Anthony Williams.

DRAFT, APRIL 1996

Rural Energy and Development

Improving Energy Supplies for 2 Billion People

A World Bank Best Practice Paper

Industry and Energy Department

Contents

Tables

Figures

Boxes

Abbreviations and Acronyms

ASTAE	Asia Alternative Energy Unit
ESMAP	Energy Assessment and Energy Sector Management Assistance Program
GEF	Global Environment Facility
GNP	gross national product
IFC	International Finance Corporation
ITDG	Intermediate Technology Development Group
kW	kilowatt
kWh	kilowatt hour
LPG	liquid petroleum gas
NGO	nongovernmental organization
OED	Operations Evaluation Department
PV	photovoltaic
WDR	World Development Report

Executive Summary

This paper envisages a renewed commitment by the World Bank to support its member countries' efforts to extend modern energy supplies to populations still without them and to promote the sustainable supply and use of biofuels for as long as they remain important sources of energy. Modern energy is defined to include new forms of renewable energy.

The purposes of the paper are threefold. First, it argues why meeting the energy needs of rural—and also unserved urban—populations is a priority for sustainable economic development. Second, it reviews twenty-five years of experience with rural energy programs in developing countries; it finds that notwithstanding some mistakes, many approaches are working well and provide an excellent basis for a substantial expansion of effort to address rural energy problems. Third, it seeks to disseminate and share these lessons of experience with others on whom much responsibility will fall for the implementation of policies; indeed, the preparation of the paper itself entailed extensive sharing of experiences between representatives of the Bank, industry, and numerous governmental and nongovernmental organizations.

Why Meeting the Energy Needs of Unserved Populations Is a Priority

The most impoverished of the developing world's population still lack access to modern sources of energy. Nearly 2 billion people lack access to electricity and modern fuels, and their widespread dependence on fuelwood and dung for cooking results not only in economic hardship and ill-health, but causes environmental damage to soils, woodlands, and forests.

Development practitioners have long recognized rural energy problems, and during the past twenty years or so, all regions have undertaken substantial investments: in rural (and urban) electrification to expand service; in improved woodstoves and related programs to improve energy efficiency and reduce the damage to people's health caused by smoke; in afforestation and forest management to raise the productivity and sustainability of agriculture and reduce damage to forests, while increasing the supply of biofuels; in the supply of improved cooking fuels such as kerosene and liquid petroleum gas; and more recently, in renewable energy, including solar energy technologies, for small-scale supplies.

After faulty starts, and some disappointments as well as successes, we now have a considerable body of experience to draw upon when designing investments. In addition, we understand the requirements of policy better than we did just twenty years ago. The roles of prices and taxes, of market mechanisms for the supply of energy services and credit, and of the various social and institutional agents needed to carry out programs are now clearer. Furthermore, we have identified the sources of market failure more precisely so that we are better able to define the roles of the public and private sectors. Successful examples can be found in all regions, of which the following are a few:

- Of the liberalization of energy markets as a means of improving access to modern energy forms for people without them. (When liquid petroleum gas markets were deregulated in Hyderabad, there was rapid substitution from fuelwood to liquefied petroleum gas.)
- Of how financially sustainable pricing policies for rural electrification similarly improves service provision. (In Thailand's rural electrification program, the number of electrified villages rose from 20 to 98 percent during 1975–94.)
- Of the contribution of agro-forestry and participatory approaches to forest management and woodstove programs in making the supply and use of biofuels environmentally more sustainable. (In numerous countries in Africa, Asia, and Latin America, field research has found farmers consistently obtaining good financial returns to agro-forestry and related measures to protect soils and supplies of biofuels.)
- Of the importance of local institutional development and local participation in the design of investments and policies. (Again, examples can be found in many countries—woodstove programs in Tanzania, Madagascar, and China; agro-forestry programs in Latin America, Asia, and Africa.)
- Of the successful emergence of new renewable energy forms to meet the energy needs of rural consumers. (Solar energy systems provided electricity to 20,000 homes in Kenya during 1990-94, more than were newly supplied by the grid. New renewable energy programs are being facilitated by Bank staff in Brazil, China, India, Indonesia, and more than twenty-five other countries, and there is considerable local interest.)

Despite our growing confidence in policies and "best practices," many countries have yet to fully implement the approaches reviewed in the following chapters. With the exception of its work in afforestation, the Bank's efforts in terms of lending (though not policy), like those of others in the development community, had languished until recently in the face of disappointments with some projects, of formidable institutional obstacles to achieving a more efficient and financially sound energy sector, and of frequently unfavorable macroeconomic enabling conditions for investment. Such hindrances were worst in areas of Africa, South Asia, and Latin America in the 1980s, and still persist in some countries. However, many countries are laying a foundation for renewed efforts, and our analysis of experience to date shows that, given the will, the challenges described can be addressed.

Renewed Commitment by the World Bank Group

The World Bank has been engaged in policy work and lending for rural energy for more than twenty years. Its initial efforts focused on rural electrification, and were followed in the early 1980s by lending for afforestation—mainly woodlots and agro-forestry—and for woodstove programs. Total investments amount to some US$4 billion for roughly 100 projects, including the rural energy components of larger energy projects, of which US$2.5 billion was for electrification, US$1.2 billion was for afforestation, and the rest was for woodstove and some pilot small-scale renewable energy projects.

In addition, numerous studies have been undertaken in approximately 100 countries in the past 15 years that have dealt both with general issues and details of energy policies as they bear on the rural energy situation. Most of these were a product of the Joint United Nations Development Programme/World Bank Energy Assessment Program, and later the Energy Sector Management Assistance Program, initiated in 1980, which also identified a number of rural energy projects that the Bank later financed.

Hence the Bank has long been committed to addressing rural energy problems, and has substantive experience on which it can base future efforts. As regards biofuel supply and use, initial investments were in community woodlot programs. In general, they were not successful in obtaining the participation of rural communities as intended, because they left a number of social and organizational questions unresolved. The focus has since shifted to agro-forestry and participatory approaches to forest management, which are proving to be very successful. Overall, the Bank's work on afforestation has accelerated since the early 1980s in response to concerns about the sustainability of agriculture.

Energy lending, in contrast, dipped substantially in the mid-1980s and has been volatile ever since because of a deterioration in the finances of electricity utilities in many countries and in the enabling conditions for investment. Thus since the mid-1980s, the Bank has concentrated on restoring price and managerial efficiency to put the energy industry on a commercial footing.

Reflecting this, in 1992 the World Bank's Board of Directors approved a set of policies outlined in two papers: *The World Bank's Role in the Electric Power Sector* and *Energy Efficiency and Conservation in the Developing World.* The Bank was only to lend to countries committed to operating their electricity industry on commercial principles; to introducing less intrusive and more transparent forms of regulation; and by implication, to being more open to private investment, to market pricing, and to trade in energy services. The Bank also reemphasized its long-standing commitment to seeing environmentally sound technologies and practices introduced. The same principles carry over to the Bank's work in oil and gas. Box A summarizes the policies' main features and the added dimensions raised by the concerns of this paper.

Box A Broadening the Scope of Energy Operations

What the Board approved in 1992:

Commitment lending

Promotion of clean technologies

Sector reform

- **Transparent regulation**
- **Commercialization/corporatization**
- **Private involvement**
- **Importation of services**
- **Market pricing**
- **Demand management**

Added dimensions—a renewed commitment to

- **Extend modern energy supplies to unserved populations**
- **Promote sustainable supply and use of biofuels**
- **Introduce new and renewable energy technologies.**

And thus to

- **Promote commercial pricing and private involvement in distribution**
- **Provide incentives for extension of service**
- **Support agroforestry and biofuel programs.**

Future Operations

The Bank can work with its member countries during policy analysis and through its investments. In recent years, its work in energy has become largely concentrated on reforms of the commercial and utility sector (the items identified in the upper half of box A), with less attention being paid to the energy needs of the rural (and urban) poor. Now that these aspects of the Bank's energy policy are firmly in place and are being vigorously pursued in all regions, an excellent opportunity presents itself for us to work with our member countries to deepen and adjust this reform agenda to ensure that the benefits spread beyond the middle- and higher-income groups.

Energy Policies

Energy sector reforms, which are now being implemented by many of the Bank's clients, have hitherto tended to concentrate on the liberalization of energy markets and the introduction of independent regulation or, more generally, on the creation of good enabling conditions for private and public investment. However, we must go beyond merely creating good enabling conditions (chapters 3 through 6). No country so far has succeeded in providing universal energy services without some form of public leadership, for example, through providing education and training; developing rural institutions; introducing economically responsible regulation for the supply and extension of service to the lower-income groups; and providing tax or other incentives, and often moral pressure, to encourage companies to invest in lower-income markets.

Investments in electricity distribution, for example, even to serve established higher-income markets, raise institutionally complex issues, and private sector follow-up on investment opportunities in distribution has so far been much lower than in generation—which is not surprising given the greater market uncertainties, the high initial costs of extension to areas with initially low load densities, and the long-term (twenty- to thirty-year) financial commitment often required to recover costs.

In the areas of biofuel supply and use, local participatory mechanisms, now widely acknowledged as the key to successful projects, are often weak. With the introduction of new renewable energy technologies, significant investment may be needed in surveys of resources, in demonstration projects, and in education and training. All such matters need to be weighed early on in discussions of policies.

Investments

Supported by a broader dialogue on energy policies, the Bank Group will be better able to tailor its energy portfolio more closely to developing countries' needs and concerns. How the portfolio develops will vary from country to country, but a rising commitment of Bank Group resources is likely for the following:

- Rural electrification and its alternatives (chapters 4 and 5)
- New renewable energy forms, guided by the Bank's Solar Initiative (chapter 7)
- Improved approaches to the supply and use of biofuels, including agro-forestry and local participation in encouraging sustainable use of local forest and woodland resources (chapter 6).

An increase in the supply and use of modern cooking fuels in rural areas should follow (chapter 6), although this would be a private investment activity rather than a Bank-financed activity.

World Bank loans and credits have been available for such projects for more than fifteen years, in the case of electrification for more than twenty years, and well-prepared projects can meet the investment criteria of both the World Bank Group and the Global Environment Facility. No changes to the World Bank's internal policies are therefore required, but more systematic application and transfer of best practices are needed.

We can, however, expect to see some innovations in lending—and in the ways policies are applied. Experience has shown that neither technologies nor economic or institutional arrangements stand still, and that most success has been achieved where there has been a willingness to learn from experience and consider new approaches. A good example on the technological side is the revived interest in agro-forestry, and an emerging one is investments in solar and other forms of renewable energy. On the institutional side perhaps the most important examples are the growth of interest in participatory approaches and local institutional development.

Guiding Principles for Operations

Operational experiences have differed greatly between countries and with time. The more successful approaches

- Have less restrictive pricing and regulatory policies, such that utilities' financial positions are not undermined by increases in rural investments;
- Keep subsidies within bounds—and carefully targeted—and ideally avoid them;
- Confine public involvement to addressing market failures, principally environmental externalities and high startup costs;
- Put a great deal of effort into local institutional development and participation by intended beneficiaries in the design of projects and policies.

Box B summarizes some recommendations based on these principles.

Box B Summary of Recommendations on Rural Energy Policies

Rural Electrification and its Alternatives (chapters 3, 4, 5, 7)

- Economically justifiable investments can be found in large areas, principally areas of high load density where the output of and incomes from agriculture and local businesses are rising, and are inducing economic growth in villages and towns. Investments need to be selective, however: Alternatives to grid-connected schemes are more cost-effective in areas with lower load densities. These include diesels for motive power and autogenerators, in some areas small-scale hydro-schemes, and new renewable energy technologies such as solar energy.
- Cost recovery over the long term needs to be achieved. Most subsidies in the past have benefited the higher-income consumers the most, and frequently have undermined the electric company's capacity to provide reliable service, and also to extend it. Lifeline rates can be introduced for low levels of household consumption without serious financial losses.
- Institutional options need to be examined where the sector is being reformed. These include cooperatives; joint public-private arrangements; where the company is privately owned, a regulatory requirement to expand service coupled with permission to recover costs through general or, preferably, rural-specific tariffs; or continued public involvement where the private sector is reluctant to become involved.

Cooking Fuels (chapters 3, 6, 7)

- Agro-forestry is proving to be the most promising approach. In contrast to the earlier investments in woodlots, which often failed, it involves a high degree of farmer participation, serves several valuable environmental and economic purposes, and for these reasons offers good financial returns to the farmers: it improves soil moisture retention, reduces erosion, and increases the supply of soil nutrients, in addition to supplying wood for fuel and other purposes. Another promising approach involves granting property rights and involving intended beneficiaries in managing local forest resources.
- Woodstove programs involving local beneficiaries and artisans in the development of investments are capable of raising energy efficiency and greatly reducing damage to people's health from smoke.
- Kerosene and liquid petroleum gas are the fuels of choice as incomes rise. Their distribution and use is greatly facilitated by more liberal economic policies toward the energy sector. Subsidizing these fuels cannot be justified, but high taxes need to be avoided so as not to discourage substitution from fuelwood. Depending on the case, moderate rates of taxation on liquid petroleum gas, kerosene, and diesel fuels will often be the best options.

Partnerships

The following report draws on the World Bank's own experiences with rural energy policies and investments as well as on the experiences of others. In an effort to broaden the paper's perspectives and facilitate cooperation among the many players on whom the successes of an expanded rural energy development effort will depend, several drafts were shared with and critiqued by representatives of twenty governments and nearly fifty nongovernmental organizations, while the ideas were presented for comment during workshops with private industry. Although differences are bound to remain in some areas, there is no disagreement among concerned parties about the importance of addressing the problems discussed or about the broad directions that rural energy policies and investments need to take.

1

Introduction

Policies on energy and the environment are overwhelmingly preoccupied with the production and use of modern energy forms. Thus they focus on private versus public ownership, global warming, acid deposition, urban smogs, and so forth. While all these matters are extremely important, and the energy, industry, policymaking, and environmental communities, including the World Bank Group, pay a great deal of attention to them, another aspect of energy production and use gives rise to developmental and environmental problems of equal, if not greater, importance: half the populations of developing countries lack access to modern energy forms.

Approximately 2 billion people depend on traditional fuels—animal dung, crop residues, wood, and charcoal—for cooking, and an equal number are without electricity.[1] We also know that fuelwood and dung are inefficient energy sources—gas, for example, is fully ten times more efficient for cooking—and that their use leads to environmental damage through the stripping of forests and woodlands, and to respiratory diseases and premature death for millions of people through smoke inhalation.

Dependence on such fuels is also an economic hardship, as in many parts of the world people spend excessive amounts of time gathering and cooking with these fuels. While using traditional fuels more efficiently and in ways less damaging to the environment and to people's health is possible, this is not happening in large regions of the world, while the shift to modern fuels (which most people in developing countries would surely count as a blessing) is not progressing as rapidly as it could.

---

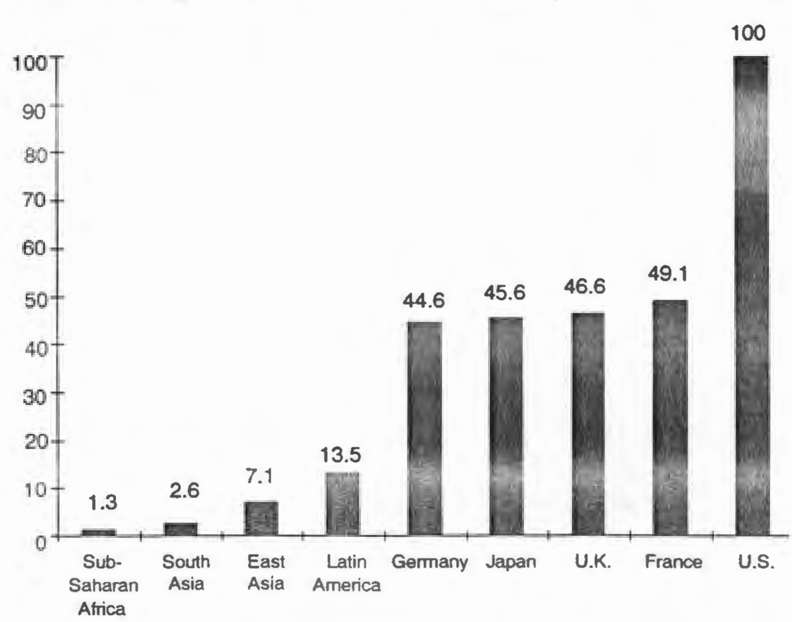
1 . The term *traditional fuel* refers to such fuels as wood, charcoal, agricultural residues, dung, grass, leaves, and other biomass materials using open fires, "three-stone" stoves, and wood and charcoal stoves. These are sometimes also called *biofuels*. The term *modern* includes liquid fuels, such as liquid petroleum gas (LPG) and kerosene; electricity; coal; modern biomass, including improved stoves and bagasse gasification and cogeneration; and innovative renewable energy technologies, such as those that use wind, solar, and small-scale hydroelectric resources. The term *commercial* energy is sometimes used instead of modern energy.

The Challenges Ahead

The total population of developing countries will grow by more than 3 billion people in less than four decades and by 5 billion within the lifetimes of children now in school. Thus energy policies will not only have to grapple with the task of meeting the needs of the 2 billion people currently without service, but with new demands resulting from population growth. The alternative, a situation in which billions more people continue to lack access to modern energy forms and to depend on fuelwood and dung for cooking, would be socially iniquitous, environmentally unsustainable, and a failure for development.

In addition, developing countries need to meet the rapidly growing demands for modern or commercial energy from households and businesses that already have service. Their per capita consumption of commercial energy is extremely low relative to that in the industrial countries. For example, per capita consumption of commercial energy in the United States is 8 tons of oil equivalent energy per year, or 80 times more than in Africa, 40 times more than in South Asia, 15 times more than in East Asia, and 8 times more than in Latin America (figure 1.1). Electricity consumption is also much higher in industrial countries, about 13,000 kilowatt hours (kWh) per capita per year, compared with about 600 kWh per capita in developing countries.

Figure 1.1 Per Capita Consumption of Commercial Energy in Selected Regions and Countries, 1992 (Index: US = 100)



Source: World Bank (1994b, Statistical Annexes).

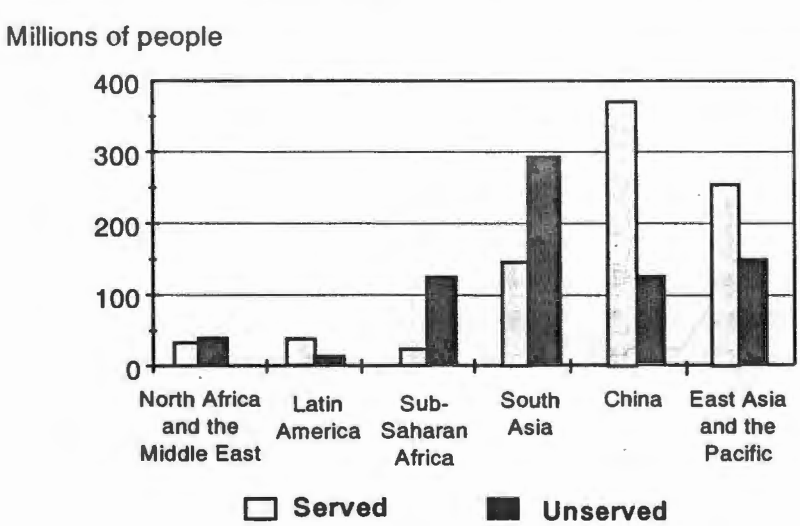
The financial and managerial requirements of serving those lacking access, of keeping up with population growth, and of meeting increased demand on the part of those already served are driving the current movement to liberalize the energy industry in many countries.

Past Responses

How might rural energy demands be met in ways that are sustainable? A good starting point for answering this question is to consider what has been done already and what can be learned from experience.

Rural energy problems have long been recognized, and for more than two decades the electricity industry, forestry and agricultural agencies, development organizations, nongovernmental organizations, and many others have made innumerable efforts to address them. Few, if any, ideas and approaches have not been thought of or tried. India's interest in rural electrification, for instance, goes back three generations. In the past 25 years, developing countries have extended electricity supplies to more than 1.3 billion people (500 million in rural areas, 800 million in urban areas), equivalent to almost twice the population of the Organization for Economic Cooperation and Development countries. Whatever the shortcomings of electricity supply industries in developing countries, this is an impressive achievement, and testifies to their commitment to expanding service. In Africa and South Asia, however, the efforts to expand service still lag behind population growth, which underscores the immensity of the task that still lies ahead (figure 1.2).

Figure 1.2 Rural Electrification, Increases in the Number of People with and without Service, Selected Countries and Regions, 1970–90



Many countries have tried to provide incentives, some successful, others counterproductive, to improve the supplies of LPG and kerosene for cooking and lighting. As concerns biofuels and renewable energy, countries have experimented with numerous approaches: introducing woodstove programs, promoting agro-forestry, demonstrating sustainable ways to use local forest resources, and encouraging the use of biogas from dung and crop residues. They have also attempted to introduce new ways of utilizing solar, wind, and hydroelectric energy resources on a small scale. Practically all these efforts were pioneering, and much can be learned from both the successes and the disappointments.

The World Bank has also had significant experience with rural energy, and has supported rural energy programs for more than twenty years. Its policy paper on rural electrification was published in 1975 (World Bank 1975), and was followed by thirty-four projects in eighteen countries amounting to US$2 billion, plus several general electrification projects that had rural electrification components. In addition, the Bank financed more than forty fuelwood-related projects during 1980–95, often as components of agricultural and forestry development projects, and twenty-one renewable energy projects, with a total commitment of more than US$4 billion. The joint United Nations Development Programme / World Bank Energy Assessment and Energy Sector Management Advisory programs, begun 15 years ago, facilitated extensive policy discussions on the energy sector (including the rural energy sector) and project preparation activities in nearly 120 countries.

In addition to investment and policy advice to improve the rural energy situation directly, developing countries also need a financially sound and well-managed modern energy supply industry to meet the energy needs of the millions currently unserved. The 1980s, however, saw a marked deterioration of finances and managerial efficiency in the industry in numerous countries, often with deleterious consequences for their public revenues (given the frequent recourse to subsidies). This eventually culminated in the recent surge of interest in regulatory reform and the liberalization of energy markets around the world. The Bank's own policies on the subject were laid out in its policy papers on electric power and energy efficiency (World Bank 1993a,b), approved by the Bank's Board in 1992, and in a number of subsequent publications and seminars.

Important as efforts to reform and liberalize the energy sector are, they leave several questions unaddressed. How will fundamental shifts in policy affect the energy supply situation for the rural—and also the urban—poor?[2] In all countries, rich and poor, public utilities have historically undertaken almost all rural electrification programs. Is service provision likely to become more widespread in the new institutional and economic

2 . This was a recurrent question members of the World Bank's Board posed during the discussions of the policy papers in 1992 and during a review of progress with these policies in 1994.

settings, as many believe it will, or will the low-income markets for electricity and other modern fuels, such as LPG and kerosene, be neglected without public leadership? Will services be affordable? Who will be concerned about using traditional fuels in more sustainable and healthier ways? Will the reforms help with the introduction of solar energy technologies? More generally, how will public policies on energy and the environment ensure that the world's most impoverished people are not left out?

