can be harnessed for cooking, lighting, and mechanized irrigation through village-based production and distribution networks. Such arrangements can enhance rural residents' self-sufficiency during periods of load shedding and diesel shortages. Currently, tens of thousands of household- and village-level biogas plants are in place throughout the country.

Over the past 30 years, an array of government agencies, university research institutions, and non-governmental organizations (NGOs) have participated in the development, piloting, and implementation of household- and enterprise-scale biogas programs. Key entities are:

- Rural Electrification Board
- Local Government Engineering Department
- Bangladesh Council for Scientific and Industrial Research and Institute of Fuel Research and Development (a Council agency)
- Renewable Energy Research Centre (Dhaka University)
- Bangladesh University of Engineering and Technology
- Grameen Shakti
- Bangladesh Rural Development Board
- Bangladesh Rural Advancement Committee
- Proshika

Although large-scale plant production appears economically and financially feasible, several key issues must be addressed. First, it is unclear whether the subsidy culture that characterized past programs will create future difficulties. Second, it is likely that biogas plants will benefit better-off households more than the poor (Ghimire 2005). Third, the number of potential plants is unknown.[42]

Power Sector

Bangladesh's power sector has lagged overall economic growth, resulting in chronic unmet energy demand. Only 40 percent of the total population and less than 30 percent of rural residents have access to electricity. Low connection rates and unreliable power supply result in fewer opportunities for economic development or improved rural livelihoods. Though rural households grasp the benefits of electricity, they perceive it as expensive, in part, because of frequent power outages.

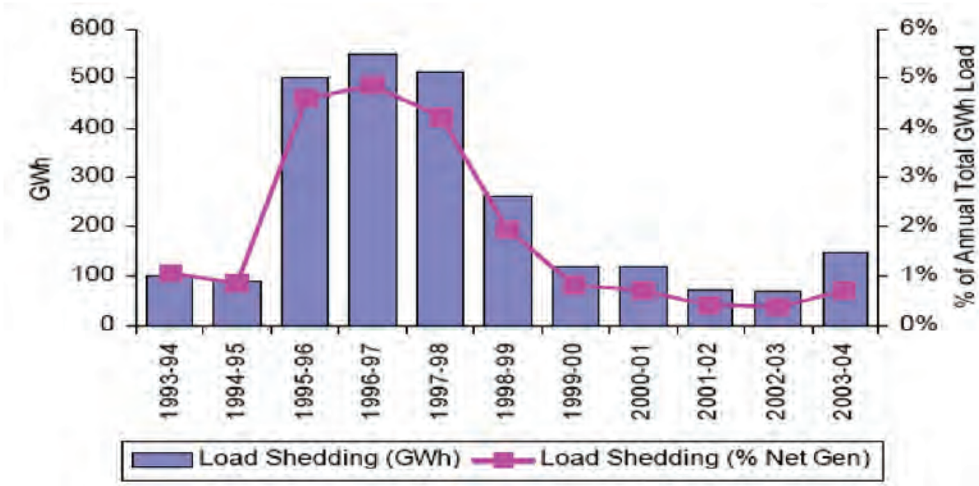
As Figure 6.1 illustrates, total effective power-generation capacity has fallen below electricity demand, resulting in extensive daily load shedding. In turn, load shedding has obscured the reality of unmet demand. Over the next nine years, electricity demand is expected to double (at 8 percent annual growth). The investment required to generate sufficient capacity to accommodate future demand growth is immense.

In response to this challenge, the state-owned Bangladesh Power Development Board has put forward an ambitious expansion plan calling for installation of an additional 4,210 MW of generation capacity by 2010. The plan, which relies on natural gas, consists of combined-cycle, gas-turbine baseload units and simple-cycle, gas-turbine peaking units (Nexant 2006).

[42] Although the daily cow-dung input for cooking three meals a day is known, reports conflict regarding the number of cattle owned by rural households (BBS 2005). Anecdotal evidence suggests seasonal, rather than year-round, ownership. In addition, use of power tillers and tractors is widespread.

Figure 6.1

Annual Load Shedding, 1993–2004



Source: Nexant (2006).

Power-sector reform, initiated in 1994, envisions the separation of sector regulation from ownership and operation and independent, commercially oriented sector entities. It calls for the unbundling of generation, transmission, and distribution functions and increased private-sector participation in generation and distribution. Formerly a monopoly operator, the Bangladesh Power Development Board is being converted into a holding company. The Energy Regulatory Commission, established in 2004, is to play a vital role in a range of sector operations, as noted in the following sections, but has been hampered by slow organizational approval processes and lack of funding.

Key power-sector entities and their functions are as follows:

- *MPEMR*. The Ministry of Power, Energy, and Mineral Resources oversees sector management.
- *ERC*. The Energy Regulatory Commission has authority over consumer protection, approval of tariffs and pricing, issuance of generation and distribution licenses, and promotion of competition.
- *Power Cell*. Within the MPEMR power division, the Power Cell oversees power-sector reform.
- *BPDB*. The Bangladesh Power Development Board operates most publicly owned generators and some urban distributors; it acts as a single buyer, purchasing from public and private generators and selling to distributors.
- *PGCB*. The Power Grid Company of Bangladesh, a wholly owned subsidiary of the BPDB, operates the national transmission grid, schedules grid operations, and wheels energy to distributors.
- *DESA*. The Dhaka Electricity Supply Authority (not yet functional) distributes energy and conducts commercial operations in Dhaka and adjoining areas, except for Mirpur and Gulshan.
- *DESCO*. The Dhaka Electric Supply Company distributes energy and conducts commercial operations in the Mirpur and Gulshan jurisdictions of the Dhaka metropolitan area.
- *REB*. The Rural Electrification Board oversees operations of consumer-owned rural electric cooperatives (PBSs). It performs supervisory and regulatory duties to ensure that technical standards are met and performance is monitored.
- *WZPDC*. The West Zone Power Distribution Company is responsible for regional distribution in Khulna.
- *IPP*. There are some independent power suppliers (IPP) in Bangladesh that sell electricity to the transmission company.
- *EA*. Electrical Advisor.
- *CEI*. Chief Electric Inspector.

Over the next several years, the newly constituted Rural Power Company, which runs a 140-MW generator and sells power to the Rural Electrification Board, plans to own and operate a substantial portion of the power sector's generation assets. As part of the unbundling process, regional distribution companies are being established in Khulna (West Zone Power Distribution Company), Rajshahi (Northwest Distribution Company), Chittagong and Comilla (South Zone Distribution Company), and Mymensingh and Sylhet (Central Distribution Company).

Toward a Pro-Poor Approach

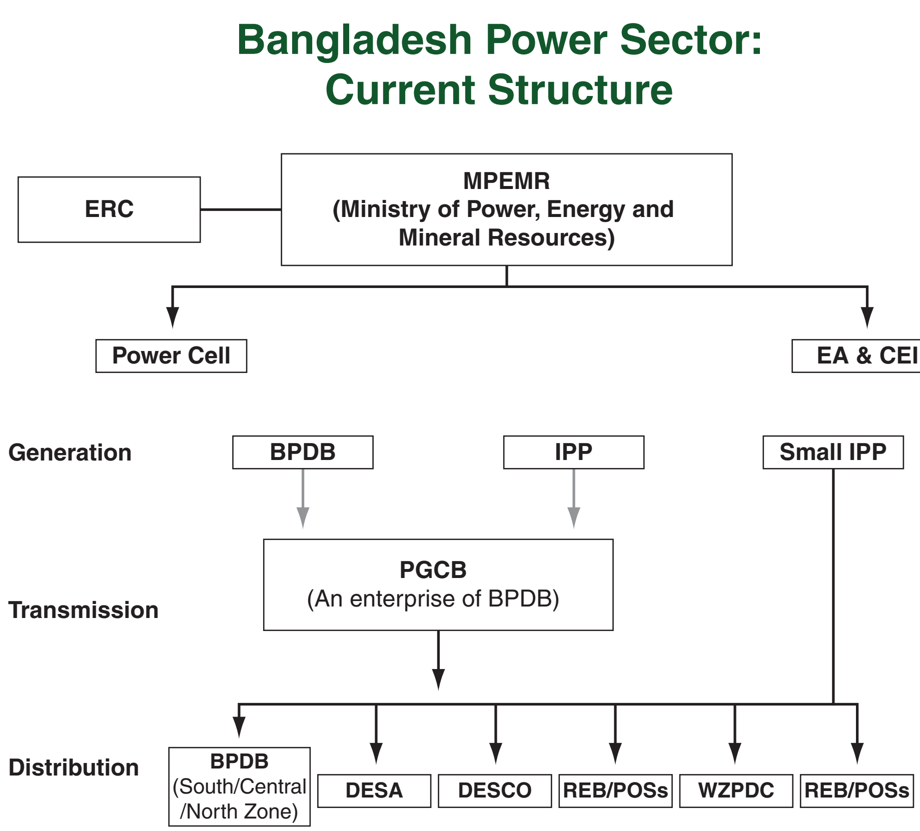
The Rural Electrification Board (REB), a semiautonomous government agency, is responsible for electrifying rural Bangladesh. Established in 1977, REB operations are based on the U.S. model of consumer-owned rural electric cooperatives. Today, rural Bangladesh is divided into 70 cooperatives or PBSs (*Palli Bidyut Samities*), which benefit an estimated 6.78 million households—a remarkable achievement in a country of 140.5 million people. Yet most of the PBSs are not financially viable. Massive operating and capital subsidies are required to keep the program functioning and expanding. Although the PBSs are allowed to set their own tariffs, reflecting local costs, most agricultural and household consumption is highly subsidized.

Another key issue is that the rural power sector relies heavily on the Bangladesh Power Development Board for its power supply and the Power Grid Company of Bangladesh for load scheduling. As a result, rural load shedding exceeds urban load shedding, even though the REB network accounts for only 40 percent of national electricity consumption.

As this survey's results highlight, providing village access to electricity does not guarantee access

Figure 6.2

Bangladesh Power Sector Organization



Source: Nexant (2006).

at the household level. The government's Poverty Reduction Strategy Plan has identified various measures to improve the pro-poor orientation of rural electrification. These include: (1) setting up a microcredit mechanism to help poor households surmount the hurdle of first connection, (2) breaking up the REB into regional boards to create a more locally driven approach to the economic development aspects of rural electrification, and (3) increasing PBS financial viability by their taking over peri-urban enclaves still served by the Bangladesh Power Development Board.

Oil and Gas Sector

Natural gas is by far the most important commercial fuel in Bangladesh, accounting for more than 70 percent of primary commercial energy production. Most oil is imported in the form of refined products. Since 1998, urban marketing and use of bottled gas has grown rapidly. In and around the capital city of Dhaka, bottled compressed natural gas (CNG) is now a cheap substitute for gasoline in the transport sector. Total in-country production of liquefied petroleum gas (LPG) is 23,000 tons per year, with another 35,000 to 45,000 tons imported and locally bottled. Yet only 10 to 15 percent makes its way beyond the peri-urban centers to more remote rural areas.

Promoting rural access to natural gas could result in significant welfare gains for many rural households. For example, by switching from biomass to LPG to meet a portion of their cooking needs, rural family members, especially women, could realize large time savings (through fewer hours spent collecting biofuels) and better health (through reduced exposure to indoor pollution).

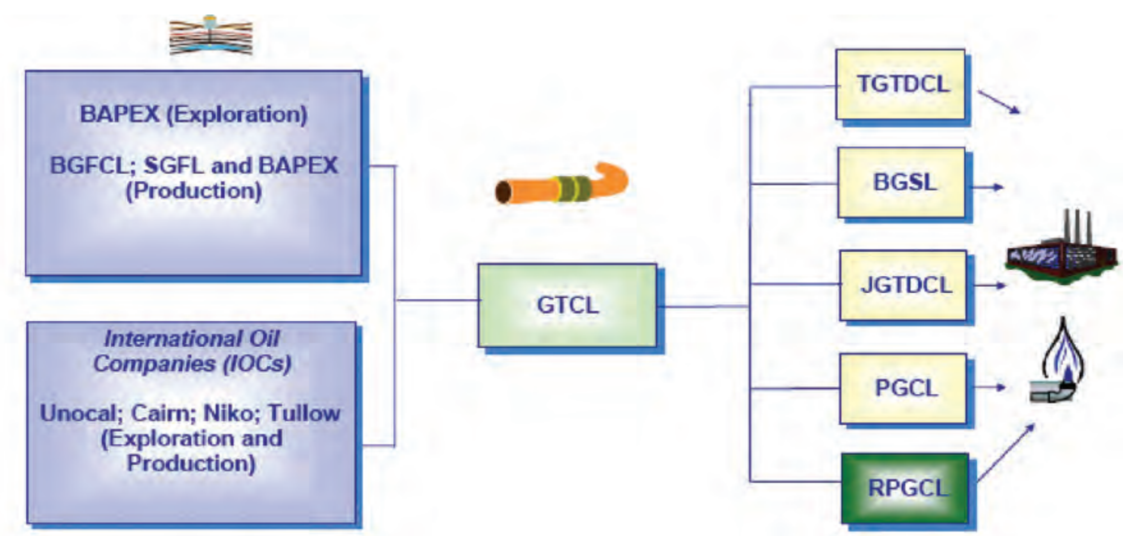
Rural populations' access to pipeline gas is also inadequate. Indeed, rural residents represent only 6 percent of national coverage. By contrast, in major urban areas served by regional distribution companies, non-bulk sale to commercial and residential customers is extensive. One exception to the poor rural distribution network is a US$300 million project financed by the Asian Development Bank that plans to expand transmission infrastructure into the western region surrounding Rajshahi by 2010.

Sector Organization

The oil and gas sector is organized into four segments: exploration, production, transmission, and distribution (including marketing) (see Figure 6.3).

Figure 6.3

Oil and Gas Sector Organization



Source: McKenzie (2006).

Key sector institutions and their functions are as follows:

- *Petrobangla*. Successor to the Bangladesh Mineral Oil and Gas Corporation, Petrobangla is a public-sector holding corporation responsible for oversight and coordination of 11 subsidiary gas companies.
- *BAPEX*. The Bangladesh Petroleum Exploration Company is a state-owned entity that manages exploration and production.
- *BGFCL*. The Bangladesh Gas Fields Company Limited is a state-owned entity that manages production.
- *SGFL*. The Sylhet Gas Fields Limited is a state-owned entity that manages production.
- *IOCs*. The International Oil and Gas Companies are private-sector exploration and production entities; they include Unocal Corporation, Cairn Energy, Niko Resources, and Tullow Oil.
- *GTCL*. The Gas Transmission Company Limited manages midstream.
- *TGTDCL*. The Titas Gas Transmission and Distribution Company Limited is a state-owned, regional distribution entity.
- *BGSL*. The Bakhrabad Gas Systems Limited is a state-owned, regional distribution entity.
- *JGTDCL*. The Jalalabad Gas Transmission and Distribution Company Limited is a state-owned, regional distribution entity.
- *PGCL*. The Pashchimanchal Gas Company Limited is a state-owned, regional distribution entity.
- *RPGCL*. The Rupantarita Prakritik Gas Company Limited is a CNG marketing entity.

Downstream Deficiencies and Reform

The downstream gas sector includes pipeline gas, bottled LPG, and CNG. Downstream sector performance is hampered by network losses of about 20 percent, as well as pricing and commercial performance deficiencies. Fiscal drain due to inadequate pricing prevents operating companies from reinvesting in required exploration and production facilities and network expansion.[43] Although LPG is widely available in most peri-urban areas, it is estimated that only 10 to 15 percent finds its way to rural areas for consumption. In more remote rural areas, where LPG prices are fixed, it is not unusual for local dealers to charge significantly higher prices.

The government has agreed to a roadmap for sector reform, which emphasizes clear separation of policy making, regulatory, and service provisions through the creation of well-structured, adequately funded entities. Key decisions include transferring Petrobangla's quasi-regulatory functions to the newly formed Energy Regulatory Commission and resolving retail-market arrears to alleviate fiscal drain on Petrobangla.

Renewable Energy Sector

Non-biomass renewable-energy systems also hold promise for rural Bangladesh. Solar photovoltaics (PV) are used widely throughout the country, with more than 80,000 reported household- and enterprise-level installations (3.5 MW total capacity). Solar PV could be used within a broader rural electrification program if affordable products that meet consumer needs were supplied and supported.