The purposes of this paper, therefore, are to take stock of the efforts of the developing countries and of the support the development community has provided, to see what we can learn from experience to date, and to identify ways by which the World Bank Group can help its member countries address the problems discussed. To this end, several drafts of this paper have been shared with and critiqued by many people and organizations that have been involved in developing policies and projects in this area.

As the title implies, the paper is mostly about rural energy supply and use. However, the problems it discusses are not confined to rural areas. Millions of people in urban areas also lack access to modern energy forms and depend on supplies of wood, charcoal, and in some countries dried dung, for cooking—another manifestation of urban poverty and a source of damage to rural and urban environments, as well as to people's health. The policies discussed in the following chapters are often equally applicable to unserved urban populations, for whom the costs of service extension are much lower.

2

The Rural Energy Situation

Approximately one-third of all energy consumption in developing countries derives from the burning of wood, crop residues, and animal dung (biofuels). By some estimates, it amounts to around 1,000 million tons of oil equivalent energy per year, more than three times the energy of the coal mined in Europe in a single year and twice the energy of the coal mined in the United States or China. Most of this energy is used in rural areas, which account for about 60 percent of the population of the developing world, or up to 70 percent in the low-income economies. Consumption of fuelwood and charcoal in urban areas is also large in many countries, and results in deforestation and environmental damage in the surrounding countryside, with fuelwood eventually having to be trucked over large distances. This is especially true in African countries, where the costs of distribution and of acquiring appliances often inhibit the use of gas and electricity.

Effects of Biofuel Use by the Poor

Aside from the economic hardship associated with gathering and cooking with biofuels, the indoor air pollution created by such fuels is a health hazard, particularly to women and children (see box 2.1). In addition, collection of biofuels frequently leads to ecological damage to forests, woodlands, and farmlands, and biofuels are generally energy-inefficient.

Pollution and Health

As the 1992 *World Development Report* (WDR) noted (World Bank 1992), studies of smoke from the use of biofuels in rural areas (Smith 1987, 1988; Smith and others 1993) have found levels of solid particulate matter that regularly exceed the safe levels cited in World Health Organization guidelines by several orders of magnitude (table 2.1). Cooking can expose women and children to such levels for several hours a day, and has serious health effects that have only recently been studied systematically, even though they are often just as serious as the effects of cigarette smoking. Carbon monoxide emissions may give rise to ambient concentrations that interfere with the body's normal absorption of oxygen. Estimates indicate that smoke contributes to acute respiratory infections that kill some 4 million infants and children a year. Recurrent episodes of such infections show up in adults as chronic bronchitis and emphysema, which can eventually lead to heart failure. Studies in Nepal and India of nonsmoking women who are exposed to biomass smoke have found abnormally high levels of chronic respiratory disease, with mortality from this condition occurring at far earlier ages than in other populations and at rates comparable to those of male heavy smokers.

Box 2.1 Time, Health, and Cooking with Woodfuels

When woodfuels are scarce, the time people spend collecting fuels reduces the time they can devote to productive agricultural activities. A recent survey in the hill areas of Nepal, for example, found that even in regions with relatively good supplies of fuelwood, women still need to spend more than an hour a day collecting biomass, and the time they devoted to agriculture was correspondingly less compared to people not dependent on these fuels. In the more deforested areas where fuels are scarcer, the time and effort women expended were even greater, with about 2.5 hours per day being spent collecting fuelwood, fodder, and grass. Surveys in Africa dating back to the 1970s have similar findings.

The use of biofuels also has an adverse effect on the health of women and children, especially children, though the provision of improved woodstoves along with household education and extension programs can help remedy this. A study of 500 children under five years of age in The Gambia found that girls who were carried on their mothers' backs as they cooked in smoky huts had a risk of acute respiratory illness six times that of other children. Studies in Papua New Guinea and India show that nonsmoking women who have cooked on biomass stoves for many years exhibit a higher prevalence of chronic lung disease than those who have had lower levels of exposure to cooking smoke.

In conclusion, the quality of life of women and children can be improved by improving access to biomass and providing improved biomass stoves.

Source: Kumar and Hotchkiss (1988); Smith (1987, 1991). See also Cleave (1974) for surveys of people's use of time in Africa.

Ecological Damage

The costs to the environment of biofuel use in terms of increased deforestation, soil erosion and reduced soil fertility have also attracted much attention. The consumption of fuelwood and dung is not the only cause of these problems—logging and clearing land for agriculture often cause greater damage—but it is, nevertheless, a source of environmental damage and cannot be ignored (see World Bank 1978, 1991). A study on Ethiopia (Newcombe 1984) found that where tree cover losses were severe, all the natural cycles through which nutrients were returned to an initially rich topsoil had been breached: first through the losses of trees themselves, and then through losses of grasses, crop residues, and dung when they were used for fuel instead of being used to fertilize the soil. Another consequence is that the soil retains less moisture, which results in reduced crop yields. Investigators have found that farms with good tree cover—where farmers have planted trees as windbreaks or shelterbelts, for example—have yields 20 to 50 percent higher, depending on local climates, terrain, and ecosystems, than those without good tree cover (Anderson 1987; Doolette and Magrath 1990; Gregersen, Draper, and Elz 1989; Spears 1986).

Table 2.1 Indoor Air Pollution from Biomass Combustion in Developing Countries

Location and year of study	*Measurement period*	*Concentrations of suspended particulate matter as multiple of WHO peak guideline*[a]
China, 1987	Cooking	11
The Gambia, 1988	Average over full day	4–11
India, 1987–88	Cooking with — wood	75 (15-minute peak)
	— dung	90 (15-minute peak)
	— charcoal	25 (15-minute peak)
Kenya		
1987	Average over full day	5–8
1972	Overnight (space heating)	12–34
Nepal, 1986	Cooking	9–38
Papua New Guinea, 1975	Overnight (space heating)	1–39
Zimbabwe, 1990	Cooking (two hours)	6
Brazil, 1992	Stoves with flues	< 0.4

Note: The studies are not completely comparable because of different measurement methods.

a. The WHO peak (98th percentile) guideline recommends that a concentration of 230 micrograms per cubic meter not be surpassed by more than 2 percent (seven days) of a year.

Source: Smith (1988).

Recognition of the linkages between biomass use and the productivity—many would argue the sustainability of—agriculture has done much to revive interest in the once time-honored practice of agro-forestry. Development practitioners now understand that they should not view the "fuelwood problem" and its resolution in an isolated way, but as part of the larger problem of energy supplies, poverty alleviation, and the protection of natural resources in rural areas (see chapter 6).

More people now also recognize that the use of biomass need not be inherently negative. In principle, biomass fuels can be supplied—from forests, woodlands, or farmlands—and used in sustainable ways. One can cite several examples from Kenya and India of farmers turning to agro-forestry autonomously to respond to local demand for wood and to improve the local ecology. Biofuels are traded and are an important source of cash income for many of the world's rural people, and growing fuelwood can yield a comparatively high return. In Africa alone, the production and marketing of biofuels represents a US$5 billion business that provides gainful employment to more than 400,000 people.

Nevertheless, some regions in densely populated countries have already passed the point of sustainable production of biomass fuels. In areas of China and India, the combination of intensive use of land and rural population growth has already transformed many forests into farmland, leaving only marginal lands to supply trees and shrubs. In the northern Chinese county of Kezuo, for example, people have already cut most of the trees around the agricultural lands and are now turning to less efficient fuels—straw and dung—while wealthier households are using coal. Deforestation has other undesirable effects on energy production: in Yongchun County, Fujian Province, China, lands and forests had become so degraded by 1983 that siltation had reduced annual hydroelectric production from the 1960 level of 5,000 hours to only 2,200 hours.

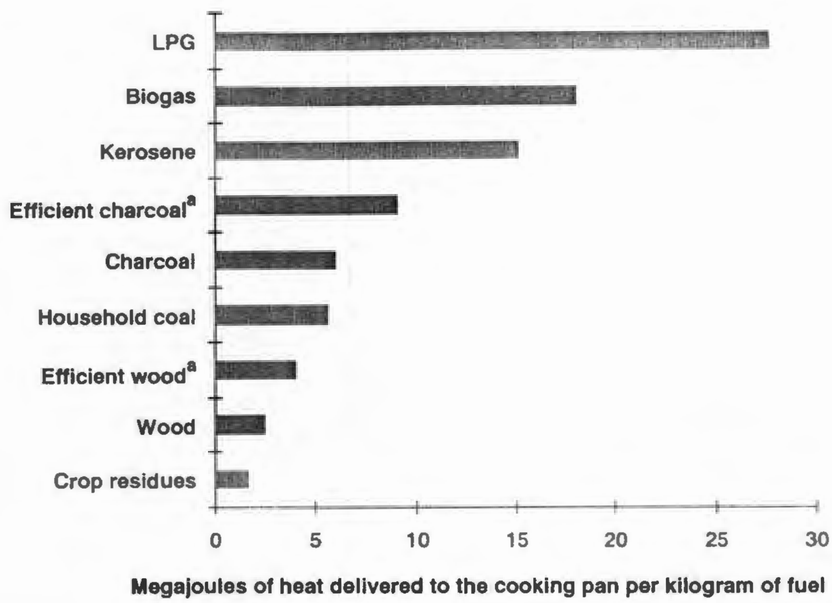
Energy Efficiency

Figure 2.1 presents data on the efficiency of various cooking fuels. Biofuels are generally much less efficient for cooking than modern fuels such as liquid petroleum gas (LPG) and kerosene. An exception is biogas. This is derived from digesters of dung and farm residues, and both China and India have done much to develop biogas and encourage its use among people in rural areas.

The least efficient fuels are agricultural residues, leaves, and grass. With few exceptions, people use these fuels because they are available from the local environment at no cash cost, not because they value them as convenient cooking fuels (Agarwal 1983). Many parties have worked hard to try to raise the efficiency with which biofuels are used by introducing improved stoves, often with positive results.

Urban and some rural households generally purchase wood, charcoal, coal, and kerosene. These fuels have higher energy values per unit of weight than wood and are generally used in more efficient stoves. In addition, the level of heat output of kerosene stoves can be adjusted relatively easily, so kerosene is more convenient for preparing a wide variety of dishes. Households with the highest incomes use gaseous fuels such as LPG. LPG burns cleanly and efficiently, it is convenient, and it has an easily adjustable heat level.

Figure 2.1 Energy Efficiency of Selected Cooking Fuels



Note: The values in this figure are derived from a combination of the fuels' energy content and the efficiency with which the fuels are typically burned for cooking in developing countries.

a. Used in an efficient stove.

Source: Floor and van der Plas (1991), ESMAP (forthcoming).

The Transition to Modern Fuels

As their incomes grow, rural people begin to use modern fuels more extensively. Table 2.2 summarizes some typical changes in patterns of energy use by households and in agriculture and small industrial enterprises. The initial dependence on biofuels in the home eventually gives way to the use of electricity for lighting and fossil fuels for cooking. In agriculture and industry, diesel engines and electricity replace manual and animal power for a variety of purposes. Where rural electrification from the grid is not available or is too costly, diesel generators may be used instead. More recently, photovoltaic systems have become an attractive option for small-scale electricity supplies for homes, businesses, refrigeration and lighting in health clinics, and water pumping.

However, as figure 2.2 shows, the transition to modern fuels is likely to take some time. In the lower-income developing countries, high percentages of rural people in particular, but also of the urban poor, continue to rely heavily on biomass.[1] Even residents

1 . The term *lower-income developing countries* refers to the classification in the WDR's statistical annexes. This group had per capita incomes of less than US$695 in 1993.

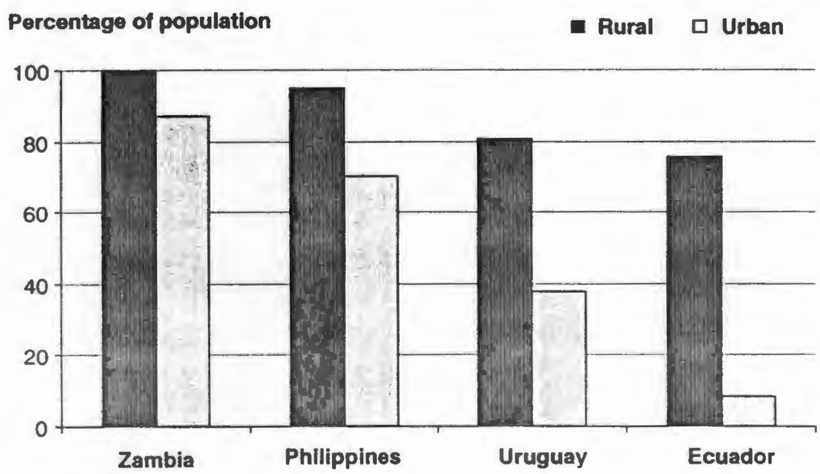
of countries approaching the lower-middle income range, such as Ecuador and Uruguay, still consume large amounts of biomass energy.

Table 2.2 Rural Energy Use Patterns in Developing Countries by End Uses

	Household income		
End use	*Low*	*Medium*	*High*
Household			
Cooking	Wood, residues, and dung	Wood, residues, dung, kerosene, and biogas	Wood, kerosene, biogas, LPG, and coal
Lighting	Candles and kerosene (sometimes none)	Candles, kerosene, and gasoline	Kerosene, electricity, and gasoline
Space heating	Wood, residues, and dung (often none)	Wood, residues, and dung	Wood, residues, dung, and coal
Other appliances	None	Electricity and storage cells	Electricity and storage cells
Agriculture			
Tilling	Hand	Animal	Animal, gasoline, diesel (tillers and tractors)
Irrigation	Hand	Animal	Diesel and electricity
Post-harvest processing	Hand	Animal	Diesel and electricity
Industry			
Milling and mechanical	Hand	Hand and animal	Hand, animal, diesel, and electricity
Process heat	Wood and residues	Coal, charcoal, wood, and residues	Coal, charcoal, wood, kerosene, and residues

As regards the regional use of biomass, in Africa, about 85 percent of the total energy used is in the form of biomass, in South Asia this figure amounts to 60 percent, and in East Asia and Latin America to 25 to 30 percent. Table 2.3 provides estimates of the current shares of biomass in total energy consumption and of likely levels in 2000 and 2010. The actual rate at which the transition to modern fuels will occur will depend on countries' economic performance and development policies; the extent to which people currently use biomass, coupled with population growth, suggests that a large number of people will depend on biofuels for many years to come. Even in East Asia and the Pacific, a region that has experienced significant economic growth and a major increase in the use of commercial energy, biomass use still accounts for 33 percent of energy supplies and is expected to decline only by some 50 percent during the next fifteen to twenty-five years.

Figure 2.2 Use of Biomass by Rural and Urban Populations in Four Developing Countries



Note: Per capita gross national product for the four countries is as follows (in 1993 U.S. dollars):

Zambia	US$290	Philippines	US$770
Uruguay	US$3,340	Ecuador	US$1,070

Source: Barnes and others (1994a); World Bank (1993c, 1994b).

Table 2.3 Current and Projected Use of Biomass by Region, Selected Years
(percentage of total energy used)

Region	*1990*	*2000*	*2010*
Sub-Saharan Africa	85	83	80
South Asia	60	52	43
East Asia and Pacific	33	26	20
North Africa and Middle East	27	23	19
Latin America and Caribbean	26	22	19

Note: World Bank estimates.

The conclusion must be, therefore, that energy policies will need to be as concerned about the supply and use of biofuels as they are about modern fuels, and so have two aspects, not one. They must create the necessary conditions so that modern fuels—primarily electricity from the grid, renewable energy sources, liquid fuels, and LPG—can be efficiently supplied to large populations that still lack them. Second, they must support ways to use biofuels more efficiently and sustainably, a task that is not confined to those working in the energy sector, but must also involve those working with agriculture and forest management.

3

Emerging Practices and Policies

The transition to modern fuels and the sustainable provision and use of biofuels will both depend on the quality of the enabling conditions for development. When human resource programs are in place and enabling conditions for investment are favorable, policies to extend energy services to those without them, whether rural or urban, are much more likely to succeed. Under such circumstances, the markets for energy will be stronger, and suppliers of electricity, photovoltaic (PV) sets, liquid petroleum gas (LPG), kerosene, woodstoves, biofuels, and so forth will have better financial returns both to investment and to labor. Such situations give rise to a "virtuous circle," because with increased rewards, efforts to expand services further will grow. Thus development policies can accomplish a great deal independently of policies that focus directly on the rural energy problem, though both types of policies are necessary.

There are five general principles that experience has shown to be relevant to the provision of both modern and traditional fuels, namely:

- Enabling people to choose alternative forms of energy
- Avoiding unnecessary subsidies
- Addressing market failures
- Emphasizing participation and institutional development
- Recognizing the central role of enabling conditions.

We consider these before examining the specifics of policies toward each type of energy.

Enabling People to Choose from among Alternative Forms of Energy

In economic terms, giving people choices and allowing them to express preferences means liberalizing the pricing of and regulatory policies toward energy supply and use, and allowing people to express their willingness to pay for service. In the past, interventionist financial and regulatory policies restricted people's ability to make choices and ultimately undermined the provision of services. Notable examples are the restrictions often imposed on electricity prices and, in some countries, on LPG and kerosene prices. By reducing energy companies' revenues, such restrictions often had the counterproductive effect of limiting their financial capacity to invest and extend services.

Evidence from rural areas suggests that people are willing to spend a significant portion of their incomes on higher quality energy services that improve their quality of life or enable them to become more productive. In Bangladesh, for example, when service is available, even the poorest people are connecting to the grid. In Kenya, where the possibility of timely connection to grid service is remote, higher-income rural households are buying solar PV systems. In rural China, people without easy access to energy for cooking are investing in efficient stoves and in tree planting. In India, during the 1970s and 1980s people shifted from using animal power for irrigation to diesel or electric pumps. In some parts of rural Bolivia, those without access to electricity use LPG lanterns as an alternative to candles.

Experience shows that if services are available and reliable, rural people are willing to use many different types of energy, and that given a choice, they generally select the combination appropriate for their daily demands.

Avoiding Unnecessary Subsidies

Many governments have sought to promote the provision of affordable modern energy services in rural areas by subsidizing particular forms of energy. Rural electrification is perhaps the main example, although governments have sometimes offered subsidies for kerosene, LPG, solar energy, woodstove programs, and so on. Although well intentioned, such policies have often proved to be counterproductive for the following reasons:

- They worked against consumers making least-cost choices, and in doing so also undermined investors' efforts to provide alternative energy forms. Commonly cited examples are the choice between diesel engines, solar PV systems, and grid-supplied electric motors for irrigation pumping and small-scale power supplies. When load densities are high or connection distances are short, the least-cost alternative is generally grid-supplied electricity, but subsidized investment programs of electric utilities have too often led to grid supplies being extended to small loads when diesel, solar energy, or in some areas wind energy, would have been cheaper.
- Widespread recourse to unnecessary subsidies has frequently proved to be fiscally unsustainable, and when coupled with price restrictions, eventually limited energy companies' investment programs (see chapter 4). This has not only happened to some countries' rural electrification programs, but sometimes to the suppliers of fuels such as kerosene and LPG for cooking.
- Subsidies have discouraged efficient energy use.

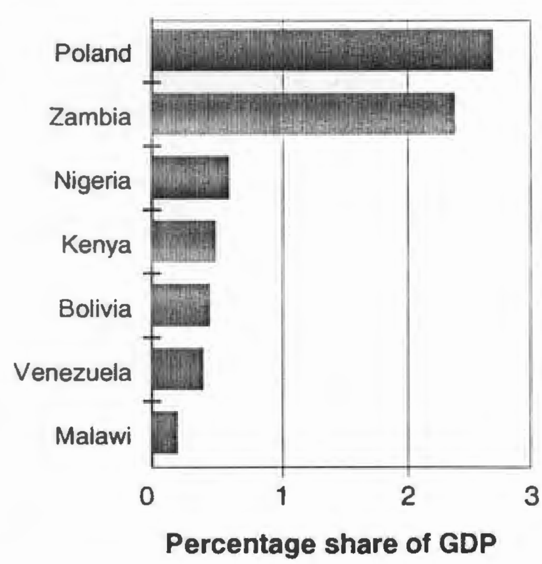
Subsidies have also, for the most part, gone to higher-income households (see box 3.1).

Box 3.1 Who Benefits from Electricity Subsidies?

The shift from subsidized tariffs to economic pricing is urgent in several transitional and emerging market economies. Many governments have historically set prices far below cost recovery levels through subsidies and cross-subsidies to serve social and political objectives. Generally, however, the wealthiest benefit the most. The subsidies often amount to a significant portion of gross national product (GNP) and lead to excessive demand, higher investment requirements, fiscal stresses, and inefficient energy use.

A recent Bank study looked at the distributional impact of electricity subsidies in seven countries. Electricity subsidies are significant in all seven, ranging from 0.2 percent of gross domestic product (GDP) in Malawi to 2.7 percent in Poland. The higher the household income, the greater the subsidy realized, with the extent depending on the level of electricity used. However, as high-income households have more electrical appliances, they benefit more than poorer households. Thus a poor consumer in Malawi receives US$0.04 a year in electricity subsidies, while a rich one receives US$6.60.

Electricity Subsidies as a Percentage of GDP in Seven Countries



Source: Gutiérrez (1995).

Subsidies also have gone to farms and commercial enterprises willing and able to pay for the full costs of service. For example, in Indonesia, subsidized kerosene for cooking and lighting is available to anyone who wants to buy it, but middle-class and better-off households, who can afford to buy more energy than the poor, reap a disproportionate share of the benefits. Until several years ago, the government of Ecuador subsidized kerosene, a fuel used predominantly by the poor. However, the poorest households ended up receiving only limited amounts, because retailers could make higher profits by diverting supplies to those using them for vehicles. Large subsidies have also been ineffective in reaching the poor through rural electrification programs, particularly when decreased cash flows undermine power companies' ability to maintain the quality of service and to extend service to remote areas.

Addressing Market Failures

Limited subsidies or financial support can be justified for some programs in areas where education and training may be needed or where the costs and risks of startup are high.[1] No country so far has succeeded in providing universal electricity service without some form of public support or cross-subsidies in the tariff structure. A typical approach that most industrial countries followed was for the government to mandate a regulatory requirement or to stipulate that a utility had to expand services in rural areas and towns, but could recover the costs through an overall increase in average electricity tariffs. As the costs of service are higher in rural areas, such policies led to some cross-subsidization from urban consumers, though without undermining the utilities' financial position.

Most countries also recognize the wisdom of supporting the development and use of new and innovative technologies, for example, by providing tax incentives, and sometimes investment grants, for solar energy technologies, which have considerable promise as commercial and environmentally attractive sources of energy (see chapter 5).

Public doubts about the capacity of unfettered markets to meet the needs of the lowest income groups are often important in policies. The use of "lifeline" rates (that is, low tariffs) for low levels of electricity consumption is not an uncommon practice, and such rates are effective if properly targeted. Experience has shown that they can be implemented without undermining industries' financial integrity (see the example of Thailand in chapter 4).

Aside from the social justification of such polices as lifeline rates, are there any ground rules for the application of subsidies and other forms of public support? Experience and economic principles both suggest that they work best if they are targeted directly on—and are limited to—addressing market failures. In the case of rural energy provision and use in developing countries, two circumstances merit attention: high startup costs and risks and external costs and benefits.

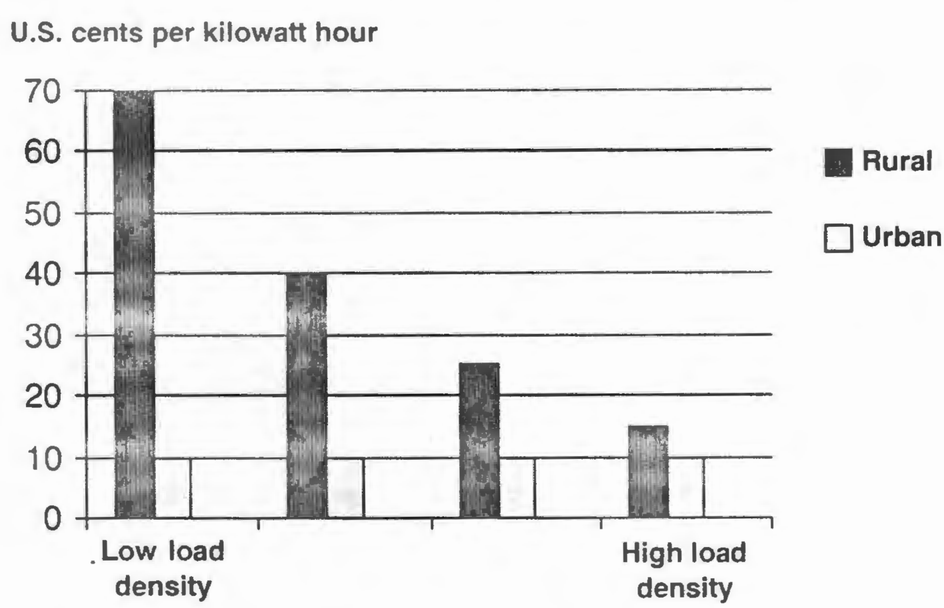
---

1 . The distinction between subsidies and financial support is not always clear-cut. Some programs may require subsidies in the short term to absorb startup costs, but more than compensate for this by their revenues and profitability in the long-term. The topic is discussed further in relation to rural electrification and renewable energy.

High Startup Costs and Risks

Programs to extend electricity to rural areas and towns and to establish solar energy programs are perhaps the best known examples of energy sector activities that entail high startup costs and risks. The costs of grid extension can be high initially because of the lumpiness of the investments needed to reach rural areas and towns for the first time. Costs are often US¢40 to US¢70 or more per kilowatt hour initially, but can decline rapidly toward the levels found in urban area as load densities rise (see figure 3.1). Average costs during a program's early years may greatly exceed the marginal costs of expanding service, and some allowance for this in the tariff structure and financing arrangements may be justified to encourage use.

Figure 3.1 Costs of Grid Electrification in Relation to Load Density, Urban and Rural Areas



Source: Staff calculations based on project data (see also table 4.4).

The situation is similar in relation to the costs of connection and the purchase of appliances and of solar home systems. Setting up a community grid can cost tens of thousands of dollars, and the expense of connection to grid electricity is a pervasive problem, with initial connection costs being as much as US$1,000 in some cases (not including the additional costs of internal house wiring). A solar home system costs between US$500 and US$1,000 or more, depending on the system's configuration, import tariffs, and profit margins. Stoves and cylinders necessary to burn LPG are also a significant investment for the rural poor (see chapter 6). Another startup cost for many programs is that of providing education and training, which was an important feature of Kenya's PV program, which is discussed more fully in box 4.4.

The problems posed by startup costs and risks arise partly from a real or perceived lack of creditworthiness of low-income consumers, and partly from a shortage of long-term credit. Although many researchers have found that rural savings (like people's willingness to pay for service) are often higher than commonly thought (Von Pischke, Adams, and Donald 1983) the absence of affordable credit can be a barrier to meeting the initial costs of more modern energy. However, emerging innovations in credit delivery systems, such as the establishment of the Grameen Bank in Bangladesh (a rural cooperative organization), offer some promising approaches to easing the credit situation in rural markets. Leasing arrangements for equipment such as PV sets, such as are being considered in India, are another possibility. While micro-financing and other programs have been directed mainly at nonenergy uses, they seem well suited to financing energy investments, such as small-scale generating and distribution equipment and appliances.

Electricity companies can also provide credit by including connection and service fees on consumers' bills and spreading the costs over several years. The five-year installment payment for the connection charge operated by the Bolivia public utility is a good example (see box 4.2). Similarly, and perhaps with the aid of a participatory program, wholesalers or retailers of household PV systems, LPG, and improved appliances could, in principle, also become useful conduits for consumer credit. Nongovernmental organizations, cooperatives, extension services, and other community organizations could play a role in designing and overseeing such programs.

Private industries in the rich countries frequently absorb startup costs themselves, and also extend credit to their customers in anticipation of commercial rewards later when markets develop. Examples of this abound in appliance markets. While the same may eventually occur in developing countries as they liberalize their economic policies, it cannot be assumed that it will. Public policies to address the problems posed by high startup costs are both necessary and desirable.

External Costs and Benefits

Public support is also merited to address indoor and outdoor air pollution and the damage to natural resources arising from the use of traditional fuels for cooking. Economists have long recognized that the most effective way to address environmental problems is to tax or regulate pollution. However, the idea of taxing or regulating rural households in developing countries for cooking with wood and dung is not a practical proposition, and other policy instruments are more appropriate, for example, working through rural education and extension services to inform people about the fuels' health effects and initiating related efforts to encourage the use of more efficient woodstoves with flues.

Not all externalities are negative, however, and in relation to energy supplies, rural (and urban) energy policies now need to take into account the positive externalities of new renewable energy technologies. The costs of solar technologies and solar-derived technologies, such as wind, are declining steeply for several reasons: learning by doing, the opportunities for innovation provided by new investment, and scale economies in the manufacture and provision of support and marketing services.

Given the considerable economic potential and environmental advantages of these technologies, both for small- and large-scale applications, the idea of subsidies to develop them further is fully consistent with the economic principles of public policy (Arrow 1962; Baumol 1995). The World Bank Group has also accepted this argument in relation to Global Environment Facility projects (see GEF 1995, 1996, various years).

Emphasizing Participation and Institutional Development

As with other endeavors, development practitioners now recognize that participation by community organizations and local social units is crucial for the success of rural energy policies. To many community workers, scholars, voluntary organizations, and others who pioneered participatory approaches, this has long been self-evident; their efforts are now beginning to bear fruit.

Participation

The World Bank Participation Source Book (World Bank 1995b) summarizes the main features of the participatory approach and draws on case studies from many countries to provide pointers toward good practices.

Cooperatives, nongovernmental organizations, and local community organizations can be highly effective vehicles for supporting the delivery of energy services of all kinds and for managing natural resources. Such grassroots organizations are familiar with and understand local resources and needs, and are often willing to assume responsibility for implementing policies and projects.

For example, in Karnataka State, India, residents of the village of Pura, supported by the Karnataka State Council for Science and Technology and the Centre for the Application of Science and Technology to Rural Areas, now administer household electricity and water generated by large community biogas digesters (see box 3.2). Subsequent chapters of this report present further examples of the participatory approach.

Box 3.2 Decentralized Power Meets Village's Needs for Clean Water

Near Bangalore, south India, the village of Pura supplies household electricity and water through large community biogas digesters. Although community biogas digesters have a history of problems in India, the key to Pura's success was in listening to what villagers viewed as their main problems and needs.

Original attempts to promote community biogas systems in Pura failed because they were directed at substituting biogas for wood as a cooking fuel. Abundant wood resources in Pura make fuelwood collection relatively easy, and therefore villagers had no incentive to maintain the system.

Subsequent discussions with villagers revealed they were more interested in obtaining clean and reliable water supplies near their houses. Because grid electricity supplies were unreliable, the community decided to establish a system of biogas production for fueling a five-horsepower diesel generator. Electricity from the generator was supplied to households through a micro-grid, and also powered a deep tubewell pump. All households participating in the program received a tap with clean water in front of their houses, eliminating long walks to the local tank and significantly improving their health. Each household is charged a fixed rate for the water tap and each electricity connection. Some households now have both a grid and a village connection, which some villagers refer to as "people's power."

Source: Ramani, Reddy, and Islam (1995).

Even the participatory approach, however, does not guarantee success; given its nature it must be tailored to the local situation and the task at hand. Experience has shown that unless projects are related to social groups or actors interested in their outcome and capable of carrying them out, they are unlikely to succeed (see Cernea 1992). Several World Bank-financed community woodlot or community forestry projects, for example, proved to be disappointing for this reason (Cernea 1992). Undertaken in the late 1970s and the 1980s, these projects were intended to reduce fuelwood shortages and pressures on local forests and woodlands by involving communities in planting local woodlots. However, even though they were based on local inquiry and sought to have high levels of local participation, planting rates and woodlot maintenance often fell below expectations. The underlying mistake was to view communities as units of social organization or economic agents, when in actuality, the interests of community subgroups frequently differed and worked against collective actions; community land was limited and the tenure of common lands was uncertain; the local systems of authority had uneven influence over subgroups' decisions; the distributional arrangements for sharing the products of the common endeavor were disputed; and, more generally, the communities were geographical residential groupings, were not organized as joint producers, and were not systems onto which external economic activities could be grafted (Cernea 1989, 1992).

In contrast, when project designers identify the appropriate social unit, the chances of success are improved enormously. An excellent example is afforestation based on farm- or agro-forestry, in which the farmers themselves plant trees on farmlands in association with agriculture. Such projects began to receive more support in the 1980s, and have often exceeded the project designers' expectations, largely because "as an enduring social unit able to sustain forestry development, the farm family is a powerful social resource" (Cernea 1989, p. 53). Participation in the development of woodstove programs by women's groups is another successful example.

Local Institutional Development

Community action may however be effective when people from several villages and towns in a particular region are seeking electricity services. To this end, various approaches are possible, namely:

- Establishing an electricity cooperative, a model followed in parts of the United States and encouraged in the 1960s and 1970s in several Latin American countries. Bangladesh's rural electrification program has recently used cooperatives and has achieved considerable success in terms of the number of connections achieved, cost recovery (close to 100 percent), and service quality.
- Sending deputations from the communities to the regional or national electricity utility to request service, perhaps in conjunction with offers of community self-help to reduce costs.
- Establishing village-level or community ownership of a local system where grid supplies are not available (box 3.2)

Historically, however, providers have used other means of making electricity available to villages and towns. In the first few decades of this century, it was often supplied by a local enterprise willing to invest in a small generator and establish a small, local grid to retail the electricity service or by an agro-industrial plant that had surplus power available. In other cases, local governments established public companies to provide electricity service to their communities, either using their own generators or medium voltage links to a grid. Joint public-private partnerships were another arrangement commonly followed in both industrial and developing countries. As villages and towns expanded following migration from rural areas and economic growth took place, the area's public or private companies also grew, and were the predecessors of the larger municipal—and sometimes regional—electricity companies we still see in some regions. Interconnection then followed, initially to pool reserve capacity, and later to reduce costs further through trading power and energy and through the scale economies that could be obtained by increasing the capacity of power stations. All this took place, if not always in a competitive environment, at least in a situation where good financial returns to investment could be, and generally were, being achieved.

In developing countries, public ownership succeeded local private or quasi-private ownership of electricity distribution in the 1950s and 1960s, and took place somewhat earlier in most industrial countries. Since then, the principal source of service expansion has been the direct extension of supplies from a national electricity authority under public ownership and regulation.

With the privatization and unbundling of the electricity industry in many countries, the question arises as to whether these historical models will reappear or, where countries do not pursue full privatization, ownership will be in the hands of municipalities that operate on commercial principles. This is a difficult question to answer, because no country has followed this path before, and it raises new issues, not only about ownership, but about risks, taxes, regulation, and the roles of local or regional governments (see chapter 4).

A monopoly element would still be present in any public or private involvement in distribution, though the companies would be more visible than their nationalized predecessors, and thus more accountable locally. However, this scenario assumes that companies are willing to invest extensively in extending distribution networks to villages and towns. Yet despite the progress made with institutional reform in the electricity industry since the beginning of the 1990s, private companies have so far shown comparatively little interest in distribution and much more in generation. Will local or regional governments have the capacity to attract private investment in distribution on the scale required? We are at the beginning of a new and complex process of institutional development, the path of which is not yet clear. In the meantime, service expansion needs to proceed. Chapter 4 pursues the discussion of options.

Decentralization

In a broad sense, participation by local people in choosing and designing local investments is moving countries toward decentralized economic development. Thirty years ago a Nobel Laureate, the late Sir Arthur Lewis, drew attention to the importance both of decentralizing financing and of building up local government units. He also noted that public services (schools, water and electricity supply systems, local roads, and health centers and hospitals), which in mature economies are run by local authorities, were in many countries still being run by central governments and financed from central revenues, a situation that persists in most developing regions (Lewis 1969). Local participation and the development of local institutions in this broader sense is desirable from both the demand- and supply-side perspectives.

On the demand side, it helps to reveal people's preferences among different services and may also reveal other things. For example, many studies have found that people's willingness to pay for electricity and other services is far higher than had been assumed (Whittington, Lauria, and Mu 1991; World Bank 1992). Similarly, as noted earlier, rural savings are also often greater than assumed, which makes the problem of people raising enough money for initial connection somewhat less severe. On the supply side, decentralization increases local accountability and provides incentives for more efficient provision of services.

In sum, then, the general aims of seeking greater local participation in rural energy programs are to ensure that such programs are far more responsive to people's needs than they often have been in the past.

Recognizing the Central Role of Good Enabling Conditions for Development

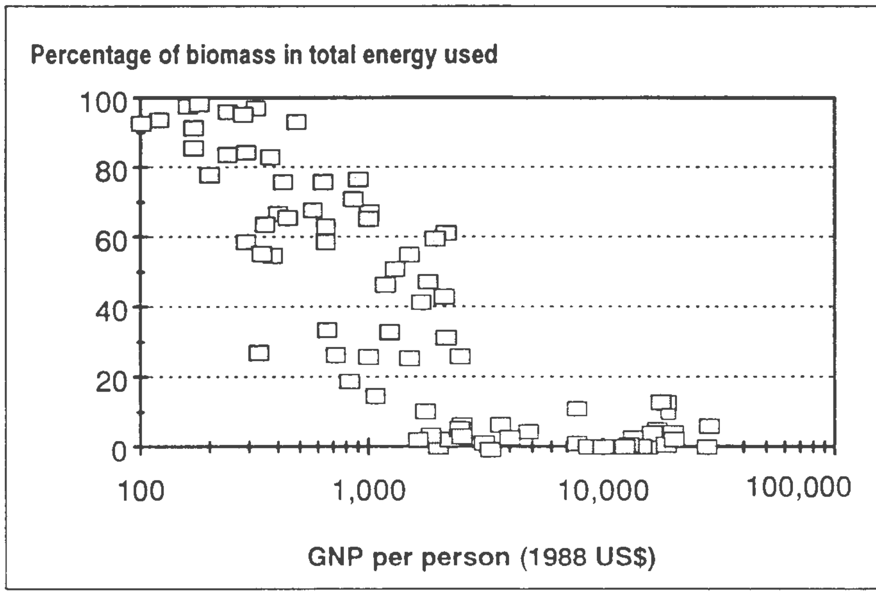
The dependence of so many people who lack access to modern energy forms on biofuels is above all a manifestation of poverty, and unless development policies in general promote economic growth and development on a broad basis, not only will the rural energy problems described in this report persist, they will become worse as developing countries' populations grow.

Even well-conceived investments in rural energy may falter, not because they are intrinsically wrong, but because economic conditions may be working against them. For example, in rapidly developing agricultural regions, the provision of electricity helps to raise the productivity of local agro-industrial and commercial activities by supplying motive power, refrigeration, lighting, and process heating. In turn, increased earnings from agriculture and local industry and commerce raise households' demands for electricity. However, when development efforts fail because of, say, poor crop pricing and marketing policies, electricity supplies may be able to do little to remedy the situation, nor will electricity or other modern fuels be in great demand. If it is to serve a useful purpose, electricity needs a "market," as do other energy forms such as LPG and renewables.

Thus it is no coincidence that investments to improve energy supplies in rural areas are more successful when development is proceeding and incomes are rising. The higher a country's per capita income, the greater the use of modern fuels (figure 3.2). When per capita annual incomes are US$300 or less, 90 percent or more of the population typically depend on fuelwood and dung for cooking. Once annual per capita incomes reach US$1,000 to US$1,500, substitution to modern fuels is almost complete.

With technological progress and reductions in the costs of supplying modern fuels, the income levels at which the transition takes place have been declining for more than a century. This can be illustrated by comparing the experiences of the United States and the Republic of Korea. In the United States, the transition from being 90 percent dependent on woodfuels to eliminating them almost entirely took nearly seventy years, from 1850 to 1920. In Korea, the same transition took about thirty years, and was almost completed by 1980.

Figure 3.2 The Use of Biomass in Relation to GNP per Person in Eighty Countries



Source: World Bank data.

For each 1.0 percent increase in per capita incomes, roughly 0.6 percent of the population turn to modern fuels. Based on projections of per capita income in *Global Economic Prospects and the Developing Countries* (World Bank 1995c), the population served by modern fuels could rise from around 2 billion in 1990 to more than 4 billion by around 2010, and if this happens, the number dependent on traditional fuels would decline by 0.5 billion or more during the period. The biggest gains would be in Asia and Latin America, but there is no reason why Africa could not make good progress, given a good enabling environment.

Looking at the relationship between per capita incomes and fuel use in this way is, of course, a simplification. When development policies are such that incomes in a region are growing, both public and private investments in energy supply, in natural resource management, in soil erosion control, and so forth are all more likely to "work" better and show good returns. When assessing the prospects for policies and investments focused directly on improving energy supplies, therefore, one should also ask whether local health and education programs are being put in place; whether complementary infrastructure, such as rural roads, water supplies, and sanitation is being given proper attention; and whether macroeconomic and pricing policies are such that the investments will function and will serve useful purposes. Rural energy policies and investments are an adjunct to good general development policies, and their chances of success are greatly increased when the answers to such questions are positive.

4

Options for Rural Electrification

Rural electrification is generally thought of as grid electrification, and this is indeed the most common and most desired means of supply. Where load densities are low, however, diesel generators, renewable energy (solar energy, micro-hydro, wind, and small biomass-fired generators), and "hybrids" of such options are more cost-effective.

Progress to Date

Developing countries' efforts to extend electricity supplies to their populations have been impressive. During 1970–90, nearly 1.3 billion people were newly supplied with electricity from national grids, of whom 800 million were in urban areas and 500 million in rural areas (table 4.1).

Table 4.1 Urban and Rural People Connected to Electricity in Developing Countries, by Region, 1970 and 1990 (percent)

	Urban		*Rural*	
Region	*1970*	*1990*	*1970*	*1990*
North Africa and Middle East	65	81	14	35
Latin America and Caribbean	67	82	15	40
Sub-Saharan Africa	28	38	4	8
South Asia	39	53	12	25
East Asia and Pacific	51	82	25	45
All developing countries	52	76	18	33
Total served (in millions)	320	1,100	340	820

Note: These estimates are only approximations.

Source: World Bank project and sector reports, other materials, and surveys of electricity statistics by the World Bank's regional staff in Asia and Latin America.

In all regions the share of the population served rose. China accounted for nearly half of the increases, but the extent of service in Africa remains low. During this period, populations grew by 1.5 billion, and in low-income economies outstripped the growth of people with service: in Sub-Saharan Africa, the number of people with service grew by 55 million, total population grew by 220 million; in South Asia, the number of people with service grew by 250 million, total population grew by 320 million.

Low-income households in developing countries use electricity mainly for lighting, television, radio, and ironing; as incomes rise, refrigerators and other appliances become affordable. Table 4.2 provides data from a survey of electricity use in urban households in Indonesia, where the pattern was similar to that found in rural households in other countries. Unless one counts fans, which are quite popular, air conditioning, which is one of the biggest sources of electricity demand in the rich countries, is virtually absent. Electricity is also rarely used as a cooking fuel, for which it is both expensive and energy inefficient.

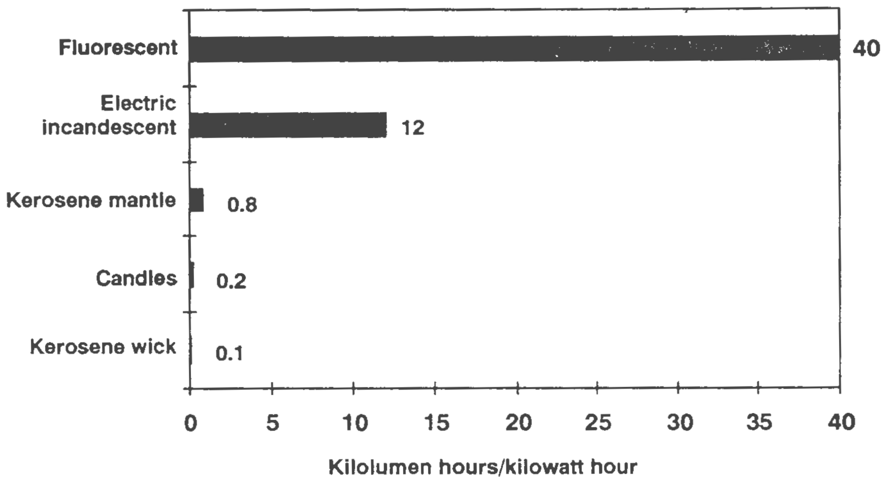
Table 4.2 Appliance Use in Households with Electricity in Urban Indonesia, 1987
(percent)

	Income class		
Activity	*Low*	*Middle*	*High*
Lighting	100	100	100
Television	31	63	83
Ironing	21	51	77
Economic activity	5	6	9
Refrigeration	1	6	9
Water pumping	1	4	26
Air conditioning	0	0	1
Cooking	0	2	8
kWh/household/month	24	47	130

Source: Peskin and Barnes (1994). This paper was a background paper for *the World Development Report 1994* (World Bank 1994b).

One sometimes overlooked feature of electrification programs is that they may improve the efficiency with which energy is produced and used. A particularly dramatic case is that of electric lighting, in which even the incandescent lamp represents a 50- to 100-fold increase in energy efficiency relative to the kerosene wick lamp (figure 4.1). The florescent lamp, which is well suited to solar home systems, raises energy efficiency several hundred times. The quality of the light electric incandescent or fluorescent bulbs provide is also vastly superior to that of kerosene lights or candles.

Figure 4.1 Energy Efficiency and Lighting



Source: van der Plas and de Graaff (1988).

Although electricity from central grids, local grids, or renewables can be expensive in absolute terms, the combination of higher efficiency and better quality service is attractive to those rural consumers able to afford it, and may also reduce the real costs of the service (for example, light) itself. On the island of Java, Indonesia, for example, the use of electricity compared with kerosene led to a seven- to tenfold increase in lighting for newly connected consumers, the cost of electricity per kilolumen of light output being about 5 percent of the costs per kilolumen of light provided by kerosene lamps. In most countries, the biggest sources of demand for electricity in rural areas and towns are often farms, agro-industries, and small commercial and manufacturing establishments (for irrigation pumping, water supplies, crop processing, refrigeration, and motive power). Typically 60 to 80 percent of the electricity supplied in developing agricultural regions is used for such purposes.

Thus rural areas and towns often use electricity for purposes that are socially and economically valuable. They do so often enough to justify the investment from an economic perspective. The main questions about grid electrification in rural areas and towns relate less to its usefulness, than to financing and costs and whether alternatives are more cost-effective. As noted in the introduction, current moves toward market and regulatory reform in the industry are also resulting in new questions being raised about the role of public policy in the expansion of service. Let us consider these questions in turn.