Other potential renewable-energy sources include wind, hydropower, geothermal, tidal, and wave. Although wind energy has made some inroads, its potential is likely limited to coastal areas and islands with strong wind regimes; currently, the country has 2 MW of installed wind turbines in operation. The potential for micro- and mini-hydropower is also limited (with the exception of Chittagong and the Chittagong Hill tract); the country has one large facility at Kaptai, installed some 40 years ago, which produces 1,000 GWh per year.

Until recently, renewable energy was developed on an ad-hoc basis. Over the past 20 years, various government agencies, research institutes, NGOs, and private-sector companies have participated in development, demonstration, and implementation. Current institutional arrangements reflect the sector's nascent state.

[43] Petrobangla buys IOC gas at US$2.6–2.9 per MCF but charges domestic customers only US$1.40 per MCF.

Key sector institutions and their focal areas are as follows:

- *Grameen Shakti*. A subsidiary of the Grameen Bank, Grameen Shakti focuses on solar home systems (SHS), having installed 5,000 systems over the past two years; household biogas systems; and improved stoves.
- *REB*. The Rural Electrification Board centers on household- and village-scale, off-grid PV systems; it installed nearly 2,000 SHS through the PBSs.
- *IDCOL*. The Infrastructure Development Company Limited focuses on household- and village-scale, off-grid PV systems.
- *IFRD*. The Institute of Fuel Research and Development, within the Bangladesh Council for Scientific and Industrial Research, centers on small- and medium-sized biogas digesters.
- *Local Government Engineering Department*. The Department handles small- and medium-sized biogas digesters.
- *BRAC*. The Bangladesh Rural Advancement Committee, the largest national NGO, centers on SHS, having supplied nearly 1,200 systems, and biogas installations.
- *Proshika*. A leading NGO, Proshika focuses on biogas installations.

To date, Grameen Shakti and private-sector companies have led much of the work in renewable energy. In addition, the World Bank has supported the scaling up of solar PV systems. Other donors have included the United Nations Development Program and the U.S. Agency for International Development.

Building an Integrated Approach

The 1996 National Energy Policy, developed by the Ministry of Power, Energy, and Mineral Resources as part of power-sector reform, represented a policy milestone in visualizing the country's future energy needs. But it failed to comprehensively address rural energy as a unique and important energy-sector issue. Although the policy covered such critical areas as rural electrification, rural penetration of commercial fuels, and reforestation, it overlooked improved use of biomass, biogas production, and other programs equally vital to energizing rural Bangladesh.

The 2006 policy revision takes a more comprehensive approach, focusing on integration across subsectors, demand-side issues, more effective institutional arrangements, and policy monitoring. Among the critical rural energy issues identified are the financial viability of loss-making PBSs, indoor air pollution, and the effects of commercialized biomass supplies on the poor.

Tackling rural energy issues in a more integrated way calls for establishing a Rural Energy Steering Committee within the Ministry to improve linkages between energy and rural development institutions. The Sustainable Energy Development Authority (SEDA), the proposed secretariat for the Committee, would coordinate with ministries and government agencies to develop and oversee policy and program implementation. It is envisioned that the new Committee and SEDA would work together to recommend ways in which to improve coordination between all levels (national, district, subdistrict, and local) and form local organizations that could plan and implement sustainable energy projects.

Summing up, the many diverse institutions currently addressing rural energy issues in Bangladesh are committed to providing rural residents better energy services. But the multitude of institutional players creates a significant role for improving inter-institutional coordination. That this role has often gone unfulfilled may explain why rural energy remains invisible to many policy makers. Suggested steps toward filling this institutional gap are the focus of the final chapter.

7 Policy Recommendations

This study—the first in 30 years to examine energy access in rural Bangladesh—reveals several stark realities. Rural residents continue to rely heavily on traditional biomass to supply most of their energy. But biomass used in traditional ways has energy efficiencies of only 15 to 25 percent; thus, extensive time is required for fuel collection and meal preparation. Furthermore, biomass cooking fuels result in indoor air pollution (IAP), which is linked to respiratory disease and related health risks. Rural residents face an increasing fuelwood shortage, meaning that many are relying on residues, including dung, leaves, and grass, to meet their basic cooking needs. Rural businesses also depend on biomass as one of their main energy sources. Thus, the problems associated with biomass energy are widespread.

Significant bottlenecks prevent most forms of modern energy—a main alternative to biomass fuels—from reaching many rural people. Although well managed, rural electrification has reached less than one-third of the population. Households and businesses fortunate enough to have electricity must contend with frequent power outages, which imply added expenditure on backup diesel or kerosene fuel and hindrances to rural productivity and quality of life. That liquefied petroleum gas (LPG) is used little for cooking reflects its high cost and lack of availability.

But the rural energy picture is not all bleak. As this study reveals, significant benefits, including more lucrative rural businesses and better educated rural households, can result from promoting access to modern and sustainable energy. Thus, the development of energy infrastructure is sound development policy that policy makers should actively promote.

With the exception of rural electrification, Bangladesh's energy policies and institutions have focused mainly on urban markets. In 2006, the country still lacked a comprehensive, unified rural energy policy with appropriate institutional support. As a result, the rural energy issue remains invisible to many policy makers.

The major recommendations for the rural energy sector in this study focus on developing the capacity for implementing high-quality programs rather than specific policies. Energy policies cannot be static, given the ever-changing energy markets around the world. The main recommendations are as follows:

- There is a need to further develop the institutional capacity to deal with biomass energy problems, including the strengthening of the Infrastructure Development Company Limited (IDCOL) and perhaps other agencies to diversify into such areas as biogas, improved stoves, and other household energy technologies. In addition, more attention needs to focus on improving local biomass supply in and around farms.
- The recent progress in off-grid electrification and renewable energy through the IDCOL program is encouraging and should be continued and diversified.
- The Rural Electrification Board needs to maintain its distance from political pressures. It also needs to deal with the problem of brownouts and blackouts prevalent in the program and assess ways to financially strengthen the country's weaker rural electric cooperatives or PBSs. Given the spread between village and household electrification and the low number of agricultural pump connections, an assessment of whether

financially viable electricity intensification policies might be pursued is needed.

- Given the extensive commercialization and increasing scarcity of quality biomass energy in rural areas, there appears to be a market for liquefied petroleum gas (LPG), with the right marketing strategies. Currently, the reach of LPG into rural areas is low compared to other South Asian countries.
- Finally, given the government's weak capacity to assess rural energy policies in an objective way, it is recommended that a policy group be created via an independent agency, part of another agency, or a consortium of existing research institutions. It is also recommended that a more complete set of energy questions be incorporated into the national income and expenditure surveys, as purchase and collection of biomass energy are nearly absent entirely from existing ones.

The sections that follow bring the broad array of fuels that sustain rural people's lives into focus. Tackling the constellation of issues surrounding their effective use is critical to the sustainability of Bangladesh's economic future. But the task will not be easy. It will require complementary efforts on many diverse fronts.

Problems and Potential of Biomass Energy

Biomass—a vital energy source in rural Bangladesh—is often overlooked by energy policy makers. As this study shows, biomass is the country's primary rural household fuel. More than 95 percent use it to cook all or part of their meals. Moreover, most household- and village-based enterprises use biomass for heating.

As the survey findings illustrate, beneath this biomass dependence, an energy crisis is simmering. In regions experiencing a continuing decline in the availability of quality biomass, many people seem to be turning from fuelwood to dung, straw, tree leaves, and grass. As the previous chapter discussions underscore, quality biomass in the form of wood is fast becoming monetized, a reflection of its scarcity. In areas where wood is not purchased, all family members, but especially women, spend significant amounts of time (nearly 200 hours annually) collecting all forms of biomass. Such arduous chores divert time from competing tasks and important human-development activities. Moreover, poorly designed biomass-burning stoves without chimneys have low energy efficiency. Used indoors, such stoves emit high levels of smoke and other products of incomplete combustion that collect at high levels indoors. The result is significant health problems for all family members, especially women and children, who spend many hours indoors within the vicinity of the stove.

Mitigating the ill effects of biomass burning requires both demand- and supply-side solutions. Because all biomass shortages vary by region, the solutions must be local; thus, one should caution against any blanket interventions covering the entire country. Surveys during various times of the year might be undertaken that ask household members a range of questions regarding the availability of biomass (both collected and purchased), alternative fuels, cooking devices, food preparation methods, and kitchen practices. Various proposed solutions could then be offered householders, local leaders, and non-governmental organizations (NGOs). The participation of women would be especially important as they are the ones who deal daily with biomass collection, processing, and cooking. With these groups' active participation and cooperation, the most suitable solutions should be found.

Biomass demand can be reduced by using improved cookstoves and kitchen practices. Where possible, fuel substitution including the use of kerosene or LPG should be encouraged. Biomass supply can be increased by planting trees around homes, maintaining and improving local natural resources, and increasing agricultural productivity. Although the impetus for improvement should come from rural residents, the government needs to play a supportive role through such activities as stove testing and quality control, providing seedlings and other inputs, and offering extension advice and demonstrations of relevant technologies.

Because biomass is an important fuel in rural industry and service sectors, improving intermediate and end-use efficiency in these sectors is essential.

The increased commercialization of biomass fuels is a double-sided issue: In areas where commercialization has accelerated, many rural residents face shortages of locally available, quality fuelwood; conversely, a certain proportion earns income through biomass growing, production, transport, and trade, which should assist in alleviating poverty.[44]

In short, promoting a sustainable supply-demand balance of biomass energy, supported by appropriate policies, should be encouraged. To this end, rural residents can be encouraged to move toward more efficient use of biomass energy, in combination with tree planting on farmsteads and improved local forest management.

Increasing Biomass Efficiency and Use

This section reviews past and ongoing initiatives that have aimed to improve biomass energy efficiency and use in rural areas, highlighting lessons and potential solutions that can mitigate risks to human and environmental health.

Improved Stoves: Potential for Revitalization

Some 20 million Bangladeshi households own up to 40 million biomass stoves, most of which are inefficient and produce excessive smoke and other products of incomplete combustion. As this study shows, millions of people in close proximity to such stoves suffer adverse health effects. At the same time, the products of incomplete combustion contribute to the accumulation of greenhouse gases. For these reasons, all relevant ministries—health, environment, energy, and forestry—should be much concerned about the human and environmental damage caused by using biomass energy in inefficient, polluting ways.

Worldwide, 1.5 million people die prematurely each year because of indoor air pollution (IAP), caused by using inefficient biomass stoves (WHO 2006). Many millions of days are lost through sickness caused by inhaling excessive smoke. Although biomass drying, improved kitchen practices, and better ventilation can mitigate the negative health effects, such measures cannot reduce biomass demand. More sustainable solutions call for efforts that increase stove efficiency and vent smoke from people's living areas.[45] There are some recent estimates in Bangladesh that IAP might account for as much as 8 percent of the burden of disease.

In Bangladesh, most intervention programs to popularize improved stoves were proven ineffective or were small in scope. The largest program, terminated in 2001, was that of the government of Bangladesh. The program was supported by various organizations, including the Institute of Fuel Research and Development, the Bangladesh Council for Scientific and Industrial Research, Ansar-VDP, and the Bangladesh Rural Development Board. By December 2002, an estimated 300,000 Bangladeshi households had received access to improved stoves. Based on these penetration rates, one could expect that about half a million households would have gained access by 2007. This figure is less than 0.5 percent of the population; thus, there is much room for improvement (Hossain 2003).

More recently, various agencies have continued to promote improved stoves, albeit on a smaller scale. Current NGO initiatives are not widespread for lack of trained personnel and funds. Grameen Shakti has been working throughout the country on initiatives funded by international donors, whereby beneficiaries are provided microfinance on demand; to date, its accomplishments have been modest. The Village Education Resource Center, another NGO striving to alleviate poverty in Bangladesh, is among the few large ones actively working on improved stove initiatives. The Center operates from its head office in Savar and 14 branch offices located across various districts. Its main focal areas are water, sanitation, hygiene, and improved stoves. It has pioneered a participatory assessment method to mobilize communities and generate village demand for improved stoves, house

[44] This study examined the purchase of biomass energy, but did not investigate the market structure of fuelwood or other biofuels; thus, more research in this area is needed.

[45] It should be cautioned that even the most effective improved stoves being sold or distributed in developing countries do not lower IAP levels to those recommended by international environmental agencies; but it is a step in the right direction. In developed countries, there are stoves for heating that eliminate virtually all indoor pollution and vent little pollution outside the home.

modifications, and behavioral change to transform villages into smoke-free ones. The Center's demand-oriented approaches and stoves' designs cater to consumer requirements. Even so, accomplishments to date have been modest. Finally, the Local Government Engineering Department, the technical arm of the Local Government Ministry for Rural Infrastructure Development with nationwide reach, is implementing work on improved stoves.

Various reasons account for the ineffectiveness of many earlier government initiatives. In some cases, the stoves were inappropriate to the needs of the cook. In others, programs were driven by installation targets with little follow-up activities. Many programs were subsidized, with benefits going to the organizers or installers rather than the recipients. In still other cases, the improved stoves were no better than the originals, but were less versatile.

Where improved stove programs have succeeded, cooks have been an integral part of the process. Advice can be offered about the pros and cons of interventions. Saving time and money are usually top priorities; at the same time, comparing the health effects of various stove designs and kitchen layouts should be stressed. Improved stoves need not be complicated; they can be made from local materials. Local women's groups can be organized and trained to make and install improved stoves on a commercial basis after deciding on household cooking needs. Such groups can fabricate chimney pieces (if not purchased) from mud, using straw as a reinforcing agent and burnt clay inserts of standard sizes, thereby reducing the cost US$5–10 per stove.

Evaluation research suggests that better-coordinated efforts could revitalize the potential of improved stoves, which would reduce pressure on traditional biomass supplies and significantly improve the health of biomass-reliant rural populations. It is suggested that improved stove programs take a more pragmatic approach with regard to stove benefits and performance, including demonstrations and promotion to increase awareness of the dangers of IAP and need to conserve biomass fuels.

Undertaking a sustained nationwide program requires sufficient administrative and technical infrastructure. Specific activities include the following: stove design and testing; demonstration; research and development; quality control; promotion in all media forms; making simple tools available to stove makers; providing advice on material sources, use, and suitability (especially if clay); training of stove makers, repair-service operators, and extension workers; monitoring and evaluation; and loans. End-user feedback on the pros and cons of various stove designs should be ongoing, and suggestions should be integrated into the further refinement of stove design.

Stove initiatives should be part of a larger program to improve village life, especially the health and welfare of community members. Part of this program should provide training on biomass use (e.g., drying and using in appropriate sizes and discussion on food preparation and energy-saving methods). Many such initiatives could be initiated within the community; through these efforts, the entire village could participate and take pride in its achievements.

The overall program should promote market-based approaches that rely on local producers and distributors who profit only from satisfied customers. Direct stove subsidies should be avoided, as they create market distortions and ultimately hinder stove commercialization. Instead, subsidies should be directed toward activities that support the program (e.g., greater government backstopping, active NGOs, small-scale enterprises, and using women's groups to promote improved stoves for rural households and microenterprises). Finally, a wide range of stove designs (some of which would be suitable for the service sector [e.g., canteens, restaurants, and hot-food shops]) is needed.

Biogas Digesters for Cooking and Farm Productivity

Currently, some 25,000 biogas digesters are operational in Bangladesh. Each digester requires dung from about six cows (i.e., assuming that each produces 10 kg of wet dung per day, equivalent to 1.15 kg of air-dry dung). If 25 percent of cow dung could be utilized, approximately 1 million family-sized digesters, each supplying cooking fuel for five to six people, could be built. Unfortunately, many farmers lack access to the required amount of dung, which hinders large-scale introduction.

Passing dung through digesters has several advantages. First, the gas produced is easy to light and control; its efficiency for cooking is 50 to 60 percent, depending on the stove. Used for lighting, the gas emits a brighter light than kerosene. Most pathogens in the dung are destroyed during the production process, and the resulting slurry makes an excellent fertilizer. If dung is applied directly to paddy fields, methane, a potent greenhouse gas with 20 times the warming effect of carbon dioxide (CO_2), is produced and vented into the atmosphere. Digesters capture this methane and use it for cooking; furthermore, slurry is a better fertilizer than dung.

The Bangladesh Council for Scientific and Industrial Research (BCSIR) runs the government's active but modest biogas digester program, which focuses on relatively large units for which farmers receive advice and a subsidy of Tk 7,500 (US$120) per digester. Because these digesters are relatively expensive to build, they must be properly maintained to perform effectively. A fixed-dome, 5 m^3 unit costs US$240–290. Cheaper black plastic (PVC) models that fit into trenches are variously sized according to the number of cattle. The cost of such digesters (with appliances) is about US$100. Farmers with only one or two cows could use this type of digester to meet a portion of their cooking needs and, at the same time, produce an excellent fertilizer. Financing could be arranged through the active program of a Bangladeshi microenterprise. Farmers or villagers could cooperate to build community digesters, which could provide enough fuel to run electric generators for part of each day.