Pricing and Financial Policies

Practically all developing countries have set tariffs for electricity supplies to rural areas at below the costs of supply, even making generous allowances for declines in costs as load density increases (see figure 3.1). This is the same policy that the high-income industrial countries have used in the past. Table 4.3 shows the rural tariffs for several countries compared with the long-run marginal costs of supply. In all cases tariffs are significantly below the estimated costs of supply, although several countries do at least cover fuel, operating, and maintenance costs. A common policy is to have "uniform national tariffs," that is, the same tariffs in rural and urban areas, even though average actual costs can be two or three times higher in rural than in urban areas.

Table 4.3 Costs and Tariffs for Electricity in Rural Areas of Selected Countries, 1993

(U.S. cents per kilowatt hour)

	Cost components				
Country	*Fuel*	*Generation and transmission capacity*	*Distribution capacity*	*Total*	*Average agricultural tariff*
Bangladesh	4.6	9.2	10.6	24.4	16.0
India	2.1	5.8	8.7	16.4	0.5
Indonesia	3.8	4.1	9.8	17.6	5.8
Malaysia	2.3	8.8	4.4	15.5	7.2
Philippines	5.0	2.8	7.5	15.3	9.2
Thailand	5.0	3.8	8.3	17.1	7.0

Note: The figures relate to the long-run marginal cost of use in agriculture at low voltage.

Source: World Bank (1994a).

In cases where the overall financial position of an electric power utility has been sound, in that it has been able to recover the rural subsidies from general tariffs, then even ambitious rural electrification programs have been successfully implemented. The policy is not ideal, but Thailand's experience, summarized in box 4.1, shows what can be accomplished. The program was started twenty years ago and has achieved connection rates of more than 75 percent for the whole country, with high participation by the rural poor. An interesting aspect of this program is the low lifeline rates offered to low-income consumers: as people's incomes grow and their consumption increases, they move into a higher tariff category, eventually reaching US¢10 per kilowatt hour (kWh). The tariff thus gradually reduces the overall subsidy as incomes and demand grow, and the high costs of startup recede into the past—a highly desirable feature.

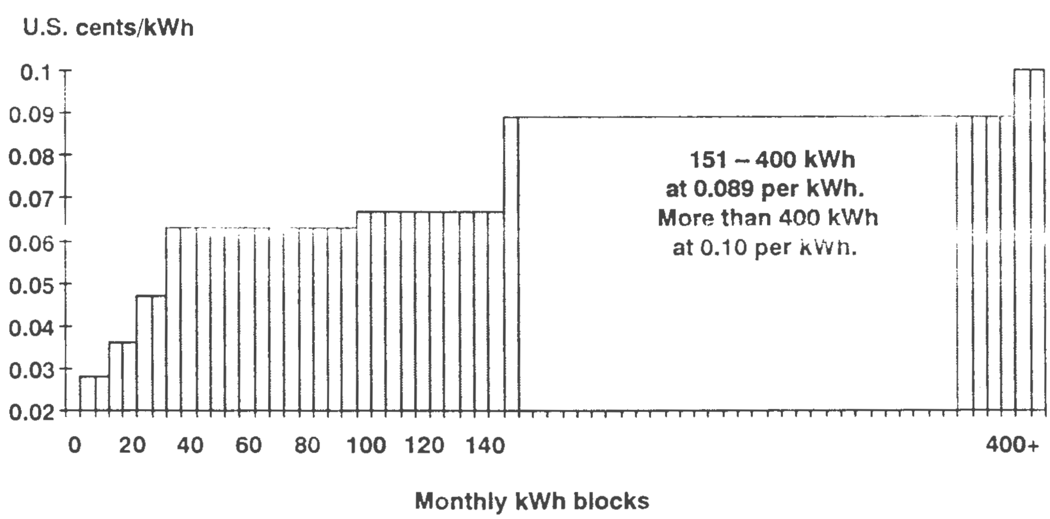
Box 4.1 Rural Electrification in Thailand

Thailand's rural electrification program began during the early 1970s. Between 1975 and 1994, the number of electrified villages increased from 20 to 98 percent. During the same period, the population covered outside the Bangkok metropolitan area increased from 18 to more than 80 percent.

Reasons for the program's success include thorough planning for careful system expansion; keeping costs low; using a unique billing program to ensure revenue collection; paying careful attention to customer service, marketing, and community involvement; and employing a system of cross-subsidies from large to small customers. Retail tariff rate structures were designed to charge larger users higher rates than small users. With respect to residential classes for both urban and rural customers, the retail tariff structure consisted of a fixed charge and several increasing blocks as shown below.

Residential Tariff Schedule
(U.S. cents per kilowatt hour)

Tariff schedule includes a fixed charge and the increasing block rate:
less than 150 kWh, a fixed charge of USc20 for the first 5 kWh or less;
more than 150 kWh, a fixed charge of US$3.56 for the first 35 kWh or less



Lifeline rates for the first 35 kWh were designed to make service affordable for poor people who used small amounts of electricity, primarily for lighting. Because of such limited use by the poor, lifeline rates did not adversely affect the company's financial performance.

Source: Tuntivate and Barnes (1995).

Long-term subsidies for grid-supplied rural electrification are not sustainable in most developing countries. For example, as the Centre for Urban Poverty Alleviation, an Indian nongovernmental organization (NGO), has commented: "The highly subsidized and free power to agriculturists in some Indian states is an extreme example of political largesse in which there are no winners, only losers. The foremost loser is the State Electricity Board, not because of financial losses, but because it perpetuates the debilitating process which makes the Board less and less capable of fulfilling any part of its mandate. Urban and industrial consumers (who pay) suffer because the system is plagued by load shedding and other inefficiencies. The agriculturists hardly get the power they need. The country loses on all counts."

More generally, cross-subsidies have five disadvantages. (Note that they do not arise in connection with the relatively small amounts, typically about 5 percent of total consumption, needed to support such policies as lifeline rates.) They are as follows:

- They undermine the utilities' financial viability, and thus their ability to provide service. In the Philippines (before the recent reforms of the electricity sector) and India, financial losses diminished the utilities' ability to support the expansion of service, not only in rural areas, but also in urban areas. In addition, financial weaknesses eventually led to deterioration of the maintenance of the power plants and electricity networks.
- The costs are high. In rural areas, per capita consumption for household uses typically ranges from 25 to 50 kWh per year, and for nonhousehold uses is some two to three times this amount, bringing the total to some 100 to 200 kWh per year per person, a figure that is somewhat higher in the middle-income countries. Meanwhile subsidies are frequently US¢5 to US¢10 per kWh, sometimes higher, and so may amount to US$5 to US$20 or more per person served per year. These are substantial costs to bear in light of both of the hundreds of millions of people already receiving service (table 4.1) and the yet greater numbers who will be demanding it in future.
- The prospects of alternatives—such as solar energy, small hydro and wind generator sets, and diesel-powered autogenerators—are all undermined. In everyday terms, the playing field is not level, a source of much concern to the numerous businesses, small-scale and large, otherwise able to offer electricity services from such sources to people living in rural areas and towns.
- Private investment in distribution is discouraged. This can, in theory, be overcome by tax incentives or direct subsidies from public revenues, but again, one must ask whether the state can afford this and whether greater claims on public revenues do not exist, for example, from education and health.
- Innovation is discouraged, for example, providing small-scale supplies from renewable energy sources.

More often than not, subsidies are not needed anyway. Rural consumers are willing to pay more if suppliers are willing to incorporate the capital costs of startup and connection in the tariffs. The cases of Pura (box 3.2) and Bolivia (box 4.2) provide good illustrations of people's willingness to pay. In Bolivia, the costs of energy supplied by diesel were five times the costs of electricity supplies in urban areas, but when the capital costs of connection and supply were incorporated into the tariff (as a form of credit), connection rates were high. In many countries people have purchased diesel engines at cost for irrigation pumping, crop processing, and off-grid electricity supplies (Child and Kaneda 1975). Recently, rural households in Kenya have been purchasing PVs at cost, inclusive of import duties, to provide electricity when grid supplies were not available.

Box 4.2 Credit Financing Compensates for High Cost of Access in Rural Bolivia

When people in the villages of Mizque and Aiquile in rural Bolivia were given the opportunity to purchase electricity service from isolated local diesel grids, the high costs prevented about 75 percent of households from accepting the offer. In addition to the high connection costs, the recurrent cost per kWh was about five times that in the central grid, reflecting the much higher supply cost from a small diesel system.

The electricity companies then decided to finance the connection charges in the isolated grids, allowing customers to pay back the costs in small monthly installments over five years. In return, they received electricity service during evening hours. As a result of this financing scheme, the number of households that were able to purchase electricity service more than doubled, and connection rates were comparable to those achieved in the lower-cost central grid. In the village of Vacas, where twenty-four-hour grid electricity service was extended without any credit scheme, the connection rate was about the same as in Aiquile and Mizque (see the table).

Credit Access and Electricity Adoption

Village	*System*	*Credit access*	*percentage on credit*	*percentage of households with electricity*	*Price ($/kWh)*
Aiquile	Diesel	Yes	51	55	0.25
Mizque	Diesel	Yes	56	59	0.30
Vacas	Grid	No	0	54	0.06

Despite paying about five times more for service limited to only evening hours, more than 50 percent of households in Aiquile and Mizque valued the benefits of electricity enough to pay for it when an affordable financing scheme became available. The example (a) shows that people are willing to pay much more for electricity than they often do, and (b) suggests why credit can be important for providing access.

Source: Torres (1993).

An ideal policy is one in which prices recover the present value of costs over the long-term, that is, prices are equal to the discounted unit cost (see Turvey and Anderson 1977). In general, this will mean that prices will be below average costs for some time until demand and load densities have increased sufficiently, but above the long-run marginal costs of supply so as to provide for an eventual recovery of the initial costs of extension. Such a policy has the advantages of including a credit component, of being financially viable, and of making it attractive to the company to expand service and promote use. As noted earlier, there is no reason why such a tariff cannot include lifeline rates without compromising the utility's financial position.

Cost-Effectiveness and the Choice of Alternatives

Electrification programs have centered almost exclusively on grid electrification. While this is cost-effective for high-density loads, planners have often overlooked the alternatives. The costs of electrification can be reduced by working with lower service standards, but other options are available (Munasinghe 1987).

Costs of Grid Supplies

Table 4.4 shows the costs of extending distribution to unelectrified areas. The incremental costs of expanding grid supplies usually have the following components: (a) the capital and fuel costs of generation; (b) the capital costs of reinforcing the transmission and subtransmission networks; (c) the extension of medium voltage transmission networks; and (d) the establishment of a low voltage distribution network and household connections. Such costs vary from country to country and among regions in a single country, and the costs of meeting peak demands are considerably higher, but the table illustrates how costs vary in a typical situation. Grid supplies are usually a cheaper option in areas with high load densities and high load growth near the grid.

Reducing Initial Investment Costs by Using Appropriate Design Standards

The high initial costs are a major barrier to service extension, but can be reduced appreciably by using design standards suitable for areas with lower demand (once demand rises, standards can be increased). The demands of most rural consumers range from 0.2 kilowatts (kW) to 0.5 kW; however, the minimum service connection ratings in developing country utilities are typically 3 to 7 kW, which raises costs. For the same reason, the costs of installation and wiring provided by the utility are high. Simplifying wiring codes and using load limiters (circuit breakers) for lower levels of consumption can reduce costs significantly. In addition, using cheaper poles and involving local people in works and maintenance will also reduce service costs. When service is being provided to millions of people, the aggregate of such economies is considerable.

Table 4.4 The Effects of Line Length and Consumption Levels on the Costs of Rural Electrification (costs in U.S. cents per kWh)

Cost component	*Unit costs*	*Totals*[a]
Generation		
Fuel	3	n.a.
Capital	2	n.a.
Transmission and subtransmission reinforcement	3	n.a.
Subtotal	8	n.a.
Medium-voltage extension and low-voltage distribution		
3 km spur line, 20 households	45	55
3 km spur line, 50 households	20	30
1 km spur line, 20 households	15	25
1 km spur line, 50 households	7	15
High-density rural loads	2	10

n.a. Not applicable.

a. Estimates rounded. Totals include generation and transmission.

Assumptions: Medium-voltage lines, US$10,000 per kilometer, low-voltage distribution, US$5,000 per kilometer, US$40 per kilovolt ampere for simple pole top distribution transformers; consumption levels of 35 kWh per month per household; 20 meters of low-voltage circuit per house; 10 percent discount rate; twenty-five year lifetime for circuits, fifteen years for transformers. The above figures are adjusted for the higher losses experienced in serving rural energy demands.

Source: Arun Sanghvi, personal communication.

Micro-Grids Supplied by Diesel Generators

Decentralized, isolated distribution systems have been common for several decades in remote population centers, and in most developing countries predate the establishment of grids. For example, such systems were serving numerous villages and towns in northern Ghana before the grid extensions in the 1980s. Box 4.2 on Bolivia provides another example. The costs of such systems typically range from US¢20 to US¢60 per kWh. Table 4.5 provides data for two schemes, each serving fifty consumers, one in Yemen, the other in Pakistan.

Maintenance and high fuel costs have been long-standing problems with diesel generators. The systems are often in remote locations, and the difficulties of purchasing imported spare parts and fuel have often made them unreliable.

Table 4.5 The Costs of Small Diesel Supply Systems in Pakistan and Yemen

System elements	*Pakistan*	*Yemen*
Number of consumers	50	50
Consumption/consumer/month	25 kWh	25 kWh
Size of generator	20 kW	20 kW
Investment cost (including network and civil works)	US$14,250	US$14,250
Fuel cost per liter	$ 0.17	$ 0.22
Electricity costs	US$0.35/kWh	US$0.51/kWh

Source: Meunier (1993), cited in Foley (1995).

Electricity Supplies from Renewable Energy Sources

The cost estimates in table 4.5 are fairly typical of small diesel plants. They also show why energy from solar, wind, and micro-hydro schemes has become attractive in regions where the solar insolation, wind regime, or hydro resources are suitable. A report by the former Office of Technology Assessment of the U.S. Congress (OTA 1992) found that the all-inclusive unit costs of electricity were as low as US¢12 per kWh for micro-hydro, depending on the site, US¢45 per kWh for PVs, and US¢25 per kWh for small wind sets (the costs of the latter two technologies have declined significantly since). Electricity for local distribution can also be generated from such fuels as biogas or biomass, depending on local availability of resources (see box 3.2 on the case of Pura).

Micro-hydropower can be one of the cheapest options for providing electricity to rural areas that are too far away from the grid to be connected to it, and can sometimes also supply the grid. This is certainly true where local capacity to manufacture turbines exists, as in China and India. In India, a program to finance micro-hydro systems privately will both serve local demand and feed into the central grid system.

Another aspect of micro-hydro is the care needed when selecting a site, given the possible variation in stream flows during the year and from river to river. Costs vary significantly, depending on the site and the terrain. In Nepal, for example, some 25 percent of total costs for a micro-hydro project can be for transportation of equipment and materials alone, but are much lower in less mountainous regions. However, if all elements of the project cycle adopted a low-cost approach, even in Nepal the costs of extending the grid to small consumers could be as low as US$150 per consumer. One important aspect of such approaches is the participation of the local community, which reduces costs, enhances consumer satisfaction, and helps to provide a financially viable investment. Box 4.3 provides an example of an innovative and successful micro-hydro development effort in Peru, at a village center distant from the national electricity grid.

Box 4.3 A Credit Program for Micro-Hydro in Peru

One constraint to the wider use of small-energy technology is access to capital. Many financiers see micro-hydro schemes as high risk, and are therefore reluctant to make funds available. This reluctance stems from the frequent lack of adequate support for training, operation, and management of schemes by borrowers.

In Peru in 1993, the Intermediate Technology Development Group (ITDG) and the Inter-American Development Bank established a rotating fund to make loans of up to US$30,000 available to rural communities and rural enterprises for micro-hydro schemes. The interest rate is 8 percent per year, and the payback period is five years.

The first scheme to be installed under the program supplies electricity to the village of Chalán, fifty miles from the national grid. Chalán has a population of 540 people in 120 families. In addition, nineteen other small settlements or hamlets in the area use Chalán as their main center for services.

The initiative for the micro-hydro scheme came from the village council and a local NGO that was working with local farmers. The funding for the scheme came from four sources: a loan from the credit program, a grant from the local NGO, the resources of the village council, and the labor of every family in Chalán, who agreed to contribute a set amount of time to construct the channel, install the pipe, and build the powerhouse (the community provided a total of 4,318 person-days of labor). The ITDG supervised construction and provided technical and management training.

The capacity of the Chalán micro-hydro scheme is 25 kW and the capital cost was US$82,700. Direct connections have been provided to eighty families to date, with most remaining households expected to connect in the future. A further 617 families from surrounding communities are indirect beneficiaries of the scheme as they now have access to improved health and education facilities, battery charging, agro-processing, and workshop and communication services and also benefit from public lighting in the village.

An elected committee that is independent of the village council manages the schemes and is responsible for overseeing operation and maintenance; collecting tariffs; promoting safe and efficient use of the energy; and managing the introduction of new uses, such as workshop equipment. At present, the power from the plant is priced at US¢9 per kWh, although this will increase to cover the costs of generation and to provide a reserve fund for repairs and replacements. Conversely, as demand increases, the costs of generation will fall, providing the opportunity to reduce tariffs.

The credit program aims to install around twelve schemes. The program has already attracted considerable interest among local communities and enterprises, government bodies, and international agencies.

Source: Courtesy of Stephen Fisher, ITDG, personal communication (1996).

The development of micro-grids, whatever their primary source of energy, requires a significant level of community consensus and support regarding such factors as billing, service, and organization. Local participation is a key ingredient in the design of such isolated systems, in their implementation, and in their day-to-day operation. This is self-evident in the case of small local systems that are the result of local self-help or private initiative. However, even isolated systems put in place by a national program are more efficient if they enlist the cooperation of local consumers. Central grid systems also benefit from local participation in rural distribution. In Bangladesh, for example, locally managed rural electric cooperatives are responsible for distributing power that they purchase from the grid or generate locally. Their record of billing, collection, losses, and maintenance is significantly better than that of the main power utility in charge of urban distribution.

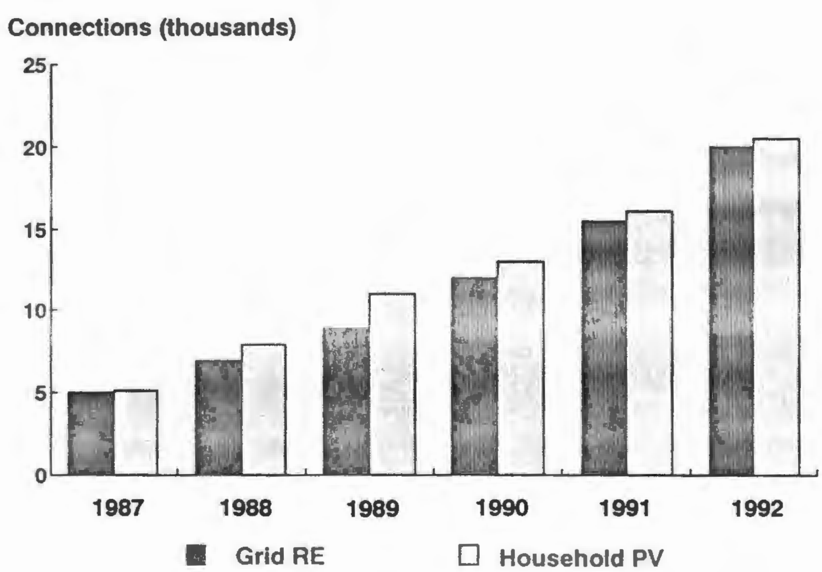
Developments in new renewable energy technologies have greatly expanded the options for supplying electricity in rural areas (see chapter 5 for a more complete discussion). Consider developments in solar PV technologies, for example. Barely twenty years ago, at the time of writing the Bank's previous policy paper on rural electrification, costs were several hundred thousand dollars per kilowatt, conversion efficiencies were low, and the only applications were in aerospace and in specialized switching circuits. Today PV systems are providing electricity economically to rural areas of developing countries for domestic lighting and appliances, vaccine refrigeration for health clinics, village water pumps, telephones, irrigation pumping, street lighting, and schools. In areas far from the grid or where delivering conventional fuels is difficult, renewables are often the least-cost options. Significant markets for PVs are thriving in rural areas of developing countries—in Kenya, for example (box 4.4).

Cost-efficient use of renewable energy technologies in rural areas can be encouraged by educating people about the possibilities and by providing training in how to install and maintain the technologies. Electricity distribution companies also need to be encouraged to consider the costs and benefits of the solar alternative to grid supplies to meet small loads and provide supplementary power on the longer distribution networks. The World Bank Group's Solar Initiative, launched in 1994, is identifying such opportunities (see chapter 7).

Box 4.4 PV Market Growth Outpaces Grid Connections in Rural Kenya

About 20,000 households in rural Kenya have purchased PV systems for electric lighting, despite the absence of any government program and in the face of import taxes of 30 percent or higher on PV equipment. The private sector has accounted for about two-thirds of the total installed capacity. By contrast, the country's highly subsidized rural electrification program has reached only 17,000 households (see the figure below). The cost of PV-supplied electricity for low levels of lighting in rural areas is now competitive with the cost of grid electricity.

Comparing Grid and PV Use, 1987–92



Rural electricians are joining forces with urban entrepreneurs and solar electric suppliers based primarily in Nairobi. Currently, at least eight companies supply the PV market and compete through agents in rural areas to market, install, and maintain PV systems. Such growth in PV use illustrates the high value people in remote locations place on electric lighting. They view PVs as an attractive alternative to waiting indefinitely for the grid system, which may never reach them.

Source: ESMAP (1994a).

Regulatory and Price Reforms, Unbundling, and Privatization

Extending electricity supplies to large numbers of people and growing markets in developing countries will require financially sound and efficiently managed electricity supply industries. However, despite a sixfold increase in electricity generating capacity and output since 1970 and the rapid increase in the number of customers served, by the late 1980s the financial positions and efficiency of electricity supply industries had deteriorated badly in many countries. Several of these countries are now attempting to reform their electricity supply industry and its ownership and regulation so that it can be operated on commercial principles and under independent management (see World Bank 1993b, 1994d). Box 4.5 summarizes the key aspects of the reform process and provides some examples.

Implications for Rural Electrification

Countries that permit more commercial policies and independent ("arm's length") regulation in the electricity supply industry will see the industry's financial position greatly strengthened, and thereby its ability to extend and offer reliable service to rural areas. Average real tariffs in the electricity supply industry in developing countries had declined from US¢5.2 per kWh (already below the costs of supply) in 1979 to less than US¢3.8 per kWh by the early 1990s, whereas supply costs were around US¢10 per kWh. Given electricity sales of approximately 2.2 trillion kWh per year, annual revenue shortfalls were thus in excess of US$130 billion per year, more than was needed to expand capacity, and ten times the amount needed for even ambitious rural electrification programs. As box 3.1 pointed out, the bulk of the implied subsidies were for commercial, industrial, and household consumers who were both able and (in the economist's sense of the term) willing to pay for service.

The main question about the reforms now being sought, therefore, is not about their desirability, but whether they will bring about sufficient commercial interest in rural electrification. Urban markets are not only easier to serve and more lucrative, but also have big supply backlogs and are growing rapidly. All the countries that have so far succeeded in providing universal service to rural areas and towns (the high-income industrial countries) did so with public leadership and financial support. Governments mandated service expansion, often coupled with regulatory permission to recover the extra costs from higher prices in urban areas, provided tax incentives, or both. Whether the private sector in developing countries will respond to the challenges involved is unknown.

Box 4.5 Institutional Reform in the Electric Power Sector

Many countries are introducing reforms to increase the efficiency of their electricity industries and attract more private sector financing and management. Reforms include

- Cutting governments' role by separating policymaking from regulation and operation of utilities
- Establishing transparent regulatory systems with predictable price setting rules and procedures
- Putting power sectors on a commercial basis, preferably as companies under a commercial code
- Raising capital on local and foreign markets
- Encouraging direct investment and competition in generation and distribution.

Since 1992, the pace and depth of energy sector reform has intensified in developing countries, particularly in Latin America and Asia. In Argentina, Bolivia, and Peru, governments are unbundling the sector and selling facilities to the private sector. Competition is evident in generation and the acquisition of distribution facilities. While each country is developing its own approach to reform, many of the reforms have been modeled on those in Chile, because it completed its restructuring and privatization long before other countries in the region. Most recently, Brazil and the smaller countries of Central America have begun to follow the trend.

In most Asian countries, progress is intensifying. As private power projects develop, reforms to encourage competition and increase the efficiency of existing producers and distributors pick up speed. Governments are paying much greater attention to the performance of the distribution enterprises to ensure that they can act as reliable power purchasers and be depended upon to collect electricity bills on time and minimize losses. Asian utilities are tending toward incorporation, as companies and governments are not focusing on unbundling to date except in Pakistan and the Philippines, but are paying particular attention to regulation. China has passed a new electricity law that is expected to pave the way for separating the regulatory functions of the provincial power enterprises. Likewise, in India, many of state boards are considering radical reform based on the "Orissa model." The government passed the first major regulatory law in Orissa, and this is likely to be adopted in the other states.

In Eastern Europe and the former Soviet Union, progress has been much slower. Many are beset by old, poorly maintained plant; excess capacity; and environmental and safety problems. These issues are limiting the focus on reform, and little new investment is now being sought. The Czech Republic and Hungary have made good progress toward privatization, however, and reforms in Poland and Ukraine are promising. Still governments seem reluctant to relinquish their regulatory roles.

In Africa, governments are increasingly recognizing the need for reform as they come to understand that reform in other regions could leave them behind and discourage private involvement unless they, too, commit to changes.

Source: World Bank (1993a,b, 1994d) and internal staff reports.

So far, private investors have been mainly interested in generation, not distribution, something that adds to the problems of public authorities that wish to encourage private investment and service extension on the one hand, but find limited private response on the other. In Asia, private ownership of installed capacity—almost wholly in generation—ranges from less than 20 percent in China, India, and Thailand, to 20 to 50 percent in Indonesia, Pakistan, and the Philippines, to more than 60 percent in Malaysia. The figures are higher, on average, for the Latin American countries, where privatization is proceeding more rapidly, but as in Asia, private investors' interest in distribution is still quite low. Yet another complication is that with rare exceptions, countries cannot accomplish the reform in a short period, so for the next several years, policymakers and the industry will have to continue to supply and expand service while reforms are under way.

Approaches

In these circumstances, rural electrification will require public involvement for some time to come, and as with the general institutional reforms now taking place, no uniquely best approach is available; much will depend on individual country's circumstances. The following are some possibilities:

- A continuance of public involvement in distribution, with regulations requiring companies to expand service in ways consistent with achieving satisfactory financial rates of return to investment.
- Joint public-private investments in distribution, with the same regulatory requirement as the first option.
- When the distribution company is privately owned, a regulatory requirement to expand service, coupled with permission to meet the financing requirements out of rural-specific tariffs or (a second-best measure) a surcharge on general tariffs.
- Full price liberalization on private investments in distribution, with regulators acting as monitors of prices and the efficiency of service, the latter being defined to include the expansion of service where the costs and returns justify it.
- The encouragement of the formation of electricity cooperatives, the private development of micro-grids, or both.

This list is not comprehensive, and other options are possible. Barring an economic surprise, however, public leadership does seem to be necessary to expand service to rural areas and towns; it will need to be open to alternative arrangements and to a variety of ways of encouraging private investment.

5

Innovations in Renewable Energy

Recent developments in renewable energy technologies have greatly added to the options available for improving rural energy supplies. The main technologies suited to rural areas are micro-hydro, biogas, wind generators, wind pumps, solar heaters for hot water, and sustainable ways to provide wood supplies. All these are important sources of energy and can be developed further, as illustrated by the examples of China (box 5.1) and Pura in India (box 3.2). A more recent development has been the use of photovoltaic (PV) systems to provide electricity supplies for such small-scale applications as electric lights and domestic appliances, refrigeration for clinics, village water pumps, street lighting, and health clinics and schools. For small-scale applications in rural areas, PVs are often less expensive and more reliable than grid supplies or diesel motors. The encouraging feature of the Kenya example discussed in box 4.4 was that it was financed on a purely private basis (van der Plas 1994). Solar thermal electric systems using parabolic dishes are also showing much promise for small-scale supplies (Ahmed 1993).

Aside from their environmental appeal, new renewable energy technologies are attracting professional interest for several reasons, namely: the abundance of the solar resource, from which most forms of renewable energy are derived; technical progress and cost reductions; and the modularity of the technologies. The rest of this chapter will focus on technological progress and on the supporting policies needed if renewable energy is to be widely used in rural areas.

Technical Progress in Using the Solar Resource

Each year, the earth receives energy from the sun equal to 10,000 times the world's commercial energy consumption and more than 100 times the world's proven coal, gas, and oil reserves. Modern solar electric schemes, such as PV systems and solar-thermal power stations, can currently convert 7 to 15 percent of the incident energy into a form useful for consumption, and in theory would need less than 1 percent of the world's land area to meet all its energy needs. Solar energy is an abundant and infinitely renewable resource.

Box 5.1 Renewable Energy in China

China has long promoted renewable energy technologies for its large rural population. Nearly 800 of China's 2,166 counties depend on small-scale hydro for electricity, and some 5.5 million households use biogas systems that process animal manure, kitchen wastes, and night soil into biogas for cooking. Many small-scale wind machines are in household use—120,000 in Inner Mongolia alone. The Ministry of Agriculture estimates that private artisans have assembled more than 4 million square meters of solar heaters using devices designed by China's Solar Energy Research Institute. This is equivalent to the heat that several hundred megawatts of electricity generating capacity could deliver. Demand has grown by 50 percent in each of the past two years, stimulated by a rise in farm incomes. Until recently, the PV program had reached a modest 4,500 households. However, an active research program is under way, and in Qinghai Province alone, where insolations are good, plans call for PV electrification of 100,000 households in the next twenty-five years.

Source: Terrado and Cabraal, staff memorandum (1996).

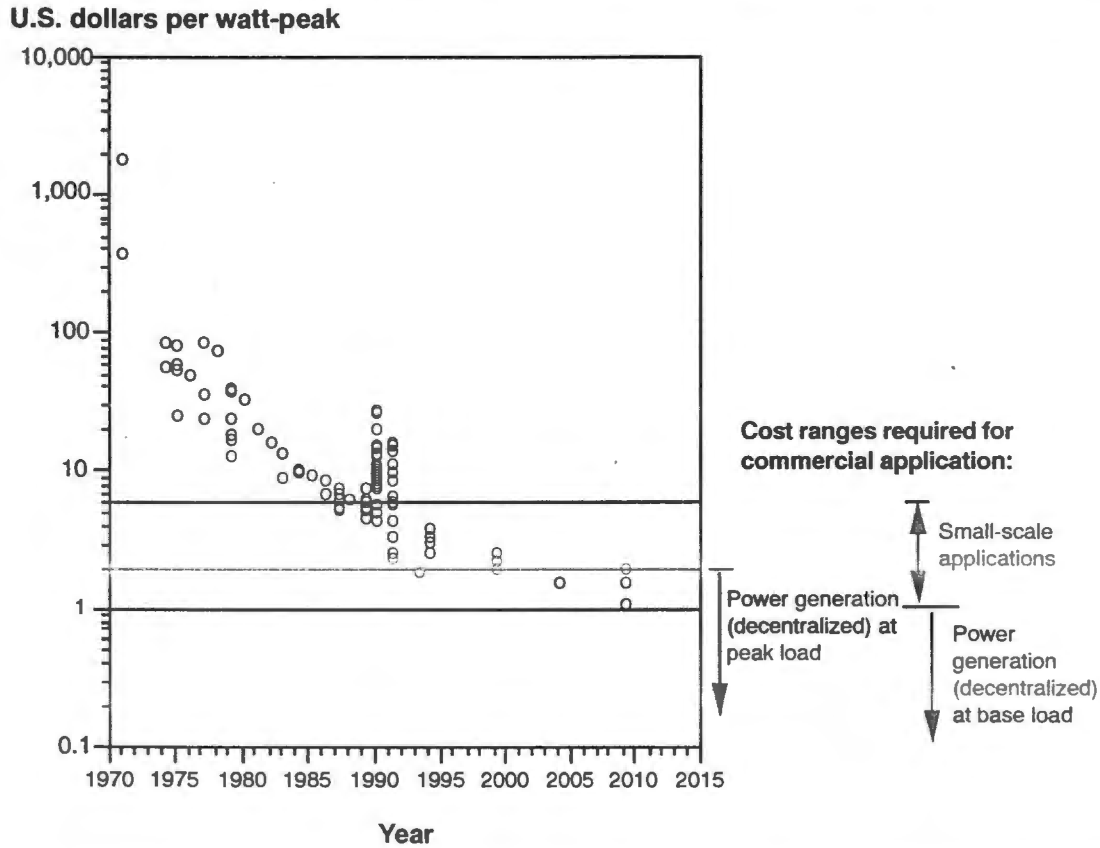
Insolations are about 2,000 to 2,500 kilowatt hours (kWh) per square meter per year in many areas of developing countries, which means that a PV scheme of 1 square meter can supply 100 to 300 kWh, depending on the type of cell used, which is sufficient for lighting, radio, television, and ironing, while a 5 square meter panel set is sufficient to meet the water pumping needs of a village or to provide for irrigation on a small farm.

Technical developments have been impressive. and reductions in the costs of all major solar energy technologies, including derived forms of solar energy such as wind, have been substantial (Ahmed 1993; Johansson and others 1993). As figure 5.1 shows, in the early 1970s PV modules cost several hundred thousand dollars per peak kilowatt and applications were largely confined to aerospace and other specialized uses. By 1990 costs had fallen to US$6,000 per peak kilowatt and PVs had become commercially viable for a wide range of small-scale uses; costs have declined by another 20 to 30 percent since. An estimated 100,000 to 200,000 systems are installed in developing countries, including 40,000 in Mexico, 20,000 in Kenya, 16,000 in Indonesia, 15,000 in China, 10,000 in Brazil, and 4,000 in Sri Lanka.

Engineering and economic data show that further progress is likely on two fronts:

- Scale and production economies. World output grew from 1 megawatt per year fifteen years ago to around 70 megawatts today, a growth rate of more than 30 percent per year. Markets are still small, but the technologies are modular, and economies of scale and the technical possibilities for batch production have barely been exploited.
- Further progress in cell, module, and systems design, along with improvements in conversion efficiencies. Improved materials, multijunction devices and novel cell designs to capture more of the solar spectrum, and concentrator (Fresnel) lenses to focus sunlight onto high-efficiency cells are further areas of rapid development.

Figure 5.1 Actual (1970–92) and Projected (1993–2015) Costs of PV Modules



Note: The range of costs marked on the graph show the PV module costs required to compete with small-scale applications and with decentralized power generation (assuming supply costs of US¢8 to US¢10 per kWh (at base load) and US¢16.5 per kWh (at peak load). The spread in the points reflects the spread in costs of different technologies.

Source: Ahmed (1993).

The technologies are now at the point where they are competitive for off-grid supplies, and are therefore of special interest to rural areas. Box 5.2 on Indonesia's experience with PVs provides a good example of the respective economics of grid and PVs for supplying rural areas. At high load densities the grid is clearly preferable, at lower load densities PVs are a more cost-effective option.

Good progress has also been made with small- and large-scale thermal solar schemes and with derived forms of solar energy, such as wind and biomass resources for power generation. In China and Middle Eastern countries solar-thermal collectors are a popular heat source for domestic hot water, and promising experiments with solar cookers are afoot in Asia and Africa. Another promising solar-thermal technology is the parabolic dish for small-scale power generation, and when scaled up, for grid supplies. Studies by the U.S. Department of Energy have indicated that the costs of 25-kilowatt modular units vary from US¢12 to US¢20 per kWh (Ahmed 1993). In the case of wind for power generation on a larger scale, costs have declined from around US¢15 to US¢25 per kWh to US¢4 to US¢8 per kWh in favorable locations. For small-scale applications the costs are US¢20 per kWh, but can be competitive for off-grid supplies.

Of all renewable energy sources, biomass (ligneous and herbaceous crops and agricultural and municipal wastes) is the largest, most diverse, and most readily exploitable. Biomass residues are often available in large quantities as agro-industrial wastes. Recuperation, more efficient production, and more rational use of biomass residues and forest resources could make many agro-industries energy self-sufficient as well as provide additional energy to the economy in general. This requires the conversion of biomass into cleaner and more convenient fuels (gases, electricity, briquettes).

Developing country agro-industries (saw mills, sugar mills, and palm oil mills) already use biomass residues to generate power and heat for the industry's own use. On-site utilization is currently limited to raising process heat and power, but its use could be expanded to heat for drying and product treatment. Also, co-generation of electricity for a mini-grid can be economically beneficial. Off-site utilization of residues includes direct utilization of residues in industrial oil-, wood-, and coal-fired combustion systems.

Biomass conversion technology may find application in situations where petroleum fuels are either unavailable or where the cost of power from engines fueled by producer gas is lower than from diesel- or gasoline engines. Gasification combined with the use of gas in an internal combustion engine or turbine is an efficient way to convert solid fuels into shaft power or electricity on a small scale, and more advanced processes for larger scale gasification are under development. Heat gasifiers are technically reliable and economically attractive compared with conventional alternatives. Apart from use in the rural agro-industry (for example, for tea drying), non-agro industrial applications are also viable (for instance, brick and ceramic kilns). Consequently, this technology is already in large use in developing countries.

Economists believe that the costs of new renewable energy technologies will decline further because of scale economies and the stimulus that market growth will give to further research and development and innovation. Japanese and American studies of the learning curves for PV technologies have found that for each doubling of the cumulative volume of production during the past fifteen years, costs have declined by 20 percent (Ahmed 1993; Anderson and Williams 1994). Renewable energy technologies are fertile ground for innovation; the possibilities for further developments and cost reductions are far from being exhausted.

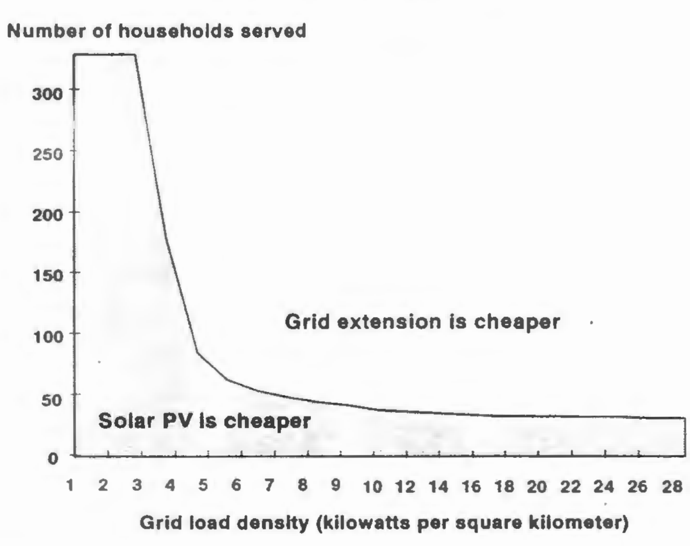
Box 5.2 Solar PV Home Systems in Rural Indonesia

Solar home systems using PV technologies have the potential to provide electricity to a large number of rural households. In Indonesia 3,000 solar home units were installed during 1988–92. A recent evaluation found that the units are working as planned. Today, more than 16,000 units have been installed through public programs and by commercial dealers.

In a typical 50-watt-peak system, a solar PV panel is installed on the roof of a rural home or shop. The panel charges an automobile-type battery that is used at night to run up to four energy-efficient light bulbs and a black-and-white TV or a radio for four to five hours a day—approximately equivalent to consumption of 0.5 kWh of grid electricity per day. Systems ranging from 20-watt-peak (for lighting alone) to 200-watt-peak (for schools, meeting halls, or higher-consumption households) have also been used successfully.

Solar home system units offer a fast and least-cost means of providing decentralized rural electrification in two "niche" markets: (a) where the grid may be nearby, but consumers are dispersed and the load density is low, making grid extension to individual consumers expensive; and (b) where the grid is more distant and is not expected to be extended soon (see the figure). In these two markets combined, the economic potential for solar home systems in Indonesia is estimated at more than 5 million of the approximately 30 million rural households that lack grid supply.

Grid Extension and Solar PV Switchover Values Outside Java Grid 3 Kilometer Medium-Voltage Extension



Solar home systems also offer (a) superior quality and quantity of light, compared with kerosene lamps, along with absence of indoor fumes, pollution, and fire hazard associated with such lamps; (b) no need to haul battery to a central charging facility; and (c) environmental benefits.

Source: Arun Sanghvi, internal communication.

Policies toward New Renewable Energy Sources in Rural Areas

New renewable energy technologies still account for less than 2 percent of the primary energy supplies of developing countries, but in light of their promise, with good economic and environmental policies and with the development of the necessary support systems for installation and maintenance, their market shares should expand. Investments will also be required to acquaint energy engineers and managers with the technologies and to educate and train engineers and skilled workers. As with all new and innovative technologies, developing the best approaches will take a good deal of effort (and some trial and error).

A recent review of PV programs in the Pacific Islands (Liebenthal, Mathur, and Wade 1994), for example, found that many PV systems failed after installation, and it was only when supporting services were introduced that the programs began to succeed. These services included training technicians, ensuring timely maintenance, collecting fees on a regular basis, providing proper oversight to prevent the diversion of revenues to other projects, and obtaining prompt feedback on needs from local user communities and passing the information on to the supplying utility. Similarly, a program in India introduced PVs in several states for domestic and street lighting, community televisions, water pumping, and other purposes during 1986-92. Yet out of more than 5,000 street lights, more than half—in some states all—were not working a short while later, and the other applications exhibited similar failure rates. The findings were particularly disturbing because PVs are durable, are relatively simple to install, and require little maintenance. As in the Pacific Islands, the problem turned out to be the lack of supporting services.

Successful programs require two main ingredients: (a) paying proper attention to program development, for example, initiating surveys of renewable energy resources, carrying out project identification and preparation, and investing in education and training; and (b) creating good enabling conditions through economically efficient pricing, credit, and tax policies.

Program Development

Establishing a program involves significant effort. The first task is to survey solar and wind resources. Such surveys have long been carried out for hydro programs, as geological and engineering investigations have usually been carried out for many potential sites, and data on river flows have been collected for several decades, but they are rarely available for solar or wind energy. In addition, a program of field tests of equipment with a fairly substantial number of consumers (often several thousand households) will be necessary not only to justify the investment in the equipment, but to establish supporting maintenance services and to monitor progress.

As with any new area of investment, issues arise in connection with risks and uncertainties. In the field of renewable energy, some of the questions raised are at a quite elementary level. For example, some projects designers may not even have assessed the level of solar, wind, and biomass resources, while potential consumers are often not up-to-date on technical developments, costs, and how similar projects elsewhere have performed. The predisposition of institutions to resist change is also a factor that widely impedes new investment and initiative.

Another major task is to familiarize professionals in the electricity industry—engineers, managers, financiers, regulators—with the new possibilities. Expanded education and training, including visits to operating projects, may help to change negative perceptions and aid the development of investment programs. Beyond this, the facilities and curriculums of universities and technical colleges may need to be developed to provide appropriate education and training.

The financial requirements needed to develop programs, identify and prepare investments, and provide education and training are generally small in relation to the costs and benefits of the investments that eventually emerge. As with the development of programs using more traditional renewable energy forms, such as micro-hydro schemes, biogasifiers, and sustainable ways of using woodfuels, the participation of nongovernmental organizations in project development can be beneficial. Bilateral aid organizations and nongovernmental organizations, often working in collaboration, have also been influential in establishing pilot schemes and offering education and training to engineers and technicians from developing countries. The many applications of PVs in developing countries owe much to such efforts.

Prices

As discussed in chapter 4, for rural areas both peak and average costs are sometimes twice the marginal costs of electricity supplies in a typical urban situation. If new renewable energy technologies are to succeed as an economic alternative to conventional power plants and to grid electrification in rural areas, then as chapter 4 emphasized, the electricity industry must adopt cost-reflecting price policies. Such pricing policies include time-of-day and seasonal, as well as regional, variations in prices.

Given the high costs of meeting peak demand and the declining cost of PVs, several European countries, Japan, and the United States are now conducting trials on the use of PVs to supplement peak loads. These trials include "net metering" arrangements such that small users can sell surplus power to the grid. Aside from the cost advantages, the relevance for rural areas and towns is that decentralized generation reduces line losses and voltage drops and provides a backup source of supplies in the event of line failures.

Credit

As with some other forms of rural energy, the initial cost of acquiring the equipment constitutes a significant barrier to the widespread adoption of renewable energy sources. The development of innovative financing schemes, including supplier credits and leasing arrangements, is thus a critical element of any renewable energy program. Those who have studied the credit problem closely have concluded that subsidies are not needed, at least for small-scale applications, for which renewables are competitive (Cabraal and Cosgrove-Davies 1995).

Taxes and Subsidies

In recognition of their positive externalities (of innovation) and their environmental advantages, one can make a good case for exempting renewable energy technologies from—or at least substantially lowering—taxes and duties, while at the same time taxing conventional energy industries' supplies in accordance with standard principles of tax policy. Experts have also long argued in favor of imposing corporate and sales taxes on electricity on the grounds that it is a fairly price inelastic product. In practice, however, governments have typically pursued the opposite policy, namely, of not only exempting electricity from taxes, but often subsidizing it, and imposing significant taxes on renewable energy equipment. (See Cabraal and Cosgrove-Davies 1995, who report that in Sri Lanka, import duties added some 30 percent to the costs of PVs. Kenya also has duties and taxes on PVs while subsidizing electricity to encourage local manufacture and assembly.)

There is, furthermore, an economic case for providing public financial support for renewable energy technologies in program development, demonstration, education, training, and monitoring, again, in recognition of their positive externalities and environmental advantages. This is the rationale behind the Global Environment Facility's (GEF's) financing of renewable energy: during 1991-94, the GEF financed renewable energy projects in eight countries that included PVs, wind power, and micro-hydro in India and biomass for power generation in Brazil (the GEF quarterly operations reports provide more details). Twenty-five renewable energy projects are currently under review or in various stage of preparation and appraisal in twenty countries.