Over the next several years, the Infrastructure Development Company Limited (IDCOL) plans to facilitate the construction of thousands of biogas plants. It might be beneficial for two complementary agencies, such as the BCSIR and IDCOL, to foster biogas development.

Higher Bioenergy Efficiency for Industry

In 2000, the formal and informal industrial sector—mostly agro-processing industries—accounted for more than 20 percent of total biomass energy demand. Energy uses included parboiling of rice, sugar production, tea drying, tobacco curing, and baking. Non agro-based industries included brick and tile manufacturing, lime burning, road tarring, and soap making. Wood was the main input for charcoal production. Most industries were based in rural areas, relying on inexpensive, readily available biomass supply, characterized by low fuel efficiency. It is recommended that the government provide a range of technical assistance, including energy audits, to improve fuel efficiency. In addition to improved stove initiatives, interventions should be pursued for charcoal production and other activities where solid biomass is used or produced.

Technical assistance should focus on a wide array of areas: improving institutional- and service-sector stoves; improving brick, pottery, and lime kilns; conducting energy audits at sugar factories and sawmills to assess energy-saving approaches; listing agro-processing factories that use biomass energy (e.g., tea drying, rice parboiling, and fish smoking); and examining ways to improve energy efficiency for all biomass users. To succeed, these initiatives require quick payback periods. Charcoal producers could be trained to better manage wood resources and improve production processes. If forests are the main wood source, the forest service should work with charcoalers to plan a cutting cycle. Cooperating with producers would enhance forest sustainability and diminish illegal cutting.

With regard to briquetting of difficult-to-burn residue (e.g., husks and sawdust), many past initiatives have failed because of inappropriate, sophisticated equipment or lack of sound marketing and management. The cost of briquetting is generally expensive, and the product may not be competitive with unprocessed biomass. Hand machines and locally made, inexpensive binders, as well as potential markets for the finished product, should be investigated. Densification may offer a solution for straw, which is bulky and quick-burning, but price is a constraint. Various types of densifying equipment, including hand presses, as well as binders, should be compared. If unemployment and underemployment are problems, simple hand devices may prove more appropriate than high-tech machines. Recently, this area has become more widespread, with several hundred factories operating across the country.

Increasing Biomass Supply

A complementary solution to Bangladesh's biomass energy problem is to increase or maintain supply through local forest management or growing of trees, bamboo, and shrubs on and around farms and along roads. Trees grown outside the forest are a principal source of rural fuelwood. Such trees are usually planted close to the demand center and are intensively managed, especially if privately owned. They provide added income by yielding multiple products (e.g., fruits, medicines and herbs, and nectar and leaves used as feedstock in honey and silk production). The upsurge in tree-planting activities over the past 20 years has resulted from the support of NGOs, government, and international donors, as well as the active involvement of rural people. Through participatory silviculture, it will be possible to increase tree planting and management both in and outside the forest.

It comes as no surprise that agricultural conversion threatens a portion of rural Bangladesh's forests and grasslands. Rural population growth is 2.5 million per year, more than 62 percent of the country's annual growth rate of 4 million. Unless agricultural productivity keeps pace with population growth, forested lands will be cleared for food production. Short-rotation, nitrogen-fixing trees could be planted in and around farmland to maintain, if not increase, productivity and provide farm animals browsing material. Such trees yield stick wood; and increased productivity and browsing may result in more agricultural residue and dung. Thus, it is essential that the relevant ministries, particularly agriculture and forestry, work jointly to facilitate increased agricultural productivity, without which the biomass resource base will surely diminish.

Biomass is rural Bangladesh's most important cooking, heating, and industrial fuel and will remain so well into the future. For perennials, this implies management that removes not more than annual growth over the long term; for annuals, it means, at a minimum, that soil fertility be maintained so that land does not deteriorate to a state of marginal or no productivity.

The expected doubling of Bangladesh's population over the next 30 years will further strain the natural resource base. Adopting an effective strategy is urgently needed, especially in rural areas, to ensure an ongoing increasing supply of renewable biomass energy. Implementation of this strategy should be guided by powerful institutional voices within the government. Thus, in addition to the Ministry of Power, Energy, and Mineral Resources, the ministries of agriculture, forestry, health, rural development, women's affairs, and others are also essential. Especially important is the proposed Renewable Energy Development Agency (REDA), backed by the Ministry's renewable energy division.

Proposed Strategy

Given Bangladesh's significant dependence on biomass energy, we reiterate some of the previously cited suggestions to conclude this section. A strategy to improve biomass energy prospects in rural areas could take various approaches, four of which are highlighted here. First, the intermediate and end-use efficiency of biomass energy production should be increased, especially at the household level. The aim would be not only to reduce unit energy consumption, but, more importantly, to decrease products of incomplete combustion, which damage human health and contribute to the accumulation of greenhouse gases. Second, biomass production (of both annuals and perennials) should be increased on all land formations so that the country can keep pace with demand for biomass and its products. Ideally, increased productivity should outpace population growth so that more biomass can be used for all purposes, especially energy. Third, use of modern energy and more convenient forms of biomass should be promoted, despite ongoing use of traditional forms of biomass, which will continue for many years to come. (Modern forms of energy include solid, liquid, and gas products used as fossil-fuel substitutes; biomass and its products could be used to generate electricity, where appropriate). Finally, buildings and habitats should be designed to conserve energy. Trees planted around buildings and along streets would reduce the ambient temperature, which would, in turn, reduce the need for cooling in offices and homes while periodically providing biomass. Trees would also mitigate erosion and improve the environment.

Within the country's current rural energy policy and institutional framework, these recommendations may be difficult to implement. Thus, the last section of this chapter turns to the complexity of institutional issues that must be tackled in order for policy implementation to succeed. However, we now turn to a successful program to promote electricity in Bangladesh.

Rural Electrification and Rural Development

In 1976, Bangladesh was a newly independent country grappling with the challenge of creating national policies and programs amid an underdeveloped infrastructure, rapidly growing population, and frequent natural disasters. Few would have predicted that 25 years later, this poor South Asian country would have succeeded in providing electricity to nearly 30 percent of its rural households.

Bangladesh's story of rural grid electrification is important for several reasons. First, despite relatively low coverage rates compared to other developing countries, an additional 600,000 rural customers receive electricity services each year. This annual increase exceeds the total rural population of many countries. Second, having a well-managed, well-run program is somewhat unique in South Asia. The rural cooperatives have low distribution system losses of only 15 to 17 percent; their 95 percent revenue-collection rate is high by developing country standards. Third, though one of the world's poorest countries, Bangladesh demonstrates how rural electrification programs can succeed under adverse economic conditions.

A complementary rural electrification story is Bangladesh's recent effort to strengthen capacity in decentralized or off-grid service. Although the grid is expanding service by large numbers every year, systems expand outward from generation stations, and transmission lines serve the most highly populated areas first. As a result, some 50 percent of rural villages—70 percent of rural people—remain without a connection. But a host of renewable technologies now available for decentralized generation and provision offer promise that many households that otherwise would remain unconnected for years will be served.

This section explores ways in which to improve both grid and off-grid electrification programs.

Grid and Off-grid Programs

Both grid and off-grid electrification programs are important to the socioeconomic development of rural Bangladesh. The evidence is convincing that electrification translates into substantial gains in household welfare and a higher quality of life. Indeed, the benefits of lighting alone are highly valued by rural households that adopt electricity. As this study shows, household- and village-based microenterprises that connect to the grid are more profitable than comparable businesses served by private or locally purchased generators.

Cooperative Grid Electrification: Role of the Rural Electrification Board

One of Bangladesh's most successful development programs over the past 20 years has been the extension of grid electricity in rural areas. As discussed in previous chapters, the Rural Electrification Board (REB) promotes the development of electricity distribution companies based on the rural cooperative model adopted in the United States. In 1977, it was argued that enlarging the public-sector electricity company's focus to include low-density, poorer rural areas was unfeasible, given the company's already overextended efforts to serve urban areas. Thus, the REB was created in 1978 as a semi-autonomous public agency to promote electricity in rural areas and implement a financially viable program.

As an agency of the Ministry of Power, Energy, and Mineral Resources, the REB is responsible for planning and implementing all investments in rural electrification infrastructure, overseeing performance of the rural electric cooperatives or PBSs, and regulating prices. Over its 25-year history, the REB has constructed the infrastructure for Bangladesh's entire national rural electrification system. In this capacity, a major responsibility has been to manage loans and grants provided by international donors with which to finance an infrastructure development program. Another essential function has been to finance short-term capital needs of newly established PBSs. Finally, the board has provided the PBSs vital technical assistance and monitoring of technical and financial performance, thus helping them evolve into modern distribution utilities.

Despite the REB's long success in promoting rural electrification, recent problems call for urgent attention. As this study's national survey reveals, rural consumers perceive that electricity supply has become unreliable. Some 80 percent of rural households report daily outages, while 60 percent report significant power fluctuations. Survey results also bring into question the REB's selected coverage approach, as 20 percent of households that receive electricity indirectly from the PBSs—most commonly via a neighbor—are billed at a higher rate than that charged by the PBSs. While not illegal in the strictest sense (i.e., electricity is metered and paid for by the collecting household), this practice suggests that some type of barrier prohibits households from receiving electricity directly from the PBSs. It may be that households are beyond the required distance from the grid or informally connected ones want to avoid connection charges.

The national survey also reveals a significant potential to replace diesel-powered irrigation motors with electric ones. Investment in infrastructure to deliver electricity to rural areas could be complemented by development of daytime loads. Since most current rural demand is during evening hours, revenue from the additional agricultural load based on availability of groundwater potential could significantly improve PBS finances.

Recent financial analysis of the PBSs has brought into question the REB's pricing and subsidy policies. In 2006, the PBS service territories differed markedly; some were characterized by lucrative households, while many others served poorer regions. The REB's standard subsidy and pricing policies mean that the financial viability of PBSs in poorer service territories tends to be poor. Amid the constant struggle to meet financial targets, these cooperatives lack the financial resources to serve their customers properly. Thus, careful review of the policies of uniform subsidies and similar tariffs for all PBSs is recommended. One potential solution might include mechanisms that give preferential treatment to companies serving poorer regions, such as permitting higher tariffs or providing electricity at lower bulk prices.

The conclusion is that Bangladesh's rural electrification program has been both active and effective in its positive development outcomes. The national survey on rural electrification confirms electricity's significant effect on rural development. In 2006, the PBSs were generally well managed; yet the program has a nationwide generation problem. Rural customers have reported significant outages, which, if they persist, may lead to dissatisfaction with PBS performance. In addition, many cooperatives in more remote areas are not yet financially viable. Policy solutions will require load promotion to increase revenue or price restructuring and subsidies. A recent initiative is studying REB management practices and the board's potential as a freestanding corporation. Such studies stress the REB's key role in supervising and promoting rural electrification for Bangladesh and its need to remain free from political manipulation.

Off-grid Electrification: Role of the Infrastructure Development Company Limited

Only 3 percent of Bangladesh's nearly 17 million rural households are gaining access to the national grid each year, creating an enormous potential for off-grid systems. Opportunity is greatest in locales where grid extension is uneconomical. Many rural residents can afford electricity if the costs are spread out over many years. Given that many components of renewable energy systems last 20 years or more, it makes sense to allow households to spread out purchases of renewable energy equipment over a period of years. Such an arrangement could be made in conjunction with rural development programs aimed at improving local incomes.

In 2002, the Infrastructure Development Company Limited (IDCOL) was made the country's focal agency for coordinating the off-grid program, the first phase of which has focused on promoting solar photovoltaic (PV) systems. To date, most work has been done by NGOs specialized in microfinance and microenterprise development. The program has succeeded beyond initial expectations. Working with 16 partner organizations, including Grameen Shakti and other NGOs involved in microcredit and solar home systems (SHS), the program has installed more than 80,000 systems over a three-year period.

The program has operated on the premise that partner organizations, who have gained the trust of rural residents, are the most efficient SHS delivery agents. Their collection history has proven strong enough to develop a credit line. IDCOL's supportive role has focused on developing consumer awareness of SHS and their potential for rural lighting. Additional responsibilities have included registering participating organizations eligible for assistance, establishing standards, and refinancing up to 80 percent of partner organizations' customer loans.

This innovative program has demonstrated that, with careful planning and adequate support in the initial stages, partner organizations can gain proficiency in equipment supplier dealings and after-sale customer support. In addition, the significant portion of income that poor rural households have been willing to allocate for basic lighting has underscored the high value they place on the service.

Initially, the program aimed to remain technology neutral. Indeed, IDCOL was selected as the implementing agency because it did not promote a single technology. Although SHS has composed most of the program's lending demand to date, a tremendous unmet need for electricity remains. Recently, several other types of off-grid systems have been implemented, but financing has been limited. As a result, a significant need remains to diversify product lines to microgrids, which could be connected directly to the national grid system once the PBSs reach these remote communities.

Toward Policies for Household Petroleum Fuels

Before independence in 1971, all of Bangladesh's petroleum products were imported and marketed by private-sector companies. Although these companies competed, they were heavily taxed, which translated into higher fuel prices. After independence and nationalization of the petroleum sector, public-sector companies were created to import, refine, and market kerosene and other petroleum products. For the past 30 years, the Bangladesh Petroleum Corporation and its subsidiaries have controlled most aspects of petroleum supply, including its pricing system. The following sections suggest pricing policies for specific fuels, where appropriate, to promote more equitable rural use.

Kerosene

Bangladesh's kerosene market consists of government suppliers, known as oil-marketed companies, and private retailers. Theoretically, kerosene is priced uniformly across the country, but transport-cost adjustments are made for market distances greater than 40 kilometers from a supply depot. Price increases occur at each distribution stage: from dealer to subdealer to retailer. The more remote the destination, the higher the fuel price. But the price difference between rural and urban areas is not great, and the system for containing kerosene within a price range works well throughout the country. Because most rural households use the fuel for lighting, it is accessible to most at world-market rates; in addition, it is available in quantities sufficient for cooking. Thus, kerosene pricing policies require no substantial revision.

Liquefied Petroleum Gas

In 1978, the Bangladesh Petroleum Corporation began commercial production and marketing of LPG. Over the next 20 years, use of LPG grew slowly. In the late 1990s, the government began to allow private companies to import and market the fuel. Today, Bangladesh has three public and six private LPG marketing companies. Private companies, which must pay import taxes and charges associated with the fuel, compete with public companies, which are exempt from such taxes and fees. Despite this price disadvantage, the private companies are viable and are expanding from large urban centers into smaller towns.

Notwithstanding such progress, LPG, which is readily available in urban markets, has largely failed to reach rural households. Because LPG is a clean fuel, it could contribute to alleviating IAP. By having the fuel on tap, rural people could reduce the amount of time spent collecting biomass.

The difficulties of promoting LPG in rural areas are well documented. Lower-income rural residents with little cash on hand usually cannot afford the high upfront costs associated with LPG. They are unlikely to pay cash for the typical 12.5 kg cylinder or double-burner stove (costing Tk 2,500–3,000). In addition, LPG transport and storage costs (unlike kerosene's narrower range of prices) are prohibitive for many.

However, in other South Asian countries, LPG is penetrating rural areas. In India, for example, more than 20 percent of rural households use LPG to meet at least part of their cooking needs; thus, increased availability appears to lead to greater use. Most such households do not switch completely to LPG; rather, they use the fuel for quick-heating items, such as tea. One should note that the poorest rural Bangladeshi households will not adopt LPG extensively; but more prosperous rural areas have greater scope for promotion.

Increased use of LPG in rural areas could be encouraged in several ways. First, commercial food enterprises could be targeted initially; they currently purchase biomass for food preparation, which requires significant cash outlays. Second, as in many other countries, the upfront cost of LPG stoves and cylinders, which are necessary for fuel use, could be partially subsidized or paid for in installments; lower upfront costs would put stoves within reach of households who otherwise could not afford LPG. Third, large-capacity cylinders, which target mainly urban consumers, could be complemented by a variety of smaller cylinder sizes. Promoting smaller cylinders in rural areas would reduce the cash outlay for refills. All three recommendations would require well-designed strategies in the safe promotion of LPG to new markets.

Because private companies must keep their prices competitive with those of public companies, they have a disincentive to service rural areas. As a result, they tend to target relatively better-off markets not served by the main public companies. Thus, it would be sound policy to promote a level playing field for all companies marketing LPG. In this way, it is hoped they would be willing to innovate and expand their markets into even more remote areas not currently served.