At the national level, financial support could come either from public revenues or from user charges or surcharges on the use of fossil fuels. The latter has the advantage of making the programs less dependent on public financing. A good example is the United Kingdom's "noffo," or non-fossil fuel obligation program, which applies the revenues from a small surcharge on electricity to support the winners of competitive bids to supply electricity from renewable energy sources. Several similar schemes exist in Europe, Japan, and the United States, all of which have active public programs to develop renewables.

6

Cooking Fuels: Toward More Sustainable Supply and Use

As incomes rise, rural and urban households gradually shift from using dung, crop wastes, and wood for cooking to modern fuels, such as liquid petroleum gas (LPG) and kerosene. Households in rural areas and lower-income urban households rarely use electricity for cooking. Given that people will be using biofuels for many years to come, policies need to focus on (a) improving the efficiency with which biofuels are used, (b) promoting more sustainable ways to supply biofuels, and (c) facilitating the transition to the use of modern fuels for cooking.

Improving End-Use Efficiency with Biomass Stoves

The modern biomass stove is an important development for the millions of people who have ready access to low-cost biomass, but who cannot afford more expensive modern fuels. The fuel savings, often as much as 30 percent, reduce cash outlays; diminish the time spent collecting fuelwood; decrease smoke by improving combustion and the use of flues, thereby reducing the worst health effects of biofuel use (see the figures on Brazil in table 2.1); and reduce pressures on scarce wood resources.

Developing country governments, donors, and nongovernmental organizations (NGOs) supported programs implemented in the late 1970s and early 1980s, and commonly assumed that their benefits were self-evident. They believed that people would adopt the improved stoves quickly, and that the initial promotional programs would lead rapidly to self-sustaining markets in the new products. Hence, most early efforts focused only on dissemination, and were oblivious to local customs, the economic setting, and the availability and prices of local biofuels. Based on laboratory experiments, early programs anticipated three- to fourfold increases in energy efficiency and a 75 percent decrease in wood consumption. With hindsight, we can see that many stoves did not perform as well as anticipated in the field, and the experiments both overestimated the energy efficiency of improved stoves and underestimated the energy efficiency of traditional stoves. Today, a 25 percent reduction in wood consumption is considered more realistic.

However, development practitioners have learned a great deal from these early efforts, and the notions that improved stoves could improve energy efficiency substantially, albeit less than originally thought, and reduce the damage to health caused by smoke, are still valid. A recent evaluation (Barnes and others 1994a) of the programs found that the best of them had the following features:

- *Identification of appropriate markets.* Through local inquiry, the best programs first identified the families most likely to adopt and benefit from the improved stoves. These were always low-income households (but generally not the poorest) who usually had some cash income, a large portion of which they spent on food and cooking fuel.

- *Participation in stove design and market testing.* The best programs involved much interaction between designers, producers, and users and included stove testing by representative households. This process kept producers and designers focused on meeting the needs of prospective users, which increased the likelihood that more people would purchase the stoves.

- *Provision of public funding.* The stoves were not heavily subsidized. Public funds were used to support marketing, design, and extension.

- *Standardization.* Standardization of stove parts and techniques facilitated widespread manufacture and reduced costs.

Properly managed, improved stove programs, such as the one in China (see box 6.1), can result in significant adoption rates. Successful programs have focused on the user groups most likely to benefit from improved stoves, including those paying significant amounts for fuel or those who must walk long distances to collect fuelwood. Subsidies have not proven particularly effective in promoting stoves because they create an artificial demand that hinges on the subsidy that is not sustainable when the subsidy is withdrawn. However, external grant support can be valuable if used for such activities as laboratory testing, carrying out field work, obtaining users' views on alternative approaches, and demonstrating the stoves.

An examination of successful stove projects in Africa leads to similar conclusions. A project in Madagascar financed by the International Development Association promoted improved charcoal stoves (Government of Madagascar 1994). After two years of preparatory activities (identifying potential users, testing stoves, selecting appropriate stove models, obtaining feedback from users and producers, and testing marketing channels), an active commercialization phase consisting of promotional activities resulted in the use of 45,000 improved stoves in the capital, Antananarivo, which amounts to about 20 percent of all stoves in use. More than ten different models of improved stoves are available (all metal, all clay, and mixed models), and several different types of production units exist, both in the informal and in the formal sectors. The private sector carried out all production, marketing, and sales. Today, the support for the project has been eliminated, but activities continue, and estimates indicate that more than 100,000 improved stoves are in use. The government intends to extend the activities to all urban areas where charcoal is the major fuel.

Box 6.1 Lessons from the World's Largest Stove Programs

The two largest stove programs in the world are the Chinese National Improved Stove Program, which has installed 120 million stoves in rural households, and the Indian National Programme on Improved Chulhas, which has provided 8 million stoves.

Chinese stoves are mainly biomass types for cooking, but include dual-use stoves for cooking and heating in the northern states, where winter temperatures are low. Improved stoves are affordable (about US$9), with government contributions averaging only US$0.84 per stove.

Indian stoves have a minimum 50 percent government subsidy (about US$4.30 per stove). While dissemination has been impressive, follow-up surveys indicate that only half the improved stoves are still in use. India has since revised much of its program to use existing commercial distribution and marketing channels.

Comparing Stove Programs in China and India

China	*India*
• Program concentrates on areas with greatest fuelwood shortages.	• Program disperses efforts, including areas with no fuelwood shortages.
• Direct contacts between government and counties bypass much bureaucracy.	• Cumbersome, top-down administration dilutes the program's effectiveness.
• Stove adopters pay the full cost of materials and labor.	• Government pays producers half the cost of every stove sold.
• Government supports producers with training in stove building and promotion.	• Government support is mainly financial.

Source: Barnes and others (1994a); Ramakrishna (1991); Smith and others (1993).

Another project funded by the International Development Association in Tanzania had a similar outcome. The four-year project (1988–92) established a production capacity, mostly among private sector artisans, of 5,000 improved stoves per month. Distribution and sales are through a network of private sector retail outlets. By the end of the project, more than 60,000 improved stoves had been sold, while production and sales of improved stoves have continued on a self-sustained market driven basis since (Government of Tanzania 1992).

The social, economic, and environmental benefits of improved stoves can be large, and the successes have demonstrated the utility of well-managed programs. The economic returns of successful programs are good. In urban areas, where most people purchase woodfuels rather than gather woodfuel themselves, the payback time is sometimes as little as a few months. In rural areas of resource scarcity, the savings in terms of the time and energy people spend gathering fuelwood are significant.

Improving Charcoal Efficiency

For many families, an intermediate-level fuel between woodfuels and kerosene and LPG is charcoal. Not only is it relatively inexpensive, but it generates much employment. Like fuelwood, people can buy charcoal in preferred quantities, but unlike fuelwood it burns without smoke, does not create dangerous flames around cooking vessels, and requires a simple stove whose heat output is relatively easy to control. However, dispersed local charcoal industries often use inefficient charcoaling kilns that use more wood resources than necessary.

The potential for increasing biomass efficiency with improved charcoal kilns has been recognized since the early 1980s. Kiln models based on traditional designs, but with higher heat-transfer efficiencies, have been developed in Rwanda, Senegal, and Tanzania in collaboration with end-users. However, this has shown that such technical innovations should be complemented by easily enforced standards, systematic training, and demonstrations to convince traditional charcoalers to adopt the improvements. Such programs, particularly in wood-scarce areas, work best when complemented by natural forest management efforts that have raised the price of wood stocks, thereby creating an incentive for charcoalers to use more efficient technologies. Recent experience in East Africa has demonstrated that a comprehensive approach to introducing new kiln technologies to the small-scale charcoaling industry can succeed. More efficient charcoal production is beginning to result in the use of fewer wood resources in peri-urban areas and is bringing down the cost of the fuel.

Developing More Sustainable Ways to Supply Biomass

In the late 1970s and early 1980s, biofuels development tended to focus on plantations and community or private woodlots. Such programs proved to be expensive and had limited success for the reasons discussed in chapter 2. During the past ten years or so, the possibilities for increasing biomass production through agro-forestry have become more widely recognized, as have more sustainable forms of forest management involving local participation.

Agro-Forestry

Agro-forestry entails planting trees, shrubs, and special grasses, such as vetiver grasses, on farmlands in association with agricultural activities, and plays an important role in alleviating fuelwood shortages and resource custody. These are old and once well-known practices that have been neglected in recent years because of such factors as persistent poverty, population pressures, and failure to address tenurial or property rights. However, interest has been rekindled. Small farmers often practice farm forestry independently in response to economic needs and ecological problems. The spread of farm forestry in Kenya is an often-cited example of relatively autonomous development of effective practices, but many others can be found in China, India, Pakistan, the Philippines, and elsewhere.

In the Philippines, the island of Cebu lost most of its forests in the early part of this century. The resulting fuelwood scarcity and rising prices caused farmers to begin planting trees to supply fuelwood to urban markets, which has helped ameliorate at least some of the environmental damage caused by the earlier deforestation (see box 6.2). In India, the first social forestry programs were aimed at establishing community woodlots, but few communities would engage in tree planting for urban markets. However, private farmers did respond to the incentives and began planting trees on their marginal lands. Recent programs in West Bengal have granted landless laborers tenure to manage trees on public wastelands.

Agro-forestry practices can be encouraged through farmer education and extension programs and supported through agricultural and forestry research. Such efforts are both environmentally desirable and economically beneficial for the following reasons:

- Farmers outnumber foresters by several thousand to one, and involving them in planting trees and shrubs can dramatically accelerate afforestation.
- By their nature, agro-forestry investments are more closely related to farmers' needs as they supply fodder, building materials, green mulch, fruit, and other by-products that are sometimes more valuable than the firewood itself (technically also a by-product).
- Agro-forestry practices reduce run-off, soil erosion, and surface evaporation and improve micro-climates and soil water retention. Farmers can use the foliage of the trees they grow to provide nitrogen-rich manure or mulch for their fields and to improve soil structure. Such attributes contribute to sustainable farming systems by raising the productivity of farm soils (Gregerson, Draper, and Elz 1989).

Field studies of agro-forestry practices in developing countries over the past twenty-five years have consistently found that agro-forestry has favorable effects on farm yields and incomes, just as similar studies have found in the high-income countries for the last century (Doolette and Magrath 1990; Gregersen, Draper, and Elz 1989). This is encouraging, because it demonstrates that biofuels can be supplied in ways that will not only help make agricultural practices sustainable, but will also improve agricultural productivity and incomes.

Box 6.2 Woodfuel Markets Promote Tree Planting on the Island of Cebu

Cebu, the island province in the south central Philippines, is one of the worst cases of environmental degradation in Southeast Asia. With virtually no forest cover, but with steep terrain, population densities of 520 people per square kilometer, and widespread cultivation of annual crops like corn throughout its rugged interior, environmentalists consider Cebu to be on the brink of ecological collapse.

Despite increased use of kerosene and LPG, most of the island's 2.7 million inhabitants continue to depend on wood, particularly households and businesses in the metropolis of Cebu City. This heavy dependence on woodfuel is often cited as a major cause of the province's environmental woes. As a result, many government and NGO officials believe that woodfuel use should be discouraged in urban areas and that commercial trade in woodfuel should be more tightly regulated, if not altogether banned.

A recent study found, however, that commercial markets for fuelwood and charcoal in Cebu City may actually be inducing more intensive tree planting and management activities among rural farmers and landowners. Most commercially traded woodfuels originate from intensively managed agricultural lands and consist mainly of fast-growing, multipurpose tree species like *Gliricidia* and *Leucaena*. The growing, harvesting, and trading of woodfuels is a substantial source of income and employment. Woodfuels meet significant urban energy demands and represent a renewable and locally produced energy source that annually saves the economy millions of dollars in foreign exchange.

Rather than promoting the cultivation of tree species that require extensive inputs, which require more labor, capital, and time to harvest, rural development programs should also recognize the benefits of the low-input alternatives that Cebuano farmers have practiced for nearly a century. They should view commercial woodfuel markets as an opportunity to promote more widespread tree planting and management practices throughout rural areas of the province rather than as a problem to be controlled by restrictive legislation.

Source: Bensel (1994).

A recent study of twenty-one agro-forestry projects in six Central American countries (Current, Lutz, and Scherr 1995) found that agro-forestry practices were profitable under a broad range of conditions (table 6.1 summarizes the results). These findings echo those of several other studies. An earlier survey of field results (Doolette and Magrath 1990) of more than a dozen studies in Brazil, Colombia, India, Indonesia, Malawi, Niger, the Philippines, the Republic of Korea, and Sudan did not find a single case in which the returns were less than 15 percent.

Table 6.1 Returns to Agro-Forestry Practices in Six Central American Countries

Agro-forestry system	*Number of systems studied*	*Benefit-cost ratio at 20% discount*[a]	*Payback period (years)*
Trees with crops	5	1.8	3.4
Alley cropping	9	2.1	1.9
Contour planting	4	1.6	2.0
Perennials with trees	4	1.8	4.0
Home garden	4	2.2	n.a.
Taungya[b]	8	2.5	4.9
Woodlot	10	1.0	9.2

Source: Lutz, Current, and Scherr (1995).

a. The high discount rate is used to give a measure of the financial returns to the farmers, not of the opportunity cost of capital.

b. A system in which new forest plantations are established together with food and cash crops, which continue to be intercropped until shaded out by the maturing plantation.

Participatory Approaches to Forest Management

Experience also suggests that effective management of existing forest resources depends on local people taking responsibility. In such participatory programs, small farmers sell all the wood extracted from local woodlands; however, to obtain the revenue from the trees, the farmers must participate in a resource management program mutually agreed upon with the forestry department. In such an environment, foresters are no longer enforcers of protective rules, but advisors to farmers on technical issues and on resource planning and management problems.

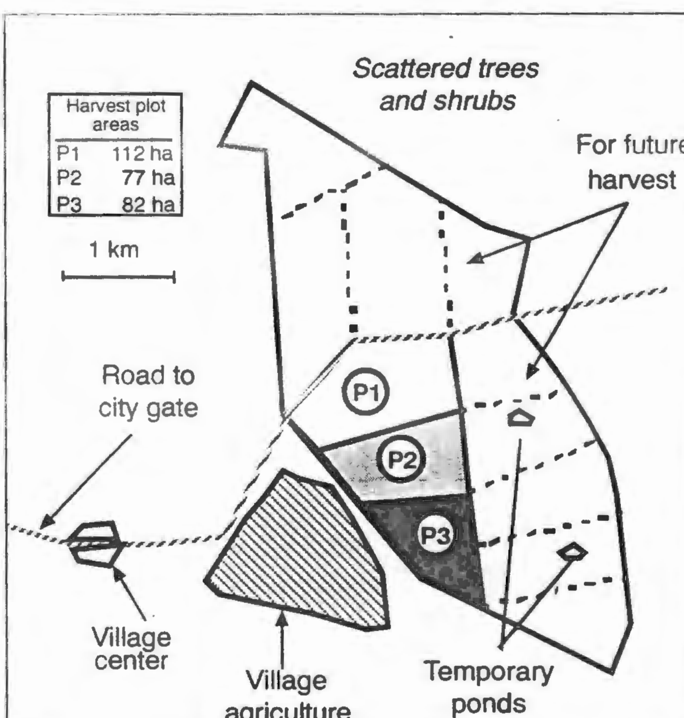
Successful programs using this approach include the Niger Household Energy Project (see box 6.3). Its initial results suggest that transferring responsibility for forest areas directly to rural communities and introducing taxes or user charges designed to ensure that the market value of fuelwood reflects its real economic costs should lead to more sustainable approaches to resource management.

To sum up, approaches to improving biofuel supplies have evolved considerably in recent decades, with the participation of farmers—and of rural communities more generally—in policymaking and the recognition that biofuel supplies are part of the wider problem of resource custody in rural areas being central features of this evolution. Many countries are now encouraging the practices discussed here through rural extension and education programs, seedling distribution, and agricultural and forestry research.

Box 6.3 Rural Market Approach Anchored in Grassroots Reality: The Niger Household Energy Project

Before the Niger Household Energy Project was implemented in 1989, indiscriminate mining of fuelwood had severely depleted the natural forest and had degraded soils. The situation was most serious around urban areas, because neither the land on which the wood was grown nor the wood itself belonged to those who cut it. Moreover, the economic value of the wood could not be easily recovered from the woodcutters.

Through an integrated program of taxation and land tenure reform, responsibility for managing forest areas is being transferred to rural communities, and local people now have the right to manage wood resources on their own land. The project's national and local-level information campaigns are helping educate rural people about their rights to harvest forest resources and about setting up rural markets. These are established at the request of villagers, who decide on the local management structure and negotiate annual fuelwood harvesting and sales quotas based on the sustainable production capacity of the village's natural forest.



A typical village plan (above) calls for sustainable harvesting and replanting on a twelve-year cycle (impending harvest plots are P1, P2, and P3). Villagers sell the fuelwood they harvest to commercial transporters at prices the villagers determine. The taxes villagers collect from local transporters ensure that the full economic value of fuelwood is reflected in its price.

Source: Floor (1995).

Improving Access to Kerosene and Gas

When people can afford kerosene and gas (mainly LPG) they prefer these fuels to fuelwood and dung for cooking. As figure 2.1 showed, kerosene and LPG are five to ten times more efficient, far less damaging to the users' health and to their environment, and easier to cook with. They also greatly reduce the time women and children spend gathering fuelwood. At the same time, however, these fuels are more expensive than wood; the poorest people thus rarely use them. In Africa, in particular, poor infrastructure, dispersed populations, and poor delivery also hinder access to such fuels.

Subsidies versus Price Liberalization

Several countries have subsidized kerosene and LPG in an effort to increase their use. A cross-country study (Barnes and others 1994b) found that household fuel subsidies do influence the rate of substitution. For example, in Indonesia the government subsidizes kerosene to make it available nationwide. The result is that most people use kerosene for cooking. In China, coal is heavily subsidized, which helps explain why coal accounts for a significant proportion of total household energy use in most parts of China. In Senegal, the government subsidizes LPG as a cooking fuel, which has led to the substitution of charcoal by high-income and middle-income urban residents.

However, as already noted, subsidies are often counterproductive: they limit use to the amount that governments can afford to subsidize, their fiscal costs can become prohibitive at high levels of consumption, and they lead to energy inefficiency. In Senegal, for instance, LPG subsidies rose from US$2 million to US$10 million per year between 1990 and 1994. As some observers pointed out at the time, this increase could have paid for the salaries of several thousand teachers at a time the country was seeking to expand its education system. Studies in Hyderabad, India, before prices were liberalized, Indonesia, and Senegal also found that such subsidies mostly benefit higher-income people already using the fuels. They do help the poor, but the higher-income groups get a "free ride." Lastly, the subsidized fuels are often diverted for other purposes. Smoky, diesel-fueled cars and fishing boats are prevalent in Indonesia and Senegal, while kerosene and LPG are exported to neighboring countries, as happened with LPG in Ecuador (Barnes and others 1994b).

In contrast, price and market liberalization can be effective in accelerating the transition toward more efficient modern fuels. A recent study of fuel use in Hyderabad (Alam forthcoming) shows how influential such policies can be. Fifteen years ago, only 10 percent of the city's households used LPG because the Indian government had restricted production and imports. Since then, the government has liberalized policies, and today more than 60 percent of households use LPG for cooking (box 6.4.)

Box 6.4 Household Fuelwood Use Virtually Eliminated in Hyderabad

In 1980, only the upper 10 percent of households in Hyderabad used LPG, most of the middle class used kerosene, and the poor mainly used fuelwood.

In 1994, however, the India Urban Energy Project found that a transition from fuelwood to LPG had transpired in Hyderabad. Fuelwood had virtually disappeared from the city center, except for small industrial and ceremonial uses, and, overall, 20 percent less fuelwood was coming into the city—a major drop, given that Hyderabad's population had doubled since 1980.

A major cause of this dramatic transition was a change in government policy that increased access to LPG, liberalized fuel markets, and eased access barriers. As a result, the middle class can now get LPG, which in turn has allowed the poor to shift from fuelwood to kerosene.

Today, kerosene, and LPG are the dominant fuels in Hyderabad's households. The decisions households make concerning which fuels to use are strongly correlated with income levels. Households in the city slums earn about Rs 1,500 per month, and their monthly housing expenses are Rs 400 to Rs 600. These households generally spend about Rs 50 to Rs 60 per month on kerosene for cooking, and about the same on electricity for lighting, television, and perhaps a fan. When asked why they no longer use fuelwood for cooking, the householders replied that it is both expensive and inconvenient (see table below).

Urban Consumer Prices of Cooking Fuels, 1994 (in Rs)

Energy type	*Price per unit*	*Price per megajoule*	*Cooking efficiency*	*Price per useful energy*
LPG (kg)	7.57	0.168	0.60	0.280
Kerosene				
Pressure (l)	3.50	0.100	0.35	0.286
Wick (l)	3.50	0.100	0.25	0.400
Wood (kg)	1.10	0.069	0.15	0.458
Electricity (kWh)	1.12	0.311	0.75	0.415

Source: Alam (forthcoming).

Cape Verde's experience is also relevant. In 1984, 50 percent of the population used biomass for cooking; 42 percent used kerosene; and 8 percent used LPG, which was in limited supply. Five years later, following market liberalization, 42 percent of households were using LPG and 8 percent were using kerosene, showing how quickly people will change fuels once they can. Note, however, that 50 percent still depended on biofuels, which demonstrates the importance of not focusing policies on the modern energy sector alone.

Subsidizing cooking fuels is not, therefore, a good policy from any standpoint—encouraging equity, protecting the environment, or even promoting greater use of these fuels. Liberalizing prices is a much more promising alternative.

Distortionary Effects of High Taxes on Cooking Fuels

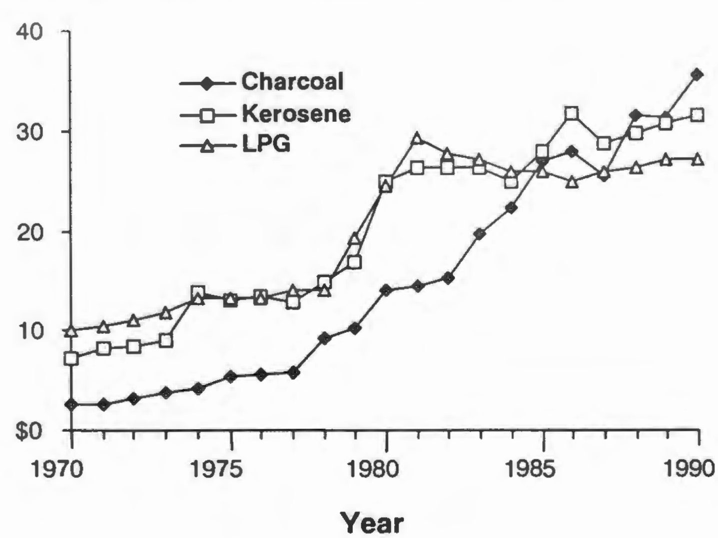
Taxes on petroleum products are an economically attractive way to raise public revenues, and many developing countries favor such taxes. The price elasticities of demand, at least for vehicle fuels, are relatively low, which means that the deadweight losses are also relatively low; the fuels are mostly used by upper-income groups, so the taxes are progressive; and they are relatively easy to administer. Such classical arguments for taxes are generally valid. Taxes on cooking fuels, however, are an exception in developing countries. Such taxes impair the substitution from biofuels to fuels such as LPG and are in effect regressive for low-income people. Furthermore, such taxes may drive up the prices of traditional fuels such as charcoal, as happened in Haiti (box 6.5).