Natural Gas (Methane)

Piped natural gas from fields in the Bay of Bengal is used mainly by householders in Dhaka and other large towns. Indeed, the government has reserved natural gas for household use. Under current pricing policy, households are charged a (subsidized) flat monthly rate, irrespective of the amount of gas consumed. Such a policy leads to abuse and waste and discriminates against households without connections in smaller towns and rural areas.

It is recommended that the government reverse the flat-rate tariff so that households are charged per unit of consumption. Also, subsidies, which invariably benefit wealthier households, should be removed. The savings from such changes could be redirected to rural areas to encourage rural electrification, increase biomass availability, and foster its more efficient use.

At the same time, the brick-making industry has requested a pipeline connection to enable year-round brick and tile production, which would reduce dependence on imported Indian coal and fuelwood (officially banned from use in brick making).[46] Although the imported coal varies in quality, its ash content is high, and thus its energy value is low (not much higher than that of dried wood). Because the price of wood is lower than that of coal, wood is used as a starter and booster fuel. But controlling the temperature of the brick stacks is difficult, and the quality of baked bricks is not uniform. The kilns are usually shut down during the rainy season due to fuel shortages caused by flooding in low-lying areas. If the kilns were fired by natural gas instead of coal, they could operate year-round. In addition, they could be designed to provide uniform heat, ensuring a superior product.

Bangladesh's brick manufacturing association has expressed a willingness to pay a non-subsidized

[46] Bricks and tiles require less energy than concrete and corrugated iron roofing; thus, brick making should be encouraged.

price for natural gas, which would generate more government revenue, save foreign exchange, and reduce fuelwood use. It would also mean that a percentage of brick makers could install more-efficient kilns and produce more uniform bricks and tiles. It is recommended that the government examine the merits of supplying brick makers natural gas.

Enhancing Rural Energy Projects, Policies, and Strategies

Rural energy is a complex issue, encompassing a broad and diverse spectrum of resources—from petroleum fuels and coal to biomass and renewable energy—spanning multiple sectors, including forestry, electricity, and health. To date, many of Bangladesh's institutions involved in rural energy have not been coordinated. One major recommendation resulting from this study is to develop the policy capacity to tackle rural energy issues in all their complexity. This policy capacity could be used to objectively analyze and promote rural energy solutions and would complement the existing institutional programs that are being used to implement rural energy in Bangladesh.

Donors have often advocated projects with a narrow technology focus. But experience teaches that focusing on single technologies does nothing to further markets and private-sector companies to support rural energy development. Such an ad-hoc arrangement is not conducive to capacity-building. Whatever experience is gained under a specific project cannot be applied to subsequent ones for lack of continuity. Moreover, single efforts generally seek exceptions to regulatory policies but are unable to change them. As a result, it is not possible to see the long-term effects of such projects in the form of greater access to quality, rural energy services. Thus, a rural energy institution could provide government advice on how to better focus use of donor funds.

To date, successful rural energy programs in Bangladesh have combined financing, institutional support, local support, appropriate pricing, competent implementing firms, and market development. They also have been characterized by a strong coordinating agency. A case in point is the REB; given that it has succeeded in moving the country's electrification rate from 10 to 30 percent, continued support of its efforts to fulfill its ambitious mandate is critical. Inevitably, such institutions face serious challenges as their programs mature. It is imperative that international agencies stay involved to support them through the critical transitions. As noted in previous chapters, the REB now faces an array of complex issues, including differential subsidies for cooperatives that service poor-load areas, takeover of towns and small cities within the boundaries of cooperatives, and the transition to greater self-reliance. Another major challenge identified by this study is access to reliable supplies of bulk electricity.

Beyond the REB, institutions that support rural energy have been working relatively independent of one another. IDCOL's recent success in promoting solar PV systems suggests that renewable and other areas of rural energy require a level of support on par with that of grid electrification. Unlike the REB model, that of IDCOL is more decentralized, and there is no overlap between the two. Both models handle financing, provision of technical assistance, lobbying on regulatory issues, vendor approval, and support of venture development. Neither the REB nor IDCOL limits its focus to technology dissemination. Both institutions are concerned with development of the market and supporting environment for delivery of rural energy services.

The recent move toward establishing REDA, while a welcome development, perhaps, does not go far enough. The recommendation is to designate an agency to handle the entire range of rural energy issues, sometimes acting as an executing agency and, at other times, playing a coordination role. Given IDCOL's solid track record, a first step might be to strengthen its off-grid electrification unit, thereby enabling it to handle a broader range of rural energy issues.

Because Bangladesh's entire range of rural energy responsibilities is divided among a number of agencies or institutions, development of an active policy unit is needed to advise the government on the diversity of rural energy problems. Such a policy unit, which could be called the rural energy policy unit, would be responsible for formulating and promoting rural energy policies, ranging from biomass to electricity and LPG. It would work hand in hand with various agencies with major responsibility for energy in rural areas, including the REB, IDCOL, and others.

There is a significant need for a group in Bangladesh dedicated to evaluating and promoting rural energy policies. It is envisioned that Bangladesh's rural energy policy unit would eventually be independent or semi-independent of the government. Over the short term, however, it might be practical to house the unit within an existing agency or public research group. Its role would be to promote sound policies for rural areas and innovative pilot projects; it would not be involved in project development, which would be left to other agencies.

In addition to providing policy support to promote rural energy, this new agency could compile and publish rural energy information. Analysis of data from the national survey undertaken for this study—the first of its kind in 25 years—would provide future market opportunities by identifying priority locations for project financing. This would be a great service to all cooperating organizations interested in rural energy, including the many above-mentioned ministries and agencies. It would be imperative to ensure that the technologies recommended were of sufficient quality to meet rural energy needs. In addition, the program scope would need to extend beyond renewable energy to include conventional off-grid power systems in remote areas. Technology coverage should be broadened to include renewable energy (e.g., micro-hydropower, PV, and wind), improved stoves, tree planting, and small diesel systems.

Summing up, rural energy is a complex and, for the most part, unprofitable business. But by using a combination of loans and subsidies, both large- and small-scale businesses can become viable to better promote a wide range of rural energy services, from LPG and grid electricity to improved stoves and tree growing. Moving forward requires a combination of research, production and delivery, support, and monitoring and evaluation, all of which must be done through a variety of businesses—including rural electric cooperatives, NGOs, private-sector companies, and local municipalities—interested in serving rural energy customers.

The Way Forward

Rural energy's importance to the Bangladesh economy cannot be underestimated, given the world's focus on globalization and market reform. This study underscores how the effects of rural energy cut across multiple, diverse facets of rural life—from income and labor productivity to education and women's health. The problems rural people face in obtaining safe, clean, and reliable energy supplies are not minor inconveniences. On the contrary, they represent a significant barrier to rural economic development and improved social well being. A multifaceted approach to solving Bangladesh's rural energy problems is not only warranted; it is an essential building block to propel the country into the twenty-first century.

The past two decades have witnessed many attempts to promote rural energy. Donor- and public-sector supported projects that have introduced and popularized improved biomass stoves have yielded only limited success, despite the large potential benefits of sustaining biomass supply and improving human health. Social afforestation programs initiated over the period have run their course. Although biogas programs have enjoyed considerable success, they fall far short of realizing their considerable potential. Renewable energy efforts, especially the popularization of solar PV, have achieved a remarkable measure of success; even so, the technical and socioeconomic issues associated with scaling up household and village electrification require capacity-building at national and local levels.

The rural energy issue identified is this: Bangladesh has a comprehensive need for better institutional coordination and attainment of a critical mass of technology and market development. With effective institutional coordination, combined with market development, appropriate subsidy and pricing policies, and government and donor support, current and proposed programs can succeed beyond expectations. The call for action is urgent, not only for rural development, but for the country's equitable economic growth.

Annex 1

Selected Tables from the Household Survey

Table A1.1

Survey Sample (number)

Survey Type	Division				All
	Dhaka	Rajshahi	Chittagong	Khulna	
Household	603	600	640	548	2,391
Home enterprise	50	27	31	29	137
Village enterprise	85	58	63	136	342
Institutions	38	32	36	50	156

Source: BIDS Survey (2004).

Table A1.2

Household Distribution by Ownership of Agricultural Assets (percent households)

Asset Type	Division				All
	Dhaka	Rajshahi	Chittagong	Khulna	
Land (acres)					
< 0.50	57.9	59.5	56.1	48.7	55.7
0.50–2.49	28.0	27.5	27.0	32.9	28.7
2.50–4.99	8.6	7.0	8.4	12.4	9.0
≥ 5.00	5.5	6.0	8.4	6.0	6.5
Non-land					
Business enterprise/shop	9.8	5.3	6.3	8.6	7.4
Bicycle/motorcycle	15.1	30.7	13.1	28.1	21.5
Rickshaw/van	8.1	9.0	5.0	8.4	7.6
Push cart /bullock cart	1.8	1.0	2.2	4.2	2.3
Boat/engine boat	12.9	6.5	2.5	8.0	7.4
Irrigation pump	4.6	13.5	3.0	4.7	6.4
Tiller/tractor	1.3	3.2	0.0	1.3	1.4
Thresher	0.5	1.5	3.0	3.8	2.2
Rice/flour mill/cane crusher	1.2	0.5	0.0	1.6	0.8
Hand tube well	45.6	60.2	30.5	17.5	38.8
Other	7.6	4.3	17.3	10.9	9.7
None	32.7	24.5	42.5	42.2	35.4

Source: BIDS Survey (2004).

Table A1.3

Household Distribution by Various Characteristics (percent distribution)

	Division				
Household Characteristic	**Dhaka**	**Rajshahi**	**Chittagong**	**Khulna**	**All**
Education					
No schooling	54.6	54.0	44.5	35.4	47.4
Primary	22.1	21.7	31.9	35.0	27.6
Secondary	18.3	19.5	18.3	24.7	20.0
Higher secondary and above	5.0	4.8	5.3	4.9	5.0
Dwelling ownership status					
Own	95.2	97.6	98.0	95.6	96.7
Rent	0.3	0.2	0.8	0.4	0.4
Allowed to reside	4.5	2.2	1.2	4.0	2.9
House type					
Pucca	1.5	1.0	2.8	0.6	1.5
Semi pucca	3.3	6.2	7.0	20.1	8.9
Kacha (but tin roof)	88.4	76.6	62.1	60.9	72.1
Kacha (thatch roof)	6.8	16.2	28.1	18.4	17.5
Latrine type					
Pucca	11.1	9.2	13.3	6.5	10.1
Slab	37.0	22.5	47.8	39.8	36.9
Kutcha	48.6	67.8	38.4	53.3	51.8
Other	3.3	0.5	0.5	0.4	1.2
Drinking water source					
Tap inside/outside home	0.5	0.3	1.1	0.2	0.6
Tube well	93.8	99.2	85.9	92.9	92.8
Dug well	0.4	0.3	5.3	—	1.6
Pond/canal	5.3	0.2	7.7	6.9	5.0

Source: BIDS Survey (2004).

Table A1.4

Annual Household Income by Source (average Tk per household)

Source	Dhaka	Rajshahi	Chittagong	Khulna	All
Agriculture	**21,096**	**28,652**	**31,498**	**25,546**	**26,797**
Crop	9,225	13,090	13,469	10,590	11,644
Non-crop	9,359	9,846	14,212	10,720	11,092
Wages	2,512	5,716	3,817	4,236	4,061
Non-agriculture	**45,510**	**19,226**	**48,210**	**24,544**	**34,832**
Processing/trade/ miscellaneous	15,824	7,277	13,109	8,828	11,349
Wages	6,191	2,442	3,420	3,141	3,810
Transport	3,042	3,047	3,681	2,786	3,156
Salaries/ allowances/pensions	5,900	3,079	6,807	4,897	5,205
Rent (including land mortgages)	2,556	1,915	1,454	1,357	1,825
Remittances	11,997	1,466	19,739	3,535	9,487
Total	**66,606**	**47,878**	**79,708**	**50,090**	**61,629**

Source: BIDS Survey (2004).

Table A1.5

Household Distribution by Income Source (percent)

Source	Dhaka	Rajshahi	Chittagong	Khulna	All
Agriculture	**94.5**	**96.8**	**95.5**	**95.4**	**95.6**
Crop	64.8	72.3	68.6	65.9	68.0
Non-crop	91.2	89.2	93.3	90.7	91.1
Wages	23.5	43.7	18.9	31.2	29.1
Non-agriculture	**88.2**	**75.3**	**78.9**	**83.6**	**81.4**
Processing/trade/ miscellaneous	35.0	42.8	34.2	41.4	38.2
Wages	29.9	19.2	14.8	21.7	21.3
Transport	10.0	14.3	7.3	13.1	11.1
Salaries/ allowances/ pensions	15.3	8.8	19.1	25.4	17.0
Rent (including land mortgages)	13.3	11.8	5.2	12.4	10.5
Remittances	27.7	11.0	28.6	13.3	20.2

Source: BIDS Survey (2004).

Table A1.6

Household Consumption Expenditure by Budget Item (Tk per year)

Item	Dhaka	Rajshahi	Chittagong	Khulna	All
Food	34,511	22,606	39,706	25,693	30,893
Clothing/footwear	3,679	2,374	3,286	2,656	3,012
Consumer durables	5,450	3,375	4,921	3,527	4,347
Miscellaneous	12,264	7,783	14,473	9,013	10,986
All	55,904	36,138	62,386	40,889	49,238

Source: BIDS Survey (2004).

Table A1.7

Household Distribution by Type of Energy Consumption (percent)

Energy Type	Dhaka	Rajshahi	Chittagong	Khulna	All
Biomass	**99.8**	**99.5**	**98.6**	**100.0**	**99.5**
Fuelwood	85.1	67.2	95.8	88.7	84.3
Tree leaves	81.4	72.0	61.6	91.8	76.1
Crop residue*	81.4	93.2	53.6	75.4	75.5
Dung cake/stick	56.9	72.3	29.5	64.8	55.2
Sawdust	0.7	0.8	0.3	1.6	0.8
Non-biomass	**100.0**	**96.5**	**100.0**	**100.0**	**99.1**
Candle	2.5	0.8	10.6	4.4	4.7
Kerosene	99.0	91.5	98.4	100.0	97.2
Natural gas	—	—	0.9	—	0.3
LPG/LNG	—	0.2	1.1	—	0.3
Grid electricity	43.8	20.3	38.9	10.8	29.0
Solar PV	0.3	—	—	1.5	0.4
Storage cell	1.3	—	0.8	0.9	0.8
Dry-cell battery	39.1	50.7	42.3	61.3	48.0

Source: BIDS Survey (2004).

* Also includes crop waste and weeds.

Table A1.8

Annual Household Energy Consumption: All Divisions (average per household)

Energy Type	All Uses	Heating: Cooking	Heating: Parboiling	Heating: Other	Cooling	Lighting	Amusement
Biomass (kg)							
Fuelwood	1,186.21	1,064.84	28.60	92.77	—	—	—
Tree leaves	501.51	470.67	29.99	0.85	—	—	—
Crop residue	708.18	538.86	164.41	2.72	—	—	—
Dung cake/stick	523.90	503.68	16.07	4.16	—	—	—
Sawdust	8.40	8.36	0.02	0.02	—	—	—
Non-biomass							
Candle (piece)	15.86	—	—	—	—	15.86	—
Kerosene (liter)	28.98	1.76	—	0.07	—	27.16	—
Natural gas (Tk)	9.59	9.59	—	—	—	—	—
LPG/LNG (liter)	0.05	0.05	—	—	—	—	—
Grid electricity (kWh)	143.83	0.25	—	4.00	49.50	80.74	9.34
Solar PV (kWh)	0.53	—	—	—	0.04	0.48	0.01
Storage cell (kWh)	0.55	—	—	—	—	0.14	0.41
Dry-cell battery (piece)	15.01	—	—	—	—	—	—

Source: BIDS Survey (2004).

Note: Electricity use for motive power is negligible (0.28 kWh/ household/year). Only 2 households used briquettes (Chittagong), but only for 1–2 months. Only 1 household used charcoal, but in negligible quantities. Only 2 households used biogas. None used generator electricity. All categories include non-users so figures may vary due to the percentage of households not using a fuel. However, at the national level they should be representative for all households.

Table A1.8.1

Annual Household Energy Consumption: Dhaka (average per household)

Energy Type	All Uses	Heating: Cooking	Heating: Parboiling	Heating: Other	Cooling	Lighting	Amusement
Biomass (kg)							
Fuelwood	1,022.74	972.05	44.56	6.13	—	—	—
Tree leaves	536.39	495.65	38.02	2.72	—	—	—
Crop residue	619.10	501.42	116.21	1.47	—	—	—
Dung cake/stick	484.26	456.77	22.35	5.14	—	—	—
Sawdust	3.19	3.19	—	—	—	—	—
Non-biomass							
Candle (piece)	1.87	—	—	—	—	1.87	—
Kerosene (liter)	26.02	3.38	—	—	—	22.63	—
Natural gas (Tk)	—	—	—	—	—	—	—
LPG/LNG (liter)	—	—	—	—	—	—	—
Grid electricity (kWh)	232.50	0.70	—	6.48	95.21	114.07	16.04
Solar PV (kWh)	0.66	—	—	—	0.15	0.48	0.03
Storage cell (kWh)	1.52	—	—	—	—	0.56	0.96
Dry-cell battery (piece)	9.92	—	—	—	—	—	—

Source: BIDS Survey (2004).

Table A1.8.2

Annual Household Energy Consumption: Rajshahi (average per household)

Energy Type	All Uses	Heating			Cooling	Lighting	Amusement
		Cooking	Parboiling	Other			
Biomass (kg)							
Fuelwood	480.05	454.31	25.74	—	—	—	—
Tree leaves	365.47	348.10	17.07	0.31	—	—	—
Crop residue	847.10	723.86	118.47	4.78	—	—	—
Dung cake/stick	737.40	708.79	26.90	1.71	—	—	—
Sawdust	8.70	8.62	0.08	—	—	—	—
Non-biomass							
Candle (piece)	0.38	—	—	—	—	0.38	—
Kerosene (liter)	22.08	0.68	—	0.01	—	21.39	—
Natural gas (Tk)	—	—	—	—	—	—	—
LPG/LNG (liter)	0.02	0.02	—	—	—	—	—
Grid electricity (kWh)	64.10	0.30	—	0.41	20.84	38.77	3.78
Solar PV (kWh)	—	—	—	—	—	—	—
Storage cell (kWh)	—	—	—	—	—	—	—
Dry-cell battery (piece)	15.50	—	—	—	—	—	—

Source: BIDS Survey (2004).

Table A1.8.3

Annual Household Energy Consumption: Chittagong (average per household)

Energy Type	All Uses	Heating			Cooling	Lighting	Amusement
		Cooking	Parboiling	Other			
Biomass (kg)							
Fuelwood	2,069.84	1,714.93	18.70	336.21	—	—	—
Tree leaves	386.68	378.17	8.24	0.27	—	—	—
Crop residue	454.007	369.07	84.80	0.20	—	—	—
Dung cake/stick	235.95	232.82	2.42	0.70	—	—	—
Sawdust	4.50	4.50	—	—	—	—	—
Non-biomass							
Candle (piece)	51.94	—	—	—	—	51.94	—
Kerosene (liter)	36.01	2.15	—	0.06	—	33.81	—
Natural gas (Tk)	35.81	35.81	—	—	—	—	—
LPG/LNG (liter)	0.15	0.15	—	—	—	—	—
Grid electricity (kWh)	226.15	—	—	7.31	65.68	139.12	14.04
Solar PV (kWh)	—	—	—	—	—	—	—
Storage cell (kWh)	0.25	—	—	—	—	—	0.25
Dry-cell battery (piece)	15.57	—	—	—	—	—	—

Source: BIDS Survey (2004).

Table A1.8.4

Annual Household Energy Consumption: Khulna (average per household)

		Heating					
Energy Type	**All Uses**	**Cooking**	**Parboiling**	**Other**	**Cooling**	**Lighting**	**Amusement**
Biomass (kg)							
Fuelwood	1,107.29	1,076.16	25.75	5.39	—	—	—
Tree leaves	746.18	685.41	60.70	0.07	—	—	—
Crop residue	941.29	575.80	360.71	4.78	—	—	—
Dung cake/stick	670.05	647.03	13.23	9.78	—	—	—
Sawdust	18.36	18.28	—	0.08	—	—	—
Non-biomass							
Candle (piece)	6.07	—	—	—	—	6.07	—
Kerosene (liter)	31.60	0.70	—	0.2	—	30.70	—
Natural gas (Tk)	—	—	—	—	—	—	—
LPG/LNG (liter)	—	—	—	—	—	—	—
Grid electricity (kWh)	37.40	—	—	1.32	11.69	21.84	2.55
Solar PV (kWh)	1.57	—	—	—	—	1.57	—
Storage cell (kWh)	0.42	—	—	—	—	—	0.42
Dry-cell battery (piece)	19.40	—	—	—	—	—	—

Source: BIDS Survey (2004).

Table A1.9

Average Energy Consumption for Agriculture and Transportation (owner–users only)

	Agriculture			
Energy Type	**Irrigation pump**	**Power tiller/tractor**	**Thresher**	**Transport**
Electricity (kWh)	3643.47 (9)	—	78.13 (17)	—
Diesel (liter)	347.95 (103)	238.24 (35)	—	13,003.55 (14)

Source: BIDS Survey (2004).

Note: Figures in parentheses indicate the number of households that own and operate the relevant equipment.

Table A1.10

Energy Consumption by Business Type

	Home Enterprise		Village Enterprise		Institution	
Energy Type	**Users (% total units)**	**Energy use/ unit/year[1]**	**Users (% total units)**	**Energy use/ unit/year[1]**	**Users (% total units)**	**Energy use/ unit/year[1]**
Biomass (kg)	**26.3**		**12.3**		**10.3**	
Fuelwood	19.7	395.12	7.3	311.46	9.0	657.00
Tree leaves	7.3	74.54	0.6	2.11	—	—
Crop residue[2]	15.3	277.62	2.0	949.09	3.2	5.67
Dung cake/stick	5.1	21.64	3.5	149.00	1.9	8.38
Sawdust	2.2	77.52	1.2	6.18	—	—
Briquette	—	—	0.6	12.81	—	—
Charcoal	1.5	2.85	1.5	3.95	—	—
Non-biomass	**72.3**		**98.5**		**74.4**	
Candle (piece)	3.6	5.26	21.1	18.16	45.5	100.87
Kerosene (liter)	55.5	13.52	78.9	84.04	37.8	18.66
Diesel/petrol (liter)	5.1	45.59	4.4	60.50	1.3	2.35
Grid electricity (kWh)	25.5	194.68	51.2	360.04	42.3	439.97
Storage cell (kWh)	0.7	3.15	2.6	12.00	7.1	39.00
Dry cell battery (piece)	2.9	0.83	23.7	6.24	12.8	3.50
All	79.6		98.5		75.0	

Source: BIDS Survey (2004).

[1] Average over all units.

[2] Includes crop waste and weeds.

Table A1.11

Household Distribution of Cooking Stove Ownership (percent)

Stove Type	Dhaka	Rajshahi	Chittagong	Khulna	All Divisions
Clay (fixed)	99.0	99.7	98.6	100.0	99.3
Clay (portable)	30.7	31.7	3.0	11.9	19.2
Kerosene	6.5	1.0	0.8	1.1	2.3
Gas	0.2	—	1.3	—	0.4
Electric heater	0.3	0.2	0.2	—	0.2

Source: BIDS Survey (2004).

Table A1.12

Household Ownership of Cooking Stoves by Type (number per 100 households)

Stove Type	Dhaka	Rajshahi	Chittagong	Khulna	All Divisions
Clay (fixed)	200.0	172.3	182.8	174.8	182.7
Clay (portable)	33.2	32.8	3.9	12.6	20.5
Kerosene	7.1	1.0	0.8	1.3	2.5
Gas	0.1	—	1.3	—	0.4
Electric heater	0.3	0.2	1.7	—	0.2
All	240.7	206.3	190.5	188.7	206.3

Source: BIDS Survey (2004).

Table A1.13

Household Distribution of Number of Meals and Cooking Times (percent distribution)

Number of Meals	Cooking Times	Dhaka	Rajshahi	Chittagong	Khulna	All Divisions
4	2	0.5	—	0.5	1.6	0.6
4	3	8.6	—	0.3	—	0.1
4	4	—	—	0.2	—	—
3	1	—	3.3	8.6	32.5	12.8
3	2	77.4	81.0	47.6	63.1	67.1
3	3	11.6	12.7	38.9	2.2	17.0
2	2	0.7	1.6	0.3	0.4	0.8
2	2	1.2	1.2	3.6	0.2	1.6
1	1	—	—	—	—	—
All		—	0.2	—	—	—

Source: BIDS Survey (2004).

Table A1.14

Hours of Operating Cooking Stoves by Type (daily)

Stove Type	Dhaka	Rajshahi	Chittagong	Khulna	All Divisions
Clay (fixed)	2.97	2.96	4.01	2.93	3.23
Clay (portable)	1.42	2.63	2.77	1.39	2.01
All	3.36	3.79	4.07	3.06	3.59

Source: BIDS Survey (2004).

Note: Kerosene stoves and electric heaters are mainly for occasional use, but more information is needed; data on gas stoves are lacking.

Table A1.15

Household Ownership of Lighting Appliances (number per 100 households)

Appliance Type	Dhaka	Rajshahi	Chittagong	Khulna	All Divisions
Grid electrified households					
Kupi/cherag	153.0	162.3	212.4	161.0	176.7
Hurricane/lantern	80.3	77.0	95.6	81.4	85.3
Petromax	1.1	1.6	—	—	0.7
Light bulbs	310.6	315.6	414.5	308.5	348.6
Tube lights	36.7	18.9	77.9	20.3	47.0
Charger (include charger torch)	—	0.8	19.3	1.7	7.2
Non-electrified and off-grid electrified households					
Kupi/cherag	162.5	160.5	210.2	196.7	182.8
Hurricane/lantern	89.7	90.2	98.2	84.7	90.3
Petromax	0.6	0.8	—	0.4	0.5
Light bulbs	—	—	—	—	—
Tube lights	2.9*	—	—	6.7*	2.5*
Charger (include charger torch)	—	—	0.5	—	0.1
All Households					
Kupi/cherag	158.4	160.8	211.1	192.9	181.0
Hurricane/lantern	85.6	87.5	97.2	84.3	88.9
Petromax	0.8	1.0	—	0.4	0.5
Light bulbs	136.0	64.2	161.3	33.2	101.2
Tube lights	17.7	3.8	30.3	8.2	15.4
Charger (include charger torch)	—	0.2	7.8	0.2	2.2

Source: BIDS Survey (2004).

*It should be noted that 11 households without an electricity connection have solar panels (10) biogas plant (1), which use tube lights.

Table A1.16

Hours of Running Lighting Appliances (cases per day)

Appliance Type	Dhaka	Rajshahi	Chittagong	Khulna	All Divisions
Kupi/cherag	1.58 (583)	2.05 (582)	2.24 (623)	2.18 (546)	2.01 (2334)
Hurricane/lantern	3.32 (375)	4.15 (390)	2.97 (470)	3.63 (347)	3.49 (1582)
Petromax	0.38 (4)	0.22 (4)	—	6.90 (2)	1.62 (10)
Light bulbs	3.80 (259)	4.09 (121)	3.83 (247)	3.85 (54)	3.86 (681)
Tube lights	3.54 (55)	4.65 (13)	3.91 (88)	3.67 (15)	3.82 (171)
Torch/charger	—	0.50 (1)	1.74 (41)	2.00 (1)	1.71 (43)
All	2.62 (1276)	3.03 (1111)	2.83 (1469)	2.83 (965)	2.82 (4821)

Source: BIDS Survey (2004).

Note: Figures in parentheses indicate number of cases.

Table A1.17

Household Ownership of Plug-in Electric Appliances (number per 100 households)

Appliance Type	Dhaka	Rajshahi	Chittagong	Khulna	All Divisions
Radio/cassette recorder	16.7	4.5	195.3	5.5	118.4
VCR/VCP/television	23.1	6.7	15.8	4.7	12.8
Electric cooling fan	50.1	17.3	56.1	8.0	33.8
Other	9.6	1.2	21.1	1.5	8.7
All	99.5	29.7	288.3	19.7	173.7

Source: BIDS Survey (2004).

Table A1.18

Hours of Running the Plug-in Type of Electric Appliances (daily)

Appliance Type	Dhaka	Rajshahi	Chittagong	Khulna	All Divisions
Radio/cassette recorder	2.06 (97)	2.95 (26)	2.41 (118)	2.84 (30)	2.38 (271)
VCR/VCP/television	3.06 (133)	3.55 (41)	3.76 (101)	3.21 (26)	3.39 (300)
Electric cooling fan	7.21 (163)	7.09 (57)	7.75 (177)	8.12 (25)	7.47 (422)
Other	4.58 (53)	0.35 (5)	2.81 (129)	0.52 (8)	3.36 (182)
All	4.54 (446)	4.87 (129)	4.57 (525)	4.22 (89)	4.62 (1175)

Source: BIDS Survey (2004).
Note: Figures in parentheses indicate number of cases.

Table A1.19

Ownership of Irrigation Pumps and Power Tillers/Tractors (percent households)

Pump/Vehicle Type	Dhaka	Rajshahi	Chittagong	Khulna	All Divisions
Irrigation pump (electric)	—	1.3	0.2	—	0.4
Irrigation pump (diesel)	1.8	12.2	0.5	4.0	4.6
Power tiller/tractor (diesel)	1.3	3.8	—	1.6	1.7

Source: BIDS Survey (2004).

Table A1.20

Hours of Running Pumps and Power Tillers/Tractors (annual hours per unit)

Pump/Vehicle Type	Dhaka	Rajshahi	Chittagong	Khulna	All Divisions
Irrigation pump (electric)	—	1,382	1,050	—	1,345
Irrigation pump (diesel)	441	404	341	283	381
Power tiller/tractor (diesel)	548	239	—	856	440

Source: BIDS Survey (2004).

Table A1.21

Cost of Household Energy Consumption: All Divisions (Tk per household per year)

		Heating					
Energy Source	**All Uses**	**Cooking**	**Parboiling**	**Other**	**Cooling**	**Lighting**	**Amusement**
Biomass	**3,798.50**	**3,379.57**	**242.17**	**176.76**	**—**	**—**	**—**
Fuelwood	1,962.25	1,749.59	44.78	167.88	—	—	—
Tree leaves	470.40	440.22	29.14	1.04	—	—	—
Crop residue*	641.23	491.80	147.08	2.35	—	—	—
Dung cake/stick	716.34	689.72	21.15	5.47	—	—	—
Sawdust	8.28	8.24	0.02	0.02	—	—	
Non-biomass	**1,303.26**	**65.24**	**—**	**10.56**	**134.33**	**—**	**—**
Candle	7.83	—	—	—	—	7.83	—
Kerosene	607.67	37.04	—	1.38	—	569.25	—
Natural gas	9.59	9.59	—	—	—	—	—
LPG/LNG	18.02	18.02	—	—	—	—	—
Grid electricity	487.69	0.59	—	9.18	134.26	311.89	31.77
Solar PV	1.08	—	—	—	0.07	0.99	0.02
Storage cell	10.73	—	—	—	—	2.75	7.98
Dry-cell battery	160.65	—	—	—	—	—	—
All	5,101.76	3,444.81	242.17	187.32	134.33	—	—

Source: BIDS Survey (2004).

*Also includes crop waste and weeds.

Table A1.21.1

Cost of Household Energy Consumption: Dhaka (Tk per household per year)

		Heating					
Energy Source	**All Uses**	**Cooking**	**Parboiling**	**Other**	**Cooling**	**Lighting**	**Amusement**
Biomass	**3,802.63**	**3,475.16**	**305.32**	**22.15**	**—**	**—**	**—**
Fuelwood	1,610.82	1,530.99	70.18	9.65	—	—	—
Tree leaves	712.86	658.72	50.53	3.61	—	—	—
Crop residue	822.78	666.39	154.44	1.95	—	—	—
Dung cake/stick	653.75	616.64	30.17	6.94	—	—	—
Sawdust	2.42	2.42	—	—	—	—	—
Non-biomass	**1,414.24**	**73.67**	**—**	**13.68**	**226.97**	**—**	**—**
Candle	7.64	—	—	—	—	7.64	—
Kerosene	560.10	72.80	—	0.17	—	487.13	—
Natural gas	—	—	—	—	—	—	—
LPG/LNG	—	—	—	—	—	—	—
Grid electricity	710.35	0.87	—	13.51	226.67	414.83	54.47
Solar PV	1.35	—	—	—	0.30	0.99	0.06
Storage cell	18.33	—	—	—	—	4.69	13.64
Dry-cell battery	116.47	—	—	—	—	—	—
All	5,216.87	3,548.83	305.32	35.83	226.97	—	—

Source: BIDS Survey (2004).