Box 6.5 Taxing the Rich Inadvertently Hurts the Poor

Haiti has among the highest LPG prices in the Caribbean, if not the world, largely because of high taxes. Although few poor people in Haiti use LPG or kerosene, prices for fuels have historically been related (see figure). Hence, when LPG and kerosene prices are raised via taxes, demand for other fuels increases. Massive deforestation during the past twenty-five years has depleted the country's wood supplies, so the poor use commercial charcoal, whose prices have risen with demand and along with those of the other commercial fuels. The taxes on kerosene and LPG thus have meant higher prices for the fuel used mostly by the poor.

Energy Prices in Haiti, 1970–90

(current U.S. dollars per gigajoule adjusted for end-use efficiency)



Source: ESMAP (1991c).

While subsidizing cooking fuels is not good policy, therefore, developing countries also need to avoid high taxes on them. At the same time, the case for taxing petroleum fuels for vehicle use especially remains sound. Depending on circumstances, moderate rates of taxation on LPG, kerosene, and diesel fuels will often be the best option. Such tax policies are, of course, fully consistent with the goals of price liberalization.

7

The Role of the World Bank Group

To recapitulate, accomplishments during the past twenty-five years include the extension of electricity services to more than 1.3 billion people, of whom more than 500 million were in rural areas and towns; the emergence of new renewable energy technologies, which were rarely an economic proposition even ten years ago, but are now well suited for use in rural areas and towns (and probably soon for grid connected supplies); and the revival of interest in more sustainable ways to supply and use biofuels based on agro-forestry and participatory approaches to rural development. The importance of good enabling conditions has also become more widely recognized. Investments in rural energy are now viewed in the broader context of rural development, and development practitioners understand that they are more likely to succeed when complementary programs, themselves dependent on good enabling conditions, are in place toward infrastructure, education, family planning, and health. It is in this context that the chapter reviews the Bank's role.

Policies and Operations Since the 1970s

The Bank's work on rural energy since the early 1970s has focused on three areas: (a) rural electrification; (b) the supply and use of biofuels; and (c) some pilot operations in renewable energy. Much of this support has been delivered through technical assistance for new types of projects and policies, much of it sponsored by the Joint World Bank/United Nations Development Programme Energy Sector Management Assistance Program (ESMAP), its precursor, the Energy Assessment Program, and the Asia Alternative Energy Unit's (ASTAE's) program. The annex provides a listing of projects; table 7.1 provides some examples.

Table 7.1 Bank Projects and Programs That Have Increased Rural Energy Access

Project or program	*Pricing energy to improve access*	*Financing and lowering the first costs of energy*	*Encouraging a diversity of investments and investors*	*Encouraging participation and decentralization in investment lending*	*Facilitating transition toward a market-oriented approach*
Bolivia Rural Energy Program (assisted by ESMAP)	Energy is priced at economic cost; temporary subsidies available for LPG.	Credit is available for rural electricity connections.	Communities have PV, mini-hydro, and other options.	Local communities choose energy interventions.	Government provides TA, but communities buy technologies from market sources.
Mexico Municipal Funding, Solidarity Program (Bank lending assistance, 1993)	Not applicable.	Households can get electricity connections at subsidized cost.	Only grid electricity is possible; energy is a component in a wider rural development project.	Local communities choose from a wide variety of projects.	Grants can be used for a variety of projects.
Niger Energy Project, 1989; Mali Household Energy Project, 1995 (Bank project, ESMAP assisted)	Tax revenue accrues locally as incentive for sustainable supply.	Kerosene stoves are subsidized.	Projects include market development for woodfuels, kerosene, and LPG; energy is component in forestry project.	Local communities voluntarily participate in projects.	Community is responsible for collecting taxes and managing local resources.
Thailand Rural Electrification Program, 1977–present (Bank loans in 1978, 1980, and 1983)	Bulk rate charged to rural distribution company acts as a cross-subsidy; monthly lifeline rates at 15, 25, and 35 kWh.	Electricity connections are cross-subsidized.	Project covers only grid electricity; rural electrification extension is coordinated with rural development plans.	Local participation includes giving right of way for lines, meetings, construction labor, and investments from social development funds.	Not addressed.
Kenya Arid Lands Project, 1995 (Bank project)	Not applicable.	Low-cost loans for purchasing energy equipment.	Options include wind pumping and solar electricity for schools, clinics.	Communities decide on priorities for their area.	All purchases are completed through the local retail market.
China Integrated Rural Energy Program (government program with ESMAP TA)	Encourages pricing above costs of supply, despite uniform national-level pricing policies.	Develops markets for such low-cost technologies as stoves, biogas, and mini-hydros.	More than 1,000 technologies approved, including stoves, mini-hydro, biogas, and forestry.	TA for rural energy planning is provided to counties.	Government fosters local planning and development of technology markets and provides TA.
West Bengal, India, Social Forestry Project, 1981; Bengal Forestry Project, 1982	Not applicable.	Not applicable.	Projects involve increase in biomass that can be used for cooking, but no other options.	Involvement of villagers in forest protection and in sharing benefits of production. NGO involved.	Farm forestry produce sold to timber merchants. Nonwood products sold or used by participants.

LPG Liquid petroleum gas. TA technical assistance. NGO Nongovernmental organization.

Rural Electrification

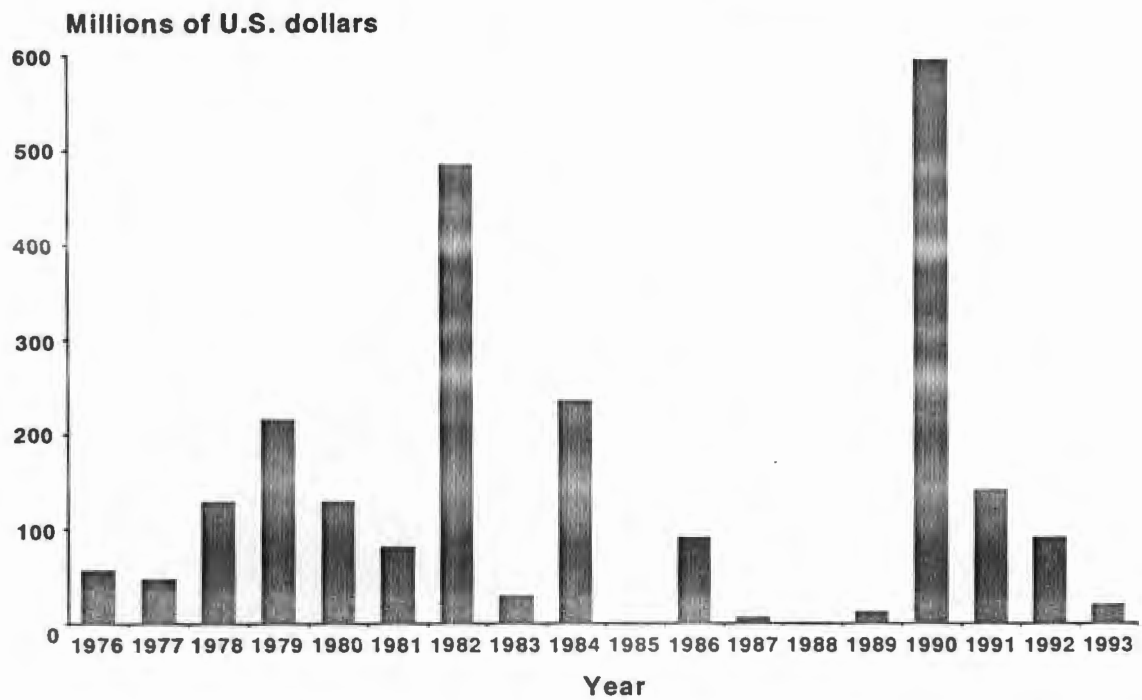
The World Bank's 1975 policy paper set the stage for Bank involvement in financing rural electrification projects. The paper reviewed the developing countries' experiences with rural electrification in the 1960s and examined the costs and benefits of such investments. The paper's main findings and recommendations were as follows:

- Economically justifiable investments in rural electrification could be found in large regions of the developing world. The situation varied from one province to another depending on the enabling conditions for development—in particular, for the growth of agriculture, rural businesses, and rural incomes—and on load density. Load densities were greatest in villages and rural towns, which often also had significant demands for electricity from small enterprises. Investments would thus need to be selective, favoring areas where prospective uses of electricity justified expenditures.
- The Bank should base its investments on the rate of return criterion. The initial fixed costs of extending service were high, although average costs declined steeply in areas with good load growth. All the significant benefits of electrification were directly related to the uses to which it was put and to the costs of alternative sources of power and energy. Thus Bank staff considered the economic rate of return to investment to be an appropriate criterion for investment. It would encourage cost-effectiveness and help focus investments in areas where they would be most likely to be beneficial. In other areas, Bank staff often found that the alternatives were cheaper and had higher returns than grid extension. At that time the main alternative for motive power, individual supplies, or to support micro-grids was diesel engines, which are still commonly used.
- Cost recovery over the long term should be encouraged. Specifically, prices should be such that over some twenty to thirty years, the present value of expected revenues equals the present value of the expected costs of service, less a small provision for lifeline rates if desired. The latter would take the form of a low kilowatt hour charge for low levels of consumption. A cost-recovery policy of this kind would increase the rate at which service could be expanded: it would help finance the high initial fixed costs of extending service and the costs of new connections, without undermining the utility's financial position.

These findings and recommendations are still valid, and are a good basis for future projects and policies, but need to be expanded given the advent of new technologies and institutional reforms in the electric power sector.

Lending Activities. From 1975 to 1984 the Bank lent a total of US$1.4 billion for rural electrification, but the level of activity dipped substantially in the mid- to late 1980s before picking up again in the 1990s (figure 7.1). Overall lending since 1975 has amounted to about US$2.5 billion for fifty projects in forty countries, with total project costs amounting to around US$5 billion. More than 70 percent of this lending went to Asia and around 20 percent to Latin America. In Africa, the Bank has not lent for stand-alone rural electrification projects since 1980, although it has supported several grid extension projects that have extended supplies to regional cities and towns in agricultural provinces, for example, the northern grid extension project in Ghana. In addition, a number of electrification projects had rural electrification components.

Figure 7.1 World Bank Commitments for Rural Electrification, 1980–93



Source: World Bank data.

The dip in lending for rural electrification in the mid-1980s was probably caused by the sharp deterioration in the finances of—and in the quality of service provided by—the electricity industry in numerous countries during this period. As a consequence, the Bank's attention turned to restoring price and managerial efficiency to put the industry on a commercial footing. Since the publication of the Bank's policy papers on power sector reform and energy efficiency (World Bank 1993a,b), it now views measures to promote private investment and finance and less intrusive forms of regulation as central for the achievement of a financially sound and more efficient industry, and the indications are that progress is being made in the areas of financial and institutional reform. (See box 4.5 for a summary of the general directions of the policies supported by the Bank and comments on progress.) The scene is therefore set for a renewed effort by the Bank to support its member countries' efforts to extend electricity to the huge numbers of people without service.

Evaluations of Experience. The Bank's experience with rural electrification is inseparably linked to that of the forty or so countries in which it has financed projects, and many other countries in which it has provided policy advice and finance for electrification programs more generally. As this experience was reviewed at length in chapters 3 and 4, a brief summary will suffice here.

First, on the positive side, rural electrification is an economically important area of investment capable of generating good economic rates of return. (In Asia, ten out of eleven Bank-financed rural electrification projects recently evaluated have had a satisfactory rating according to the audits of the Operations Evaluation Department.) With the huge populations still without service and with economic growth, further major investments, amounting to perhaps about 10 percent of total investment in electricity supply, will be needed for the next several decades. Grid extension is expensive, however, and needs good load densities and load growth to justify the investment, as the 1975 policy paper had argued. The best investment opportunities continue to be in villages and towns, which can be centers of new business opportunities, in-migration, and non-farm employment (and thus of load growth) as agricultural provinces develop. Where load densities are low, alternatives such as diesel generators and small-scale supplies from renewable energy sources were shown to be more cost-effective.

But experience has also shown that grid extension can have poor economic and financial returns, and this has happened in some Bank projects. The obvious case is when supplies are extended to areas at much expense when load densities are low, there are few demands from agriculture and agro-industries, and household use is minimal and the alternatives would have been better. Yet even where demands are high, in theory sufficient to justify the investments from an economic point of view, poor returns have sometimes resulted in practice for reasons that are now all too familiar: poor pricing and financial policies that undermined the quality of service and wasted energy and capital. The review of experience has not unearthed any evidence of a need for massive subsidies for rural electrification except, perhaps, for the very low levels of subsidy in support of lifeline rates for low levels of household consumption. As the various evaluations reported in chapters 3 and 4 have found, subsidies have widely proved to be counterproductive and to undermine the utilities' financial position and their ability to extend service.

By strengthening the finances and managerial position of the industry, the reforms now taking place to put it on a more commercial footing provide a new opportunity for electricity services to be more widely and efficiently provided. They will, however, need to be complemented by some form of public leadership. The uptake by the private sector in electricity distribution, where privatization has been taking place in developing countries, has so far been quite limited, and there has been a natural (and understandable) tendency for private investors to concentrate on investments in generation and in the more lucrative, higher growth, and higher-income end of urban markets. Thus policymakers and regulators will have to be vigilant on the matter of service extension if programs of sector reform and privatization are not to be undermined by a discontented public lacking service. Options for policy (noted in chapter 4) include tax incentives, perhaps coupled with a regulatory requirement for distribution franchises to extend service; continued public involvement in distribution, but on commercial principles; joint public-private ventures; electricity cooperatives; and the encouragement of the development of micro-grids.

Two recent reviews by the Bank's Operations Evaluation Department (OED) (World Bank 1994b, 1995a) have also contained findings pertinent to this paper, one on lending for electric power in Sub-Saharan Africa and the other on rural electrification in Asia.

Only 2 percent of the components of the projects reviewed in Africa dealt with rural electrification directly, even though about 90 percent of Africa's rural population lacks access to electricity. The OED's recommendations included (a) increasing the focus on decentralized, community-based power supply options; (b) placing greater reliance on private investment and management; (c) instituting a vigorous push for sector reform; and (d) placing more emphasis on renewable energy.

As noted, the review of experience in Asia found that nine of the ten projects had performed satisfactorily; however, only four had achieved economic rates of return in excess of 10 percent, and none were financially self-sufficient, having depended on cross-subsidies from general tariffs. In some countries, even where the investments were economically justified, the utility's poor financial performance had often been further undermined by rural electrification subsidies, which ultimately undermined the electrification programs themselves. The disparities between the economic and financial returns were due to deficient pricing policies: none of the countries had adopted cost-reflecting pricing policies for rural service.

The review concluded that rural electrification projects can, and often did, have significant economic benefits. Its summary of the conditions under which investments were likely to succeed echoed those of the Bank's 1975 policy paper. Among other things, it emphasized cost recovery in tariff policies and the need to pay greater attention to the economic rate of return when selecting investments. The most successful projects in Asia took into account "the great variations in economic conditions and growth rates among rural areas" (World Bank 1994b) and maximized benefits by selecting subprojects where a high rate of demand growth could be expected and the net economic returns would be the highest. In general, these were in regions where the "productivity of agriculture was rising and supporting service industries are growing." On commenting on the report, the Bank Board's Joint Audit Committee further emphasized the need for having more local participation and for ensuring access for low-income consumers.

Thus the OED studies arrived at conclusions fully consistent with those of many others involved with rural electrification over the past twenty-five years, as reviewed in chapters 4 and 5. Once again, they emphasized the need for financial sustainability and cost-effectiveness and the need to recognize that alternative sources of energy and power are often available when loads are small.

The Sustainable Production and Use of Woodfuels

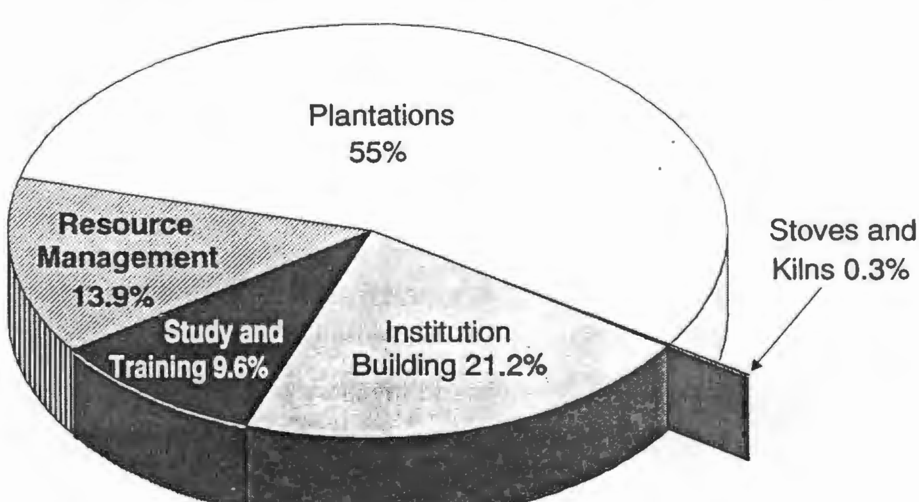
The Bank's lending in the area of woodfuels has mostly been integrated with its work on forestry and agro-forestry. Projects typically have the following components:

- Tree planting, once based mainly on woodlots, but now more commonly based on agro-forestry and participatory approaches to forestry management.
- Institution building, or general support for the development of forestry services.
- Technical assistance, training services, and research.
- Resource and forestry management focused on maintaining or improving existing forests or woodlots. Sometimes, this category will include project management costs.
- Stove and charcoal kiln programs, which have evolved as discussed in chapter 6.

During 1980–93, the Bank committed US$1.2 billion to forty-two projects in twenty-four countries in support of sustainable woodfuel supply and use in rural areas—about a third of its forestry lending (see the annex and figure 7.2). Most of the support went to low-income countries (nearly 50 percent of the projects were in Africa, 40 percent in South Asia).

Figure 7.2 Lending Commitments for Sustainable Supply and Use of Woodfuels

(Total Lending Commitments = US$1.2 billion)



Source: World Bank data.

In contrast to rural electrification, the Bank's work on biofuels did not languish in the mid-1980s, but intensified. This initially resulted from the long-standing public concerns reflected in the Bank's *Forestry Policy Paper* (World Bank 1978) about deforestation and the losses of tree stocks on farmlands and woodlands, and all that this implied for the sustainability of agriculture. The *Tropical Forest Action Plan* (World Bank 1987) provided a further stimulus when the "mining" of the forests by fuelwood suppliers and the charcoal industry was recognized as a major cause of deforestation, along with logging and land clearance. Sector studies of forestry and agro-forestry practices in the 1980s, together with the early work of the United Nations Development Programme–World Bank Energy Assessment Program, and later ESMAP, were also influential, and provided a basis for operations.

The emphasis of the Bank's work on biofuels shifted considerably during the period, however, almost wholly in the directions described in chapters 2 and 6. The afforestation components of the early loans were mostly for community woodlots, and generally yielded poor results. Although community woodlot programs aimed at a high level of local participation, the notion of "community" was often too vague a concept and too broad a social unit to be operational, overlooked the diverse needs and functions of different social groups within their communities, and left property rights and administrative and other matters unaddressed.

As the Bank's 1978 paper on forestry policy had anticipated, the agro- or farm-forestry projects that followed have yielded better results. Indeed, they have generally exceeded expectations (see chapter 6); form an excellent basis for continued Bank operations in the inter-related areas of rural energy, forestry, and agricultural development; and are now a mainstay in the Bank's work (see World Bank 1994c). The Bank has also begun to support a promising approach in areas where local forest resources are still good: providing property rights to local people to manage and maintain the resources (see box 6.3).

Chapter 6 reviewed the Bank's and others' experience with woodstove programs. As with biofuel supplies, the early projects got off to a poor start, with the projects often relying on the results of laboratory experiments, with far too little involvement by users and by artisans who would manufacture them. Evaluations of field experience, in the Bank's case facilitated by ESMAP, led to a fundamental redefinition of the approach such that local participation was central.

We can thus conclude that approaches to investment in biofuel supplies and use have taken a distinct step forward since the early efforts some fifteen years ago.

The transaction costs of developing projects and new policies in the biofuels area can be high; lending per project is typically only about one-quarter of that for energy in the modern sector, and the preparation of investments requires considerable knowledge of local ecology and natural resources and of communities, social units, and tenurial issues. Furthermore, for the reasons outlined in chapter 3, establishing the capacity simply to support particular investments without developing local institutional capacity more generally is insufficient. We are only beginning to understand what is involved. Attending to such matters will often require a significant investment in assistance for preparing programs and developing policies. Collaboration with bilateral donors and nongovernmental organizations, who frequently support pilot projects and undertake field work and project preparation activities, is indispensable. Yet even taking such partnerships into account, the transaction costs to the Bank have proved to be large.

Renewable Energy

The Bank's efforts to bring renewables into mainstream financing began in the early 1980s, motivated by the high prices of oil at that time. During 1980–95, the Bank financed approximately thirty renewable energy projects in eighteen countries, including eight projects co-financed with the Global Environment Facility (GEF). By fiscal 1995, total commitments amounted to approximately US$1.3 billion.

Until 1990, however, about 80 percent of the lending was for geothermal energy, which is an economically attractive option for grid supplies in several countries, but does not have a direct bearing on the rural energy problems discussed in this paper (see the annex for a full list of projects during 1980–95.) In the 1980s, lending for small-scale applications of new renewable energy technologies suitable for rural supplies was confined to a few pilot projects, which were sometimes components of ongoing energy projects. Aside from a number of activities identified by ESMAP, also of a pilot nature, the collapse of oil prices in 1985/86 led to such ventures being put into abeyance for a period.

Since 1990, interest and investment in renewable energy sources has been on the upswing worldwide. As chapter 5 noted, the main reasons were the continued technological developments, concomitant cost reductions, and the environmental benefits of renewable energy.

The establishment of the GEF has also proved to be a stimulus, because renewables are emerging as the most promising non-net-carbon-emitting technology for addressing global warming over the long term (Anderson and Williams 1994; GEF 1996; World Bank 1992). The Bank financed eight renewable energy projects during the pilot phase, and a pipeline of projects in more than twenty countries is currently emerging. A good example is the US$280 million India Renewable Energy Project, approved in 1993. It provides credit and investment incentives for the introduction of solar home systems in rural areas, windfarms, and micro-hydro projects. In 1992 India had only 50 megawatts (MW) of wind power plant, and experts anticipated that another 85 MW could be added over a five-year period. Within four years nearly 550 MW had been installed. The photovoltaic (PV) component had a slower start, but is beginning to generate considerable interest among public suppliers in both grid and off-grid markets.

As Bank-financed renewable projects have not yet been completed and audited, it is too soon to provide a post-evaluation. We do, however, know about the performance of renewable energy projects other organizations have financed in developing countries and about the substantial, established programs in the industrial countries. We can sum up this experience as follows:

- The basic technologies are fully proven, work well, and are no longer experimental.
- The potential for further development and cost reductions is considerable and will be facilitated by further investment and research and development.
- The failure of some has generally been for familiar institutional reasons rather than for technological or economic reasons, for example, when projects paid too little attention to establishing follow-up and maintenance services.
- Investments in renewable energy will benefit from improved enabling conditions for investment in the energy sector as a whole.
- The developing countries are becoming increasingly interested in the wider use of renewable energy, applications are increasing, and a plethora of investment and project preparation activities is under way.
- The projects can meet the investment criteria of both the World Bank Group and the GEF.
- The investments in this area are supported by nongovernmental organizations, private industry, and departments of energy and industry in many of the Bank's member countries who are urging Bank involvement and leadership with respect to both policy and project development.