Table A1.21.2

Cost of Household Energy Consumption Rajshahi (Tk per household per year)

		Heating					
Energy Source	**All Uses**	**Cooking**	**Parboiling**	**Other**	**Cooling**	**Lighting**	**Amusement**
Biomass	**2,541.51**	**2,361.38**	**174.11**	**6.02**	**—**	**—**	
Fuelwood	685.03	648.30	36.73	—	—	—	—
Tree leaves	279.58	266.29	13.06	0.23	—	—	—
Crop residue	648.03	553.75	90.63	3.65	—	—	—
Dung cake/stick	921.74	885.98	33.62	2.14	—	—	—
Sawdust	7.13	7.06	0.07	—	—	—	—
Non-biomass	**906.26**	**22.03**	**—**	**1.66**	**74.91**	**—**	**—**
Candle	0.88	—	—	—	—	0.88	—
Kerosene	474.24	14.56	—	0.13	—	459.55	—
Natural gas	—	—	—	—	—	—	—
LPG/LNG	6.00	6.00	—	—	—	—	—
Grid electricity	284.24	1.47	—	1.53	74.91	193.62	12.71
Solar PV	—	—	—	—	—	—	—
Storage cell	4.92	—	—	—	—	1.26	3.66
Dry-cell battery	135.98	—	—	—	—	—	—
All	3,447.77	2,383.20	174.11	7.68	74.91	—	—

Source: BIDS Survey (2004).

Table A1.21.3

Cost of Household Energy Consumption Chittagong (Tk per household per year)

		Heating					
Energy Source	**All Uses**	**Cooking**	**Parboiling**	**Other**	**Cooling**	**Lighting**	**Amusement**
Biomass	**4,901.92**	**4,177.90**	**111.01**	**613.01**	**—**	**—**	**—**
Fuelwood	3,762.96	3,117.74	33.99	611.23	—	—	—
Tree leaves	299.67	293.08	6.38	0.21	—	—	—
Crop residue	351.90	286.03	65.72	0.15	—	—	—
Dung cake/stick	478.97	472.63	4.92	1.42	—	—	—
Sawdust	8.42	8.42	—	—	—	—	—
Non-biomass	**1,793.87**	**141.15**	**—**	**19.12**	**187.15**	—	—
Candle	17.46	—	—	—	—	17.46	—
Kerosene	732.15	43.63	—	1.25	—	687.27	—
Natural gas	35.81	35.81	—	—	—	—	—
LPG/LNG	61.71	61.71	—	—	—	—	—
Grid electricity	761.21	—	—	17.87	187.15	507.43	48.76
Solar PV	—	—	—	—	—	—	—
Storage cell	7.07	—	—	—	—	1.81	5.26
Dry-cell battery	178.46	—	—	—	—	—	—
All	6,695.79	4,319.05	111.01	632.13	187.15	—	—

Source: BIDS Survey (2004).

Table A1.21.4

Cost of Household Energy Consumption: Khulna (Tk per household per year)

		Heating					
Energy Source	**All Uses**	**Cooking**	**Parboiling**	**Other**	**Cooling**	**Lighting**	**Amusement**
Biomass	**3,881.41**	**3,456.80**	**400.33**	**24.28**	**—**	**—**	**—**
Fuelwood	1,644.33	1,598.09	38.24	8.00	—	—	—
Tree leaves	611.87	562.04	49.77	0.06	—	—	—
Crop residue	771.86	472.16	295.78	3.92	—	—	—
Dung cake/stick	837.56	808.79	16.54	12.23	—	—	—
Sawdust	15.79	15.72	—	0.07	—	—	—
Non-biomass	**1,042.79**	**14.61**	**—**	**6.88**	**35.77**	—	—
Candle	4.42	—	—	—	—	—	—
Kerosene	660.73	14.61	—	4.22	—	641.90	—
Natural gas	—	—	—	—	—	—	—
LPG/LNG	—	—	—	—	—	—	—
Grid electricity	145.98	—	—	2.66	35.77	99.73	7.82
Solar PV	3.22	—	—	—	—	3.22	—
Storage cell	12.98	—	—	—	—	3.32	9.66
Dry-cell battery	215.46	—	—	—	—	—	—
All	4,924.20	3,471.41	400.33	31.16	35.77	—	—

Source: BIDS Survey (2004).

Table A1.22

Household Biomass Energy Behavior: All Divisions (percent distribution)

Energy Source	**Production**	**Gathering**	**Purchasing**	**Any Combination**	**None**
Fuelwood	9.6	24.6	17.8	10.3	37.7
Tree leaves	30.3	16.7	0.4	29.5	23.1
Crop residue*	36.0	9.8	4.7	27.0	22.5
Dung cake/stick	0.3	0.2	6.7	2.1	90.7
Sawdust	—	—	0.9	—	99.1

Source: BIDS Survey (2004).

*Also includes crop wastes and weeds; but mainly it is crop residue.

Table A1.22.1

Household Biomass Energy Behavior: Dhaka (percent distribution)

Energy Source	Production	Gathering	Purchasing	Any Combination	None
Fuelwood	10.1	18.1	24.9	11.3	35.6
Tree leaves	34.8	16.7	0.2	30.2	18.1
Crop residue	36.1	5.3	10.8	31.2	16.6
Dung cake/stick	0.2	—	10.4	3.5	85.9
Sawdust	—	—	0.8	—	99.2

Source: BIDS Survey (2004).

Table A1.22.2

Household Biomass Energy Behavior: Rajshahi (percent distribution)

Energy Source	Production	Gathering	Purchasing	Any Combination	None
Fuelwood	6.0	30.7	6.8	2.3	54.2
Tree leaves	17.8	24.2	—	30.3	27.7
Crop residue	38.0	14.2	3.2	42.6	2.0
Dung cake/stick	0.5	0.2	2.8	1.4	95.1
Sawdust	—	—	0.8	—	99.2

Source: BIDS Survey (2004).

Table A1.22.3

Household Biomass Energy Behavior: Chittagong (percent distribution)

Energy Source	Production	Gathering	Purchasing	Any Combination	None
Fuelwood	12.5	33.4	20.3	13.4	20.3
Tree leaves	27.3	10.5	0.6	23.8	37.8
Crop residue	32.7	10.8	1.1	9.0	46.4
Dung cake/stick	0.5	0.2	2.8	1.4	95.2
Sawdust	—	—	0.3	—	99.7

Source: BIDS Survey (2004).

Table A1.22.4

Household Biomass Energy Behavior: Khulna (percent distribution)

Energy Source	Production	Gathering	Purchasing	Any Combination	None
Fuelwood	9.7	15.0	19.2	14.2	42.0
Tree leaves	42.3	15.9	0.9	34.5	6.4
Crop residue	37.8	8.9	3.8	26.1	23.4
Dung cake/stick	0.4	0.2	2.4	1.4	95.6
Sawdust	—	—	1.8	—	98.2

Source: BIDS Survey (2004).

Table A1.23

Household Consumption of Selected Biomass Energies: All Divisions (per year)

		% Distribution by Source		
Energy Type	Household Consumption (kg/yr)	Own Production	Gathered	Purchased
Fuelwood	1,186.21	10.96	49.76	39.28
Tree leaves	501.51	52.23	46.33	1.44
Crop residue	708.18	68.55	24.67	6.78
Dung cake/stick	523.90	72.22	5.25	22.53
Sawdust	8.40	—	—	100.00
All	2,928.20	42.89	35.00	22.11

Source: BIDS Survey (2004).

Table A1.23.1

Household Consumption of Selected Biomass Energies: Dhaka (per year)

		% Distribution by Source		
Energy Type	Household Consumption (kg/yr)	Own Production	Gathered	Purchased
Fuelwood	1,022.74	6.30	26.86	66.84
Tree leaves	536.39	55.54	43.89	0.57
Crop residue	619.10	72.16	15.02	12.82
Dung cake/stick	484.26	23.19	9.23	67.58
Sawdust	3.19	—	—	100.00
All	2,665.68	34.56	24.30	41.14

Source: BIDS Survey (2004).

Table A1.23.2

Household Consumption of Selected Biomass Energies: Rajshahi (per year)

		% Distribution by Source		
Energy Type	**Household Consumption (kg/yr)**	**Own Production**	**Gathered**	**Purchased**
Fuelwood	480.05	7.32	55.42	37.26
Tree leaves	365.47	40.96	58.90	0.14
Crop residue	847.10	67.47	28.28	4.25
Dung cake/stick	737.40	24.98	17.12	57.90
Sawdust	8.70	—	—	100.00
All	2,438.72	38.57	34.73	26.70

Source: BIDS Survey (2004).

Table A1.23.3

Household Consumption of Selected Biomass Energies: Chittagong (per year)

		% Distribution by Source		
Energy Type	**Household Consumption (kg/yr)**	**Own Production**	**Gathered**	**Purchased**
Fuelwood	2,069.84	14.02	61.90	24.08
Tree leaves	386.68	57.77	41.17	1.06
Crop residue	454.07	69.36	28.85	1.79
Dung cake/stick	235.95	82.77	3.58	13.65
Sawdust	4.50	—	—	100.00
All	3,151.04	32.49	50.14	17.37

Source: BIDS Survey (2004).

Table A1.23.4

Household Consumption of Selected Biomass Energies: Khulna (per year)

		% Distribution by Source		
Energy Type	**Household Consumption (kg/yr)**	**Own Production**	**Gathered**	**Purchased**
Fuelwood	1,107.29	7.61	32.44	59.95
Tree leaves	746.18	55.51	40.33	4.16
Crop residue	941.29	66.58	25.66	7.76
Dung cake/stick	670.05	92.49	1.30	6.21
Sawdust	18.36	—	—	100.00
All	3,483.17	50.10	26.14	23.77

Source: BIDS Survey (2004).

Table A1.24

Operational Land and Household Ownership of Gardens

Characteristic	Dhaka	Rajshahi	Chittagong	Khulna	All Divisions
Operational land Households with cultivation (percent)	53.23	69.50	61.72	59.49	61.02
Operational area/household (decimal)*	214.58	376.50	321.76	276.69	276.43
Garden Household ownership (percent)	9.29	13.50	20.63	43.61	21.25
Area under garden/household (decimal)*	78.13	23.38	202.06	26.49	77.31

Source: BIDS Survey (2004).

* Refers to ownership households; 1 decimal = 50 square yards.

Table A1.25

Household Ownership of Trees and Bamboo

Characteristic	Dhaka	Rajshahi	Chittagong	Khulna	All Divisions
Trees % household ownership	89.05	83.67	88.75	89.60	87.75
Number of mature trees/household*	37.18	22.24	79.65	70.19	52.83
Number of immature trees/household*	39.15	34.36	256.27	111.56	113.73
Bamboo groves % household own	47.76	44.33	38.28	44.89	43.71
Number of mature bamboo/household*	119.05	90.77	474.22	69.83	183.53
Number of immature bamboo/household*	74.26	93.92	499.03	79.95	180.19

Source: BIDS Survey (2004).

* Refers to ownership households.

Table A1.26

Household Ownership of Cattle

Characteristic	Dhaka	Rajshahi	Chittagong	Khulna	All Divisions
Cows % household ownership	39.30	40.67	53.44	46.35	45.04
Number of cows/household*	2.63	2.83	2.77	2.48	2.68
Buffaloes % household ownership	0.17	0.83	0.31	1.46	0.67
Number of buffaloes/household*	1.00	2.00	2.00	3.50	2.69

Source: BIDS Survey (2004).

*Refers to ownership households.

Table A1.27

Household Distribution by Duration of Electricity Connection (percent distribution)

Duration of Connection	Dhaka	Rajshahi	Chittagong	Khulna	All Divisions
No connection	56.2	79.7	61.1	89.2	71.0
With connection (months)	43.8	20.3	38.9	10.8	29.0
01—06	4.6	1.7	2.5	0.6	2.4
07—12	7.3	1.3	3.4	0.7	3.3
13—24	9.6	2.0	5.6	2.6	5.0
25—36	4.5	2.3	5.6	2.9	3.9
37—60	6.3	4.5	4.8	1.6	4.4
61 or more	10.0	7.8	16.4	2.0	9.3
Date not reported	1.5	0.7	0.5	0.4	0.7

Source: BIDS Survey (2004).

Table A1.28

Electricity Sources (percent of connected households)

Source	Dhaka	Rajshahi	Chittagong	Khulna	All Divisions
Palli Bidyut Samity (PBS)	70.8	84.4	71.5	72.9	73.6
Neighbor with PBS connection	28.4	15.6	17.7	22.0	21.8
Power Development Board (PDB)	0.4	—	5.6	—	2.2
Neighbors with PDB connection	—	—	5.2	1.7	2.0
Other (own or local generation)	0.4	—	—	3.4	0.4

Source: BIDS Survey (2004).

Table A1.29

Basis of Charging for Electricity (percent of connected households)

Basis	Dhaka	Rajshahi	Chittagong	Khulna	All Divisions
Kilowatt hours consumed	67.8	81.1	75.1	62.7	72.3
Number of electric appliances/bulbs/tubes	15.9	6.6	5.2	18.6	10.7
Monthly fixed charge	7.6	7.4	18.9	10.2	11.8
No charge	1.5	0.8	0.4	—	0.9
Other	2.7	3.3	0.4	6.8	2.3
Not reported	4.5	0.8	—	1.7	2.0

Source: BIDS Survey (2004).

Table A1.30

Household Distribution by Electricity Supply Problem (percent of connected households)

Problem	Dhaka	Rajshahi	Chittagong	Khulna	All Divisions
Unscheduled power cuts	**74.2**	**69.7**	**93.6**	**59.3**	**79.1**
Daily	6.4	0.8	2.0	6.8	3.9
Weekly	10.2	27.1	4.0	20.3	11.8
Rarely	6.4	0.8	—	10.2	3.5
Never	2.7	1.6	0.4	3.4	1.7
Not reported					
Voltage fluctuation	**44.3**	**53.3**	**81.1**	**55.9**	**60.1**
Daily	14.8	1.6	—	3.4	6.2
Weekly	34.1	37.7	15.7	32.2	28.0
Rarely	4.2	5.7	2.8	5.1	4.0
Never	2.6	1.6	0.4	3.4	1.7
Not reported					

Source: BIDS Survey (2004).

Table A1.31

Cost of Kerosene—Using Devices

Device	Purchase Value/ Household (Tk)	Monthly Repair Cost/Household (Tk)
Kupi/cherag	14.05 (2,332)	0.09 (2,327)
Hurricane lantern	86.09 (1,645)	2.66 (1,641)
Petromax	810.42 (12)	25.42 (12)

Source: BIDS Survey (2004).

Note: Figures in parentheses indicate number of cases.

Table A1.32

Cost of Electric Bulbs and Tube Lights

Item	Annual Cost/Household
Bulbs/tube lights bought (no.)	5.23 (648)
Cost (Tk)	111.79 (648)

Source: BIDS Survey (2004).

Note: Figures in parentheses indicate number of cases.

Table A1.33

Women's Time Use for Various Activities (daily hours per person)

Activity Type	Dhaka	Rajshahi	Chittagong	Khulna	All Divisions
Crop processing	0.24	0.48	0.44	0.55	0.43
Collecting energy	0.22	0.48	0.41	0.31	0.36
Cooking/washing/ feeding/eating	6.26	5.81	6.34	6.18	6.15
Fetching water/washing clothes	1.38	1.62	1.47	1.26	1.44
Cleaning house/bathing	1.87	1.80	1.55	1.48	1.68
Childcare	1.27	1.03	1.29	1.17	1.19
Gainful work	0.83	0.70	0.97	0.54	0.77
Religious work	0.98	0.91	1.22	0.76	0.98
Study/reading	0.07	0.06	0.07	0.04	0.06
Watching TV/listening to radio	1.41	1.37	1.24	1.43	1.36
Visiting neighbors	0.95	1.07	0.77	0.95	0.93
Sleeping	8.19	8.46	8.01	8.61	8.31
Other	0.32	0.20	0.21	0.72	0.35

Source: BIDS Survey (2004).

Table A1.34

Time Spent Making Clay Stoves (hours per stove)

Stove Type	Adult Male	Adult Female
Fixed clay	3.83	5.10
Portable burnt clay	6.05	6.88

Source: BIDS Survey (2004).

Table A1.35

Time Spent on Clay Stove Maintenance

Stove Type	Times per Month Each Stove Is Repaired	Repair Hours per Incident	Total Monthly Repair Hours
Fixed clay	4.80	0.54	2.59
Portable burnt clay	2.60	0.41	1.07

Source: BIDS Survey (2004).

Table A1.36

Respondents' Attitude toward Electricity (percent distribution)

Advantage/Disadvantage	Rank–1	Rank–2	Rank–3
Advantage			
Electric light is superior to kerosene light	70.0	10.0	6.2
Easier to study by electric light than kerosene light	3.6	13.4	4.2
Children devote more time to study at night if electric light	6.5	16.0	12.2
People feel secure at night with electric light	5.3	26.2	18.3
Electric light is not as harmful to health as kerosene light	0.3	3.9	4.2
Running TV is easier by electricity than battery	2.4	5.7	8.5
Electricity costs less than battery to run TV	0.6	2.6	4.6
Hard to work at night without electricity	1.7	6.1	12.4
Easier to entertain guests at night if electricity	—	1.0	2.3
Electricity is important for water supply in our locality	1.1	1.0	2.0
Cooking with electricity causes no smoke	0.2	0.7	1.7
Life is easy with electricity	2.7	5.2	13.1
Disadvantage			
Children will waste reading time watching TV	16.3	12.1	5.8
Electricity often causes accident that ends in death	54.9	19.3	8.5
Cooking is not advantageous with electricity	4.9	8.7	7.5
Electricity is very expensive	9.3	24.8	19.4
Bulb/tube etc. is expensive	3.0	17.0	22.4
Electric supply is very irregular and voltage is often low	10.1	13.6	22.4

Source: BIDS Survey (2004).

Table A1.37

Respondents' Attitude toward Fuelwood (percent distribution)

Advantage/Disadvantage	Rank–1	Rank–2	Rank–3
Advantage			
Fuelwood is easy to collect	40.9	22.0	13.3
Fuelwood is cheaper in the market	2.8	10.1	11.5
Fuelwood is obtained from own trees without any cost	25.3	26.1	12.4
Disadvantage			
Cooking with fuelwood is not advantageous	6.8	4.2	2.5
Fuelwood generates smoke that creates breathing problems	56.1	16.9	8.8
Cooking with fuelwood is harmful to health	3.7	20.5	13.6
Fuelwood is very expensive	12.8	19.2	8.9
Getting fuelwood in the market is difficult	1.5	6.4	7.7
Excessive use of fuelwood is the root cause of deforestation	13.0	19.2	29.0

Source: BIDS Survey (2004).

Table A1.38

Respondents' Attitude toward Kerosene (percent distribution)

Advantage/Disadvantage	Rank–1	Rank–2
Advantage		
Cooking is easier with kerosene	22.0	12.4
Kerosene is not expensive for lighting	35.9	31.1
Kerosene is the best way for lighting for our family	28.6	21.2
Disadvantage		
Use of kerosene is very expensive for cooking	57.4	18.9
Foods cooked with kerosene are harmful to health	24.0	48.8
Kerosene is not easily available in the market	1.8	4.5

Source: BIDS Survey (2004).

Table A1.39

Respondents' Attitude toward LPG/LNG (percent distribution)

Advantage/Disadvantage	Rank–1	Rank–2
Advantage		
Cooking is easier with LPG/LNG	36.4	1.2
Foods cooked with LPG/LNG are not harmful to health	1.1	19.4
Disadvantage		
Use of LPG/LNG is very expensive for cooking	25.3	6.0
LPG/LNG is not easily available in the market	8.0	15.5
LPG/LNG cooking devices are expensive	2.0	11.1

Source: BIDS Survey (2004).

Table A1.40

Respondents' Knowledge of Price of Kerosene (percent distribution)

Factor	Dhaka	Rajshahi	Chittagong	Khulna	All Divisions
Kerosene is cheaper	1.8	0.5	0.5	1.3	1.0
Price is justified	3.8	11.2	9.7	4.6	7.4
Kerosene is costly	93.9	88.2	89.7	93.8	91.3
Do not know	0.5	0.2	0.2	0.4	0.3

Source: BIDS Survey (2004).

Table A1.41

Respondents' Reasons for Costliness of Kerosene (percent of those who reported kerosene as costly)

Reason	Dhaka	Rajshahi	Chittagong	Khulna	All Divisions
Kerosene is taxed	3.4	7.0	1.4	1.2	3.2
No subsidy on kerosene	0.4	4.7	0.5	0.2	1.4
Iraq—U.S. war	38.0	12.7	12.9	33.5	24.2
Do not know	58.3	75.6	85.2	65.2	71.2

Source: BIDS Survey (2004).

Table A1.42

Respondents' Knowledge of Price of Electricity (percent distribution)

Factor	Dhaka	Rajshahi	Chittagong	Khulna	All Divisions
Electricity is cheaper	6.3	3.0	1.6	1.8	3.2
Price is justified	8.3	3.7	18.0	6.4	9.3
Kerosene is costly	70.5	54.8	68.4	51.5	61.6
Do not know	14.9	38.5	12.0	40.3	25.9

Source: BIDS Survey (2004).

Table A1.43

Respondents' Reasons for Costliness of Electricity (percent of those who reported electricity as costly)

Reason	Dhaka	Rajshahi	Chittagong	Khulna	All Divisions
Electricity is taxed	4.5	13.4	2.5	2.1	5.4
No subsidy on electricity	0.5	8.8	0.9	0.7	2.5
Other	74.1	70.5	87.9	82.6	79.0
Do not know	20.9	7.3	8.7	14.6	13.0

Source: BIDS Survey (2004).

Table A1.44

Respondents' Knowledge of Renewable Energy (percent distribution)

		Whether Available in the Market (% of those who have heard about)		Whether Interested in Purchasing (% of those who have heard about)	
Renewable Energy Type	Heard About	Yes	No	Yes	No
Personal biogas plant	16.3	75.1	24.9	78.9	21.1
Improved stove	8.8	59.0	41.0	71.1	28.9
Solar cooker	3.2	47.3	52.7	59.7	40.3
Solar PV light	12.0	31.8	68.2	72.1	27.9
Solar PV lantern	0.9	55.0	45.0	55.0	45.0
Biogas light	3.4	82.7	17.3	67.1	32.9
Solar PV water heater	0.6	61.5	38.5	35.7	64.3
Solar PV water pump	0.6	60.0	40.0	33.3	66.7
Windmill water pump	0.7	68.7	31.3	37.5	62.5
Pressure cooker	25.0	9.0	91.0	57.5	42.5

Source: BIDS Survey (2004).

Table A1.45

Respondents' Reasons for Interest in Purchasing Renewable Energy Devices (percent of those interested in purchasing)

	Reason					
Renewable Energy Type	Cheaper	Easily Available	Prestige	Advantage	Can Buy on Credit	Other
Personal biogas plant	2.5	—	3.7	82.7	1.2	9.9
Improved stove	—	—	—	93.1	—	6.9
Solar cooker	—	—	3.4	82.8	6.9	6.9
Solar PV light	—	2.5	5.1	54.4	30.4	7.6
Solar PV lantern	—	—	11.1	77.8	—	11.1
Biogas light	3.7	—	3.7	77.8	—	14.8
Solar PV water heater	—	—	11.1	77.8	—	11.1
Solar PV water pump	—	—	—	80.0	—	20.0
Windmill water pump	—	—	—	80.0	10.0	10.0
Pressure cooker	0.4	2.8	4.3	82.3	—	10.2

Source: BIDS Survey (2004).

Table A1.46

Respondents' Reasons for Disinterest in Purchasing Renewable Energy Devices (percent of those not interested in purchasing)

	Reason						
Renewable Energy Type	Not Known Where Available	Costly	Lack of Money	Unsure about Utility	Not Easily Available	Cannot Buy on Credit	Other
Personal biogas plant	10.3	9.6	23.0	25.9	4.6	2.1	24.5
Improved stove	22.0	12.9	12.9	42.4	3.0	0.8	6.0
Solar cooker	16.7	21.4	16.7	26.2	4.7	2.4	11.9
Solar PV light	7.4	22.3	29.2	13.4	1.0	2.0	24.7
Solar PV lantern	10.0	20.0	10.0	30.0	10.0	—	20.0
Biogas light	4.0	4.0	34.0	22.0	2.0	2.0	32.0
Solar PV water heater	—	—	25.0	25.0	25.0	—	25.0
Solar PV water pump	—	—	25.0	25.0	25.0	—	25.0
Windmill water pump	—	—	25.0	25.0	25.0	—	25.0
Pressure cooker	1.8	25.2	14.7	12.7	1.2	2.7	21.7

Source: BIDS Survey (2004).

Annex 2

Statistical Models

Chapter 3

Table A2.1

Tobit Estimate of Household Energy Demand (N = 2,388)

	Household Energy Demand			
Explanatory Variable	**Fuelwood (kg/month)**	**Kerosene (liter/month)**	**Diesel (liter/month)**	**Electricity (kWh/month)**
Gender of household head (1 = male, 0 = female)	1.614	0.204	0.064	4.275
Age of household head (yrs.)	–0.051	0.005**	0.001	1.049
Maximum education adult males in household (yrs.)	1.460**	0.019*	0.001	1.485
Maximum education adult females in household (yrs.)	0.759	0.017	–0.001	2.382
Log of household landholding (decimals)[1]	2.389**	0.105**	0.025**	4.640
Log of household non-land asset (Tk)	2.591**	0.031**	0.038**	4.448**
Energy price				
Fuelwood (Tk/kg)	–34.732**	0.321**	–0.003	–0.119
Kerosene (Tk/liter)	5.951**	–0.009	0.002	0.534
Diesel (Tk/liter)	–8.807**	–0.106**	0.001	–0.411
If village has electricity	14.211**	–0.597**	–0.015	32.782**
Proportion irrigated area in village	–2.039	–0.242**	0.031*	1.739**
Whether village has any				
Paved road	7.282**	–0.033	–0.025*	9.068
Primary school	9.818**	–0.157*	0.016	–7.571
Health center	–19.016**	0.053	–0.017	6.986
Market	–8.738**	–0.002	–0.018	–0.972
Commercial bank	–47.877**	0.442*	0.048	31.080
NGO	18.844**	–0.306*	–0.024	5.418

Source: BIDS Survey (2004).

Note: ** and * represent significance levels of 5 percent (or higher) and 10 percent, respectively.

[1] 1 decimal = 1/100 acre.

(continued)

Table A2.1

Continued

Explanatory Variable	Household Energy Demand: Fuelwood (kg/month)	Kerosene (liter/month)	Diesel (liter/month)	Electricity (kWh/month)
Village price				
Rice (Tk/kg)	–2.226	–0.168**	0.002	–3.040
Flour (Tk/kg)	–5.524**	–0.027	–0.006	–2.390
Potato (Tk/kg)	–4.242**	0.016	0.005	9.337*
Lentil (Tk/kg)	–4.163**	0.006	0.005*	–2.321
Fish (Tk/kg)	–0.093	–0.001**	–0.001*	0.173
Beef (Tk/kg)	–1.196**	0.001**	0.001	1.163
Chicken (Tk/kg)	–0.694**	–0.001*	0.0001	0.720
Soybean oil (Tk/liter)	0.210	–0.019	–0.004	–3.139*
Milk (Tk/liter)	2.618**	0.001	–0.002	0.599
Sugar (Tk/kg)	3.173**	0.057**	0.001	–2.329
Salt (Tk/kg)	10.741**	0.039	0.011	7.966
Village wage (Tk/day)				
Male	0.704**	0.008**	–0.001	0.192
Female	–0.913**	–0.008**	0.002	–0.648
Child	0.488**	–0.005	0.001	0.294
Region[1]				
Dhaka	21.673**	–0.079	–0.066**	–87.485**
Chittagong	84.843**	0.172	–0.157**	–104.459**
Khulna	27.633**	0.387**	–0.041*	–88.941**
Constant	326.571**	4.702**	–0.870**	4.842
Log likelihood	–11,984.917	1,439.135	–876.239	1,342.894

Source: BIDS Survey (2004).

Note: ** and * represent significance levels of 5 percent (or higher) and 10 percent, respectively.

[1]Among the regions Rajshahi is the excluded category.

Chapter 4

It is difficult to identify the causal effect of access to alternate energy sources on household income and consumption. Since energy demand and household consumption/income are jointly determined, it is difficult to correlate them without imposing certain restrictions on the demand function. The restriction applied here is that energy demand is influenced by energy prices, which can affect household income or consumption indirectly through demand. It is assumed that energy prices are determined by supply and demand, without individual households having any significant effect. Thus, a two-stage, least-squared instrument variable was used for this estimation (see Tables A2.2 and A2.3), where demand for energy sources was determined in the first phase.

Table A2.2

Effects of Energy Use on Household Outcomes by Use Type (*N* = 2,388)

Explanatory Variable	Household per Capita Consumption (Tk/month)	Household Income (Tk/month)[1]		
		Farm	Non-farm	Total
Gender of household head (1 = male, 0 = female)	–0.0440	0.598**	–1.049**	0.074
Age of household head (years)	0.0003	–0.002	0.009**	0.001
Maximum education of adult males (years)	0.0140**	–0.023*	0.120**	0.024**
Maximum education of adult females (years)	0.0005	–0.022*	0.072**	0.021**
Log of household landholding (decimal)[1]	0.0450**	0.309**	–0.160	0.066**
Log of non-land household asset (Tk)	0.0110**	0.162**	0.060**	0.049**
Non-lighting energy use (kgoe/year)	0.1270**	0.410**	0.025	0.208**
Lighting energy use (klmn–hr/year)	0.1360**	–0.010	0.387**	0.212**
If village has electricity	–0.0130	–0.141	0.903**	–0.058
Proportion irrigated area in village	0.0120	–0.153	–0.002	0.021
Whether village has any				
Paved road	0.0080	0.005	0.136	0.070**
Primary school	0.0290	0.158*	–0.047	0.063*
Health center	–0.0060	–0.368**	0.017	–0.063
Market	–0.0120	0.079	0.132	–0.021
Commercial bank	–0.0890	0.095	–0.506	–0.158*
NGO	–0.0780	–0.020	0.235	0.081
Village price				
Rice (Tk/kg)	0.0003	–0.161**	0.210**	0.008
Flour (Tk/kg)	–0.0040	–0.089**	–0.082	0.011
Potato (Tk/kg)	0.0110	–0.013	–0.026	–0.005
Lentil (Tk/kg)	–0.0050	0.047**	–0.092**	–0.010*
Fish (Tk/kg)	0.0010*	–0.004**	–0.003	0.001
Beef (Tk/kg)	0.0020*	–0.004	0.034**	0.007**
Chicken (Tk/kg)	–0.0040**	–0.002	–0.003	–0.004**
Soybean oil (Tk/liter)	0.0010	0.007	0.073**	–0.009*
Milk (Tk/liter)	0.0090**	0.020	–0.001	–0.009*
Sugar (Tk/kg)	0.0090*	0.028	–0.063*	–0.001
Salt (Tk/kg)	0.0050	0.017	–0.123*	0.010
Village wage (Tk/day)				
Male	0.0030**	–0.007**	0.013**	0.004**
Female	–0.0020*	–0.001	–0.009	–0.003**
Child	0.0001	–0.002	–0.003	0.0005

(continued)

Table A2.2

Continued

Explanatory Variable	Household per Capita Consumption (Tk/month)	Household Income (Tk/month)[1]		
		Farm	Non-farm	Total
Region[2]				
Dhaka	–0.0510	–0.263*	1.207**	0.088
Chittagong	–0.1950**	0.255	0.192	0.145*
Khulna	–0.1920**	–0.403**	0.961**	–0.028
Constant	5.0630**	1.158	–5.955**	6.170**
R-squared	0.2220	0.340	0.199	0.423

Source: BIDS Survey (2004).

Note: ** and * represent significance levels of 5 percent (or higher) and 10 percent, respectively. Consumption and income variables are in log form.

[1]1 decimal = 1/100 acre.

[2]Among the regions, Rajshahi is the excluded category.

Table A2.3

Effects of Energy Use on Household Outcomes by Energy Source (*N* = 2,388)

Explanatory Variable	Consumption (Tk/year)	Household Income (Tk/year)		
		Farm	Non-farm	Total
Gender of household head (1 = male, 0 = female)	–0.0420	0.558**	–0.849**	0.040
Age of household head (years)	0.0002	–0.002	0.011**	0.001
Maximum education of adult males (years)	0.0140**	–0.026**	0.140**	0.023**
Maximum education of adult females (years)	–0.0003	–0.021*	0.073**	0.023**
Log of household landholding (decimal)[1]	0.0480**	0.303**	–0.066	0.057**
Log of non-land household asset (Tk)	0.0110**	0.167**	0.075**	0.048**
Energy use (kgoe/year)				
Biomass	0.0840**	0.528**	–0.323	0.144**
Kerosene	–0.0160	0.232*	–0.182	–0.037
Electricity	0.0520**	–0.025	0.042**	0.079**
Proportion irrigated area in village	0.0080	–0.151	–0.091	0.034
Whether village has any				
Paved road	–0.0050	0.022	0.083	0.088**
Primary school	0.0350	0.179*	–0.142	0.067*
Health center	–0.0270	–0.458**	0.424*	–0.068
Market	–0.0120	0.097	0.116	–0.160
Commercial bank	–0.1020	–0.010	–0.060	–0.220**
NGO	–0.0760	0.036	0.062	0.095
Village price				
Rice (Tk/kg)	–0.0040	–0.168**	0.159*	0.013
Flour (Tk/kg)	–0.0040	–0.095**	–0.067	0.010
Potato (Tk/kg)	0.0110	–0.011	–0.010	–0.008
Lentil (Tk/kg)	–0.0040	0.045**	–0.082**	–0.011**

Table A2.3

Continued

Explanatory Variable	Consumption (Tk/year)	Household Income (Tk/year)		
		Farm	Non-farm	Total
Fish (Tk/kg)	0.0010*	–0.004**	–0.0030	0.0010
Beef (Tk/kg)	0.0020	–0.007	0.0460**	0.0060**
Chicken (Tk/kg)	–0.0040**	–0.004	–0.0005	–0.0040**
Soybean oil (Tk/liter)	0.0004	0.015	0.0370	–0.0070
Milk (Tk/liter)	0.0080**	0.015	0.0010	–0.0080
Sugar (Tk/kg)	0.0120*	0.027	–0.0460	–0.0050
Salt (Tk/kg)	0.0050	0.016	–0.0930	0.0090
Village wage (Tk/day)				
Male	0.0030**	–0.005**	0.0170**	0.0040**
Female	–0.0020**	–0.002	–0.0110	–0.0030*
Child	0.0001	–0.003	–0.0020	0.0004
Region[2]				
Dhaka	–0.0720*	–0.358**	1.2820**	0.1000*
Chittagong	–0.2000**	0.200	0.2330	0.1670**
Khulna	–0.1880**	–0.484**	1.2200**	–0.0460
Constant	5.2500**	2.142*	7.8920**	6.1630**
R-squared	0.2100	0.327	0.0560	0.4310

Source: BIDS Survey (2004).

Note: ** and * represent significance levels of 5 percent (or higher) and 10 percent, respectively. Consumption and income variables are in log form.

[1]1 decimal = 1/100 acre.

[2]Among the regions, Rajshahi is the excluded category.

Chapter 5

Table A2.4

Tobit Estimate of Enterprise Energy Demand (*N* = 2,290)

Explanatory Variable	Energy Demand (Tk/month)			
	Firewood	Kerosene	Diesel	Electricity
Age of enterprise (years)	0.156	0.967	–0.215	0.354
Log of land asset (decimal)[1]	–3.889**	0.925	–1.062*	2.815
Log of non-land asset (Tk 10,000)	8.164**	2.331	12.522**	52.211**
Enterprise type[2]				
Agriculture and food	23.649**	88.441**	–25.595**	79.723**
Manufacturing	27.822**	–123.354**	9.950*	266.723**
Trade	–89.473**	–163.394**	–6.212	–25.739
If village/growth center has electricity	10.471	–26.907	–18.193**	418.724**
If village/growth center has paved road	–1.015	–39.292*	–3.127	63.939

(continued)

Table A2.4

Continued

Explanatory Variable	Energy Demand (Tk/month) Firewood	Kerosene	Diesel	Electricity
Price of energy source				
Fuelwood (Tk/kg)	5.246	1.168	0.932	–10.455
Kerosene (Tk/liter)	11.438*	–1.028	–3.758	–14.563
Diesel (Tk/liter)	–4.788	–11.166	3.287	23.379*
Electricity (Tk/kWh)	–6.065	–15.865	–13.262*	25.676
Enterprise location[3]				
Growth center	–5.148	48.409	2.351	205.446**
Village	–13.800	58.144	–2.199	198.329**
Region[4]				
Dhaka	10.324	1.224	–5.623	118.407**
Chittagong	9.598	97.450**	–21.479**	125.175**
Rajshahi	13.801	–6.282	0.036	34.074
Constant	–277.362*	317.274	–84.736	–1,455.246**
Log likelihood	–1,689.142	–11,097.043	–687.906	–13,539.475

Source: Data International (2002).

Note: ** and * represent significance levels of 5 percent (or higher) and 10 percent, respectively.

[1]1 decimal = 1/100 acre.

[2]Service-based enterprises are excluded.

[3]Home-based locations are excluded.

[4]Khulna is excluded.

The demand for enterprise energy is influenced more by growth-center/village characteristics than by the characteristics of individual enterprises; thus, a fixed-effects model that controls for growth-center or village-level heterogeneity was used for enterprise outcome regressions (see Tables A2.5 and A2.6).

Table A2.5

Effects of Enterprise's Total Energy Use on Profitability (*N* = 2,290)

Explanatory Variable	Revenue (Tk/year)	Profit (Tk/year)
Age of enterprise (years)	1,210.35	196.58
Log of land asset (decimal)[1]	11,467.57	1,516.09
Log of non-land asset (Tk)	95,605.74**	10,241.58**
Enterprise type[2]		
Agriculture and food	108,172.43**	52,372.62**
Manufacturing	165,259.12	14,183.76
Trade	236,121.32**	8,902.59*
Total energy use (Tk/year)	0.86	0.55**
Constant	–410,412.62	60,624.86*
F-statistics (9,2061)	11.28	12.42

Source: Data International (2002).

Note: ** and * represent significance levels of 5 percent (or higher) and 10 percent, respectively.

[1]1 decimal = 1/100 acre.

[2]Service-based enterprises are excluded.

Table A2.6

Effects of Enterprise's Energy Use on Profitability by Source (*N* = 2,290)

Explanatory Variable	Revenue (Tk/year)	Profit (Tk/year)
Age of enterprise (years)	990.158	153.033
Log of land asset (decimal)[1]	11,273.32	1,424.647
Log of non-land asset (Tk)	95,669.08**	10,178.643**
Enterprise type[2]		
Agriculture and food	106,775.51**	49,891.651**
Manufacturing	119,636.91	5,690.698
Trade	229,058.11**	7,567.878
Energy use (Tk/year)		
Biomass	5.716*	1.217**
Kerosene/diesel	–3.872	–0.271
Electricity	4.107	1.351**
Constant	–403,568.82	62,085.22
F-statistics (11, 2059)	9.55	11.68

Source: Data International (2002).

Note: ** and * represent significance levels of 5 percent (or higher) and 10 percent, respectively.

[1] 1 decimal = 1/100 acre.

[2] Service-based enterprises are excluded.

Annex 3

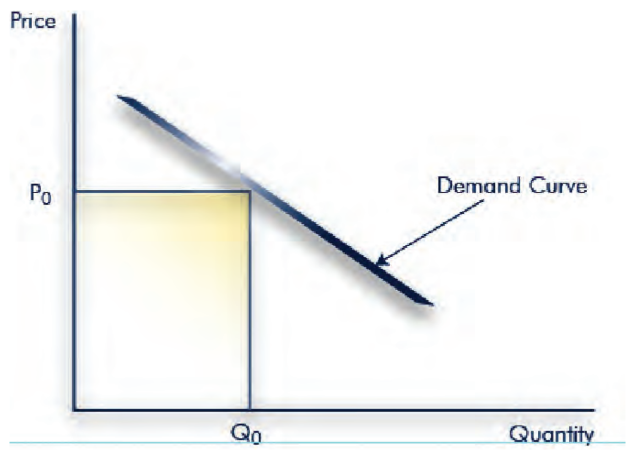
Consumer's Surplus as a Measure of Welfare

Consumer's surplus—a measure of well being that relies on the difference between what a person, household, or group is willing to pay for energy and what must be paid—has a long history in economics as a method for estimating the benefits of public projects.[47] The first use of applying consumer's surplus for valuing the benefits of electricity in the World Bank was seen as early as 1975.[48] This was followed by a more elaborate exploration of the concept in the mid-1980s.[49] More recently, the increasingly popular approach is being applied in most rural electrification projects, including such countries as Bolivia, Lao PDR, Peru, and the Philippines.[50]

Although fairly easy to apply, the procedure is not always well understood and is not without its critics, even by those educated in its underlying principles. The following sections provide a brief primer on the concept and address some of the more frequent criticisms that emerge when applying this method. One criticism not addressed is that money and well being are not necessarily the same thing; it therefore questions whether any monetary measure of benefit is valid.

Figure A3.1

Consumer Demand Curve



Source: Peskin (2006); and World Bank (2002c).

Consumer Demand

The starting point for an understanding of consumer's surplus is the consumer demand curve (see Figure A3.1).

The demand curve shows the relationship between the price facing the consumer and the quantity consumed at that price. Of course, the quantity of energy consumed at any point in time depends on far more than its price—the weather, the taste for energy-consuming items such as radio and TV, the need to support energy needs of business, and most importantly, the consumer's income. Clearly, if one chooses to focus only on the relationship between energy prices and energy consumed, these other factors must somehow be held constant. In general, if all the non-price factors remain fixed, the higher the price of a good (in this case energy), the less likely the consumer will demand it.

The demand curve shows price–quantity relationship for an individual, a household, a group of individuals, or a

Note: This section is adapted from Henry M. Peskin, "A Primer on Consumer Surplus and Demand: Common Questions and Answers," *ESMAP Knowledge Exchange Series*, No. 5, May 2006.

[47] See Alfred Marshall, *Principles of Economics*, 8th ed., MacMillan and Co., London, 1930; Hal R. Varian, *Microeconomic Analysis*, 3rd ed., W. W. Norton and Co., New York, 1978.

[48] See Dennis Anderson, *Cost and Benefits of Rural Electrification: A Case Study of Costa Rica*, World Bank Public Utilities Report No. RES 5, World Bank, Washington, DC, 1975.

[49] See David Pearce and Michael Webb, *Economic Benefits of Electricity Supply*, Energy Department Paper No. 25, World Bank, Washington, DC, 1985.

[50] See Kyran O'Sullivan and Douglas F. Barnes, *Energy Policies and Multitopic Household Surveys: Guidelines for Questionnaire Design in Living Standards Measurement Study*, Energy and Mining Sector Board, Discussion Paper No. 17, World Bank, Washington, DC, 2006.

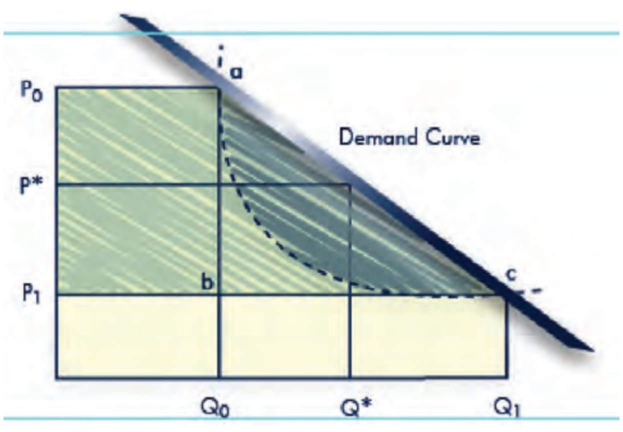
group of households. The interpretation of the curve differs if it shows an individual or a group, especially if the group contains a mix of incomes and tastes.

For a heterogeneous group, the tendency for higher prices leading to lower energy consumption usually implies that most of the consumption at high prices is by those individuals with higher incomes or with a stronger desire for energy. For an individual, the lower consumption at higher prices usually means that the individual will tend to substitute for other goods that provide a less costly means to maximize his or her satisfaction or well being. In either case, if the market price of energy is below what some people would be willing to pay for it, these people would experience a gain in their well being. This gain is the principal argument for using consumer's surplus as a benefit measure (see Figure A3.2).

If the price of energy fell from P_0 to P_1, those individuals (or a particular individual) who would be willing to pay P_0 in order to consume Q_0 of energy, can now consume the Q_1 of energy at the lower price. The original "Q_0 consumers" (or in the case of an individual, the "Q_0 consumption") realize a benefit of $P_0 - P_1$ for each of the units of Q_0 consumed. This benefit would be realized for any consumption less than Q_1 corresponding to any price higher than P_1, such as for those willing to pay P^* for Q^* units of energy. Thus, when one considers all consumption–price combinations

Figure A3.2

Consumer's Surplus



Source: Peskin (2006); and World Bank (2002c).

between the original Q_0, P_0 combination and the new Q_1, P_1 combinations, the total of all gains is represented by the shaded triangle *a,b,c* plus the rectangular area P_1, P_0, *a*, *b*.

In brief, energy is demanded for the service that it provides. Therefore, to calculate consumer's surplus requires an estimate of demand for lighting, entertainment, communications, or other services closely linked to energy. For lighting, the demand is quantified as kilolumen hours and for entertainment, it is radio or television listening or viewing hours. Thus, it is possible to obtain a measure of consumer's surplus by using the price and quantity of kilolumen or radio listening hours for households using kerosene, batteries, or electricity from a grid system.[51] This annex assumes that the benefit measured by consumer's surplus is a satisfactory measure of the benefit of policy that brings about lower energy prices and considers key challenges in this approach.

Estimating the Demand Curve

Consumer's surplus greatly depends on the shape of the demand curve, particularly between the original Q_0, P_0 combination and the new Q_1, P_1 combination. If the curve were not a simple straight line but instead bowed or bent toward the origin of the graph, such as indicated by the dotted line, the consumer's surplus would be smaller, as shown by the more lightly shaded area. Although the consumer's surplus could be far smaller than that measured in the World Bank's ESMAP energy studies, the investigators chose not to assume that it is smaller.[52]

Instead, the studies based the demand curve (and the resulting measure of consumer's surplus) on actual price–quantity observations drawn from household surveys. For combinations not observed, there was a simple linear extrapolation between points that were observed. Of course, the extrapolated points may not fall on the "true" (but unobservable) demand curve.

However, since the extrapolations rely solely on what can be observed, the investigators believe that this is a more honest approach than simply assuming some sort of curvature between the observable points. Such assumptions are necessarily arbitrary and could produce a wide range of results. Besides the problem of estimating the correct demand curve, application of the consumer's surplus method has raised a number of questions and criticisms.[53]

[51] See World Bank, *Rural Electrification in the Philippines: Measuring the Social and Economic Benefits*, ESMAP Report 225/02, Washington, DC, 2002.

[52] Ibid.

[53] Peskin, 2–4.

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Glossary

aman	rice planted in July–September and harvested in November–December
aus	rainfed summer rice planted in March–April
biri	tobacco
boro	irrigated winter rice planted in December–February and harvested in April–June
gur	molasses
hachak	(see petromax)
kupi/cherag	traditional kerosene lamp
motive power	energy source used for powering machinery
paan	betel quid
petromax	pressurized kerosene lamp
thana/upazila	rural subdistrict

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- Deploying renewable energy systems for a low carbon global economy.

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ESMAP is governed and funded by a Consultative Group (CG) composed of representatives of Australia, Austria, Denmark, France, Germany, Iceland, the Netherlands, Norway, Sweden, the United Kingdom, and the World Bank. The ESMAP CG is chaired by a World Bank Vice President and advised by a Technical Advisory Group of independent energy experts that reviews the Program's strategic agenda, work plan, and achievements. ESMAP relies on a cadre of engineers, energy planners, and economists from the World Bank, and from the energy and development community at large, to conduct its activities.

Further Information

For further information or copies of project reports, please visit www.esmap.org. ESMAP can also be reached by email at esmap@worldbank.org or by mail at:

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ENERGY AND POVERTY

Just less than one-half of the people in developing countries have no access to electricity and a similar number are reliant on biomass energy for cooking and heating. As a consequence, they are deprived of the means of moving out of poverty. Greater access to modern energy services can improve poor people's income through enhancement of productive use of energy and it can also increase their quality of life by providing quality lighting, communication, and other important services.

ESMAP has the goal of substantially improving energy use by poor people through addressing the widespread problems of the household energy. This is done through high quality analytical work on energy access, promoting an increase in the quality and number of projects dealing with energy and poverty issues by international donors, and by disseminating successful approaches to the international development community.

THE WORLD BANK

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