In every respect, therefore, renewable energy is a good area for future investment by the Bank.

Project Innovations and Advisory Services

Often an advisory activity or a successful pilot program provides the basis for a fuller Bank operation in rural energy. The Bank has often carried out such work through special bilateral, donor-supported programs, such as ESMAP, ASTAE, and the Africa Review of Policies in the Traditional Energy Sector. For example, the household energy strategy technical assistance, conducted in Niger under ESMAP, was the basis for a project subcomponent on household energy and urban fuelwood management systems in a power loan. In India, a review of renewable energy alternatives under ESMAP led to the development of the Bank's first project explicitly for renewable energy. The Africa Review of Policies in the Traditional Energy Sector has identified policies important for natural resource management and traditional energy use in West Africa. In Chad, Comoros, Kenya, Madagascar, and Rwanda, a special Bank program for nonconventional energy, supported by Dutch grants, has identified and mainstreamed traditional energy and renewable project components. The donor-supported ASTAE program has done the preparatory groundwork for innovative small rural systems in India, Sri Lanka, and elsewhere in Asia. Finally, the Bank's recently launched Solar Initiative, supported by donors and the energy industry, is identifying decentralized rural projects in China, Latin America, the Middle East, Southern Africa, and West Africa. Table 7.1 presents examples of Bank projects and programs that have increased access to rural energy.

A direct consequence of ESMAP's work has been an increase in World Bank lending operations that incorporate specific household energy components. By the end of 1995, ESMAP had designed household energy components of energy sector loans or credits in ten countries (Bolivia, Burundi, Ethiopia, Guinea, Haiti, Madagascar, Mali, Mauritania, Niger, and Rwanda) for a total of US$46 million. ESMAP studies also laid the groundwork for renewable energy investments in India and Mauritius for a total of US$240 million. ESMAP's training activities in financial and economic analysis, rural energy policy analysis, and rural survey work, including the development of training manuals and follow-up support activities, also contributed to the formulation of China's rural energy program (US$1.5 billion). Other similar activities are in the pipeline (Cameroon, Chad, China, and Vietnam), and these could lead to investments of US$75 million.

Also with the financial support of bilateral donors, in particular the Netherlands, two other Bank programs are actively advancing activities in the fields of traditional energy and renewable energy. The Review of Policies in the Traditional Energy Sector, which was launched in 1993, has led to policy and project formulation in five Sahelian countries, and this work will be extended to other African countries (Burkina Faso, Senegal). Estimates indicate that the resulting investments will amount to some US$40 million. ASTAE, which started in 1992, has helped the Bank's Asia region with developing energy components or stand-alone projects for renewable energy in countries such as India (US$280 million), and is preparing similar projects in Indonesia (US$260 million), Sri Lanka (US$50 million), and, in cooperation with ESMAP, in China (US$150 million).

The Way Forward: A Renewed Commitment by the World Bank Group

This paper envisages a renewed commitment by the Bank to support its member countries' efforts to extend modern energy supplies to populations without them, and to promote sustainable supply and use of biofuels for as long as they remain important sources of energy. *Modern energy* as defined here includes new forms of renewable energy.

The time is ripe for a renewed commitment. The experiences of the past twenty years have been substantive, spanning 100 projects of varying sizes and policy discussions in more than 100 countries, and we know much more about both the approaches that are likely to work and those that that probably will not. Where uncertainties are present–as occurs, especially with respect to institutional development–they have been recognized and options identified. Many developing countries are also committed to improving the enabling environment, at the macroeconomic level and in the energy sector, which the Bank Group is supporting, and this too should aid rural energy investments.

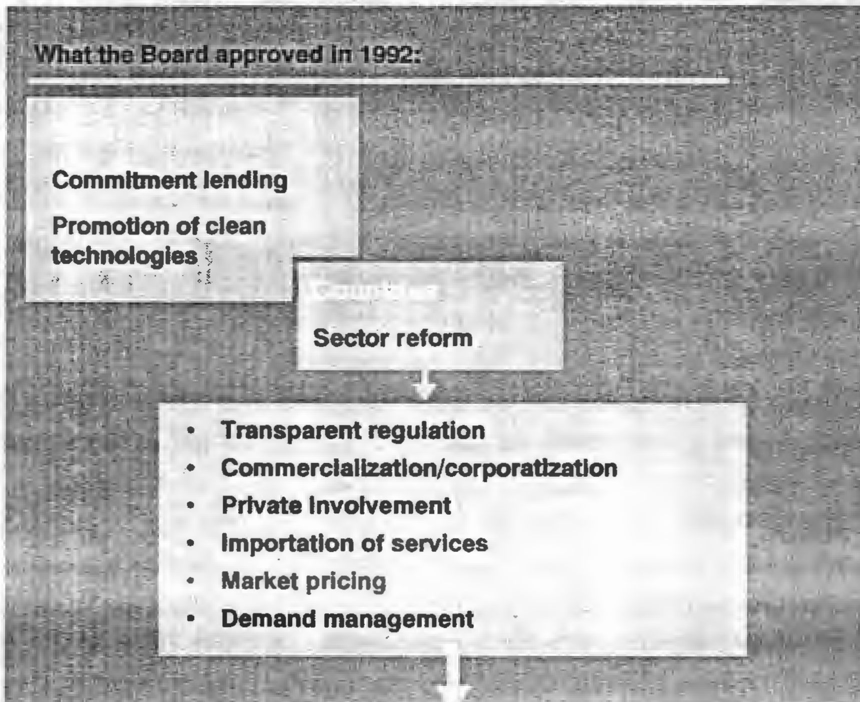
With the important exception of afforestation, however, the Bank's work on rural energy—and also the related problem of extending service to unserved urban populations—has declined since the mid-1980s, largely because of the financial and institutional problems afflicting the energy sector discussed earlier, which focused the Bank's attention on sector reform. The Bank is also still in the early stages of developing a pipeline of renewable energy projects and supporting policies. In addition, the Bank's work in these areas has become highly dependent on outside support from trust funds, secondments, and special programs such as ESMAP and ASTAE. The allocation of both Bank staff time and its financial resources to the challenges discussed in this paper amount to a modest proportion of its total efforts in the energy sector. Yet these challenges concern the most impoverished populations of developing countries, and work in this area is fully consistent with Bank policies.

The Bank's renewed commitment must be reflected in its future work on energy sector reform and through its investments. While the following recommendations focus on unmet needs in rural energy markets, in the case of modern energy forms, they are equally applicable to unserved markets in urban areas.

Broadening the Scope of Energy Sector Reform

The Bank's policy papers on the electric power subsector and energy efficiency (World Bank 1993a,b) fundamentally redefined its energy sector and policy work. It was to lend only to countries committed to operating the industry on commercial principles; to introduce less intrusive and more transparent forms of regulation; and, by implication, to be more open to private investment, the importation of energy services, and market pricing. Environmental concerns were also central in the form of a greater commitment to energy efficiency and the introduction of "clean" energy technologies. Box 7.1 summarizes the main points and indicates the added dimensions this paper brings to the Bank's approach.

Box 7.1 Broadening the Scope of Energy Operations



Added dimensions—a renewed commitment to

- **Extend modern energy supplies to unserved populations**
- **Promote sustainable supply and use of biofuels**
- **Introduce new and renewable energy technologies.**

And thus to

- **Promote commercial pricing and private involvement in distribution**
- **Provide incentives for extension of service**
- **Support agroforestry and biofuel programs.**

In 1992, the World Bank's Board of Directors approved a single set of policies that were outlined in two papers: *The World Bank's Role in the Electric Power Sector* and *Energy Efficiency and Conservation in the Developing World.* The Bank would be committed to lending only where there was a demonstrated commitment to power sector reform, and its projects would promote clean technologies and practices. These policies take on added importance in the context of this paper.

The Bank's country economic and energy sector work is devoting significant attention to sector reform (World Bank 1994d), which is now the principal focus of most Bank lending operations in electricity, oil, and gas. The policy dialogues on options for energy sector reform are therefore the ideal stage at which to review the energy problems rural (and unserved urban) consumers face. These dialogues engage the attention of those responsible for framing energy policies at precisely the right time, that is, when the policies are being framed.

The Bank is well placed to broaden the scope of energy policies during discussions with governments of structural and macroeconomic adjustments (when energy sector reforms often serve a fiscal purpose), of country assistance strategies, of energy sector reviews, and of sector and project loans. Table 7.2 at the end of this chapter provides a checklist of the sorts of questions that need to be raised, based on the analysis of previous chapters. The first set of questions deals with the general scope of the problem: the numbers of people without service, the extent and use of biofuels and their health and environmental effects, experience with policies and investments so far, and so forth. Other questions deal with prices and taxes, finance, the analysis of investment alternatives, and the institutional matters discussed in chapters 3 through 6. Often, when working on policy reform, it is not possible to address all, or even most, of the specifics at the time when policies are being discussed, as much depends on the background work already done. In such instances, the technical assistance components of loans and credits may serve an invaluable function by turning general principles agreed upon at the time into functioning policies later.

Investments

Supported by a broader dialogue on energy policies, the World Bank Group will be better able to tailor its energy investments more closely to developing countries' needs and concerns. How its investment portfolio develops will vary with the country, but increasing commitments of Bank resources are likely for the following:

- Rural electrification and its alternatives
- New renewable energy forms, guided by the Bank's Solar Initiative and joint programs with ESMAP and ASTAE
- Agro-forestry along the lines indicated in the Bank's forestry papers
- More efficient and environmentally improved approaches to the supply and use of biofuels.

An increase in the supply and use of modern cooking fuels in rural areas should also follow, though these would be private investment activities rather than financed by the Bank.

Bank loans and credits have been available for such investments for more than fifteen years, in the case of electrification for more than twenty years, and well-prepared projects can meet the investment criteria of both the World Bank Group and the GEF. No changes to the Bank's internal policies are therefore required, though their application, as shortly discussed, often entails innovation in approaches to investments and policies. The policies on electric power and energy efficiency announced in 1992 should make such projects economically more attractive by improving the enabling conditions for investment and the financial positions of energy companies. However, a significant allocation of the Bank's resources will be required to build on the policy reforms and finance investment in rural energy and service expansion.

In addition, there must be a willingness to innovate and to entertain new approaches. While the Bank has been able to finance the above kinds of investments for some time, experience has shown that institutional—as well as technological and economic—innovations have frequently paved the way to more successful investments and policies. Perhaps the best example on the institutional side has been the growing recognition of the importance of local participation in development (discussed in chapter 3), for example, in relation to managing forests and introducing agro-forestry and woodstove programs. Equally important, and in a broad sense a development that also implies greater participation, is the movement to liberalize energy markets, encourage private investment, and introduce independent ("arm's length") regulation. While this is an old idea, it is only recently that it is finding practical application in developing countries, and it is posing novel problems once we turn to the specifics of policy—not least, as noted, with respect to finance, regulation, and the distribution of energy services. On the technological side, an openness to investments in new renewable energy technologies will be crucially important from both an environmental and an economic perspective.

In Africa and South Asia in particular, major efforts will also be required for all four types of projects noted earlier (and on the supporting policies), because the pressures on soils and natural resources are especially severe in these regions. In addition to the need to put biofuel supply and use on a sustainable footing, Africa has the furthest to go with electrification and the provision of modern fuels. The Sub-Saharan Africa Power Reform Symposium, co-sponsored by the World Bank in Johannesburg in December 1995, made a promising start on addressing the major issues. Box 7.2 illustrates the challenge decisionmakers face in dealing with the power sector and rural electrification in Africa.

Box 7.2 Sub-Saharan Power Challenge:
Promoting Electricity Access to Rural and Low-Income Users

A special problem for much of Sub-Saharan African is the need to expand access to electricity beyond its currently restricted level. In none of Sub-Saharan Africa's lower-middle or low-income countries does access exceed 20 percent, and the average for most countries is less that 10 percent. This compares quite unfavorably to most countries in Asia and Latin America, where several countries have electrification rates above 75 percent, most notably, China and Thailand. By comparison, in Ghana and Kenya the rural electrification rate is around 12 percent, in Tanzania and Uganda it is less than 10 percent, and in many other countries it is barely 5 percent. The reasons for the low rates of electrification involve a combination of poor management by African power distribution companies, a hesitation by companies to get involved in higher-cost distribution, and a practice of charging high connection costs for new electricity consumers. In many countries national uniform tariffs for electricity also discourages electricity companies from getting involved with more expensive rural and peri-urban service. For instance, in Zimbabwe consumers must sometimes pay as much as US$900 for obtaining an electricity connection, which limits the number who can connect to the system. Likewise, in many African countries, the distribution companies adhere to high and expensive standards for electricity provision, which effectively rules out many consumers from being able to afford electricity service. Given that the populations without electricity are growing in Sub-Saharan Africa, the task of developing innovative ways to promote electricity service without providing extensive subsidies for poor and rural people needs to be given a high priority.

The preceding review has also shown that innovations in finance and credit will often be needed to address the high "first-cost" problem in extending modern energy supplies to rural areas. They may come in the form of leasing and micro-financing arrangements—for example, for PV sets—or incentives in support of the development of local energy companies that themselves may be willing to finance (on a cost-recovery basis) the initial costs or extend credit.

A rising area of investment activity will be the new forms of renewable energy, not only for rural energy supplies, but for grid supplies more generally, as discussed in chapter 5. The GEF, especially, is providing a golden opportunity to the Bank's clients to break new ground in the use of new renewable energy technologies (GEF 1995, 1996). To encourage investment in this area, the Bank's energy staff have launched the Solar Initiative. The initiative is being supported externally by the donor community, primarily through ESMAP, ASTAE, and the secondment of staff with technical expertise in the subject to the Bank.

The initiative encourages the Bank's client countries to develop projects and policies in this area. It provides information on project experience, technical advice, and cross-support and general encouragement to the regional operating divisions to prepare such projects and policies for Bank and GEF financing. It also serves a networking function, in association with the International Energy Agency, by linking the efforts of the industrial countries, where most of the technologies have been developed, to those of the developing countries, and in collaboration with the IFC, it encourages private investment in renewable energy (see box 7.3).

Box 7.3 The IFC and Renewable Energy

In July 1992, the IFC created its Infrastructure Department in response to the growing demand for its services in this area. The Power Division handles electric power generation projects, including projects using renewable energy resources such as hydro, geothermal, and biomass and new technologies such as wind energy, as well as conventional thermal generation projects and transmission and distribution projects, including national and international grids and metropolitan and local utilities.

The IFC has recently financed hydro projects in Belize (25 MW), Chile (450 MW and 22 MW), and Costa Rica (11 MW). Geothermal projects are under review in Antigua, Guatemala, and Nicaragua. Wind power funding proposals have been received for projects in Costa Rica, Guatemala, Honduras, Mexico, and Uruguay. Biomass or PV projects have been considered in Brazil, Costa Rica, India, and Jamaica. The IFC has also invested in PV manufacturing in China.

The IFC has made the environment one of its most urgent priorities and is encouraging private sector involvement in the development of GEF assistance strategies for the private sector. As part of these efforts, as well as in relation to its power investments, the IFC is actively pursuing potential investments in renewable energy (biomass, wind, solar thermal, and PVs). The IFC can provide nonrecourse project finance services, namely:

- Debt/equity investments in commercial technologies in developing countries
- GEF grants to buy down capital cost differences for qualifying technologies alongside conventional IFC project financing.

The IFC can also provide services for manufacturing, investment, and corporate finance as follows:

- Debt/equity investments in the manufacturing and assembly of commercial technologies in developing countries
- GEF grants to support investments in manufacturing and assembly investments for precommercial technologies.

The IFC is also considering establishing a renewable energy/energy efficiency/private equity/venture capital fund that could provide equity financing for smaller renewable energy projects (5 to 20 MW) and for promising new applications, such as off-grid power using solar energy and other renewables.

Opportunities for Partnerships

This report is based on the operational experience of the Bank's staff over the past twenty years and has benefited from the experience and perceptions of numerous other organizations. First and foremost were discussions of the substantial issues of policy toward and investment in rural energy in the course of operations with people from all walks of life in more than 100 countries, both when policies and investments were being defined and when they were being implemented. As the report was being prepared, its findings were shared with and critiqued by twenty or so organizations involved in development assistance, nearly fifty nongovernmental organizations from industrial and developing countries, and workshops with private industries investing in renewable energy technologies.

Although professional differences often remain on specifics, people working in this area usually agree on three aspects of policies on and investment in rural energy:

- There is no greater challenge facing the energy sector than to provide energy in environmentally sustainable ways to rural (and unserved urban) populations in developing countries. Good enabling conditions for energy investments will undoubtedly help, but policies and investments focused directly on the various problems to be addressed will also be necessary.
- Such policies and investments are merited not only on social and environmental grounds, but also on economic grounds, as measured by the economic rate of return to investment. In other words, there is no reason why solving the social and environmental problems arising from energy use should not bring with it appreciable economic benefits to rural people.
- Opportunities exist for collaborating and sharing experiences and information. In rural energy, as in other fields, no institution has a monopoly of knowledge or insights. Indeed, one of the most important developments in recent years has been the growing (if much belated) realization that the best information and insights come from the intended beneficiaries themselves. This has brought about the growth of interest in the participatory approach to the design of projects and policies and the current efforts to come to grips with the tenurial, economic, financial, social, and administrative aspects of local institutional development.

The World Bank Group has the capacity both to bring rural energy into the policy dialogue and to co-finance investments. Of these, it will probably be the bringing of substantive policy issues to the table and the catalytic effects of its projects that will be most important. In rural energy, as in the energy sector more generally, the developing countries will undertake the bulk of investment: the Bank's financing is unlikely to exceed 5 percent of overall investment. There will therefore be much that the Bank cannot do by itself, and it will be incumbent on all involved to work together if these endeavors are to succeed.

Table 7.2 Broadening Energy Access: A Checklist for Bank Staff

Specific actions and programs	*Main Bank instruments*
1. Acknowledge the questions and define the challenge. • Define the energy supply situation for people without access to modern energy: types of fuels used, their costs, and their health and environmental impacts. - *Modern fuels:* Evaluate past progress in supply expansion to urban and rural areas, and consider how energy sector reforms will affect the future provision of energy supplies to these people. Will the reforms increase investment in distribution of electricity, modern cooking fuels, and renewable energy alternatives? What pricing and tax policies are appropriate? Is sufficient project identification and preparation work under way? More generally, assess adequacy of current policies and investment activities of programs to improve. - *Traditional fuels:* Assess efforts to address health and environmental problems caused by use of biofuels; assess adequacy of supporting policies and programs. • Keep track of progress in extending modern energy services to previously unserved populations and of progress in afforestation and biofuel programs.	SALs, SECALs, sector loans, sector reviews, SARs, TA, and project identification and preparation (Bank and GEF)
2. Price energy to improve access. • Follow the general principle of pricing energy at economic cost. Fuel taxation and the import tariff regime should not discriminate against individual energy sources. • Avoid subsidies that restrict the market to government programs, including general fuel subsidies and targeted subsidies. • Avoid uniform national pricing that prevents extension of service to rural areas. • Generally, support incentives for market development and sustainable access, such as temporary and transparent incentives to buy down initial capital and transaction costs for electricity connections and basic end-use equipment that allows for fuel switching. • Within large energy companies (especially providers of LPG and electricity), allow modest cross-subsidization of lifeline rates and costs of basic energy end-use equipment. • Implement a resource tax on the urban fuelwood and charcoal trade that is collected by local rural communities who manage these natural resources.	SALs, SECALs, sector loans, sector reviews, SARs, GEF
3. Finance and lower first costs of energy. • Expand credit to rural consumers for connections and appliances by spreading costs over time. • Reduce service connection costs through modifying design standards to meet the needs of low-demand consumers. • Expand credit for inventory to small energy retailers and suppliers that serve rural consumers and explore leasing schemes and other such options.	Project lending, TA, sector review, CAS

continued

Table 7.2 (continued)

Specific actions and programs	*Main Bank instruments*
4. Encourage a diversity of investments and investors in rural energy.	Energy, rural development, forestry project lending, sector loans, TA, SARs, GEF
• Ensure regulatory environment does not discriminate against or obstruct rural energy investment; goal is "level playing field" for public, local, and private investments.	
• Include updated and approved energy components as options for use of development funds in rural development projects.	
• Provide direct investments for public grid electrification programs that follow financially sound pricing policies.	
• Include, as applicable, renewables, modern biomass-using equipment, and other alternative energy in public health, education, and agriculture projects.	
• Ensure a liberal trade policy for imported fuels and equipment likely to be used by rural consumers, including liquid fuels and renewable energy products/components.	
• Provide TA for innovative product development aimed at serving rural areas.	
5. Examine the institutional questions to be addressed.	SALs, SECALs, energy, rural development, forestry project lending, sector loans, TA, GEF
• Restructure government role to support local initiatives and projects, including closer cooperation with rural development agencies and programs.	
• Evaluate institutional alternatives for electricity distribution—local franchises, public/private partnerships, cooperatives and other.	
• Examine tax and regulatory incentives to encourage supply companies to expand service.	
• Provide financing and technical support for local/decentralized public or private energy supply initiatives through technical assistance and training.	
• Encourage effective, transparent regulations promoting competition among retailers and distributors; discourage monopolistic policies for electricity, liquid fuels, and renewables.	
• Transfer responsibility for managing and exploiting forest resources to local rural populations based on a mutually agreed upon forest management plan.	
• Base afforestation and woodstove programs on the participatory approach.	

Note: The term *multilateral* includes the World Bank, International Finance Corporation, International Monetary Fund, Inter-American Development Bank, African Development Bank, Asian Development Bank, United Nations agencies, and others.

CAS	Country assistance strategy.	SAR	Staff appraisal report.
GEF	Global Environment Facility.	SCC	Systematic client consultation.
NGO	nongovernmental organization.	SECAL	Sector adjustment lending.
SAL	Structural adjustment lending.	TA	Technical assistance.

Annex: World Bank Lending to Rural and Renewable Energy Projects, Fiscal 1980–1993

A. Rural Electrification Projects/Components (millions of U.S. dollars)

Country	*Region*	*Project name*	*Date*	*Loan/ credit no.*	*Total project financing*	*Bank loan[a] amount*
Bangladesh	SAS	Rural Electrification	8205	CR 1262	64.5	40.0
Bangladesh	SAS	Second Rural Electrification	8509	CR 1633	110.6	79.0
Bangladesh	SAS	Third Rural Electrification	9004	CR 2129	163.5	105.0
Brazil	LAC	Eletrobras I Power Distribution	8204	LN 2138	739.3	36.5
Brazil	LAC	Rural Electrification	8311	LN 2365	585.2	222.8
Columbia	LAC	Village Electrification	8105	LN 1999	68.7	36.0
Côte d'Ivoire	Africa	First Power Project	8006	LN 1896	46.3	33.0
Egypt	EMNA	Third Power	8006	LN1886/ CR 1052	677.8	22.2
Ghana	Africa	National Electrification	9302	CR 2467	185.3	20.0
Guatemala	LAC	Power Distribution	8605	LN 2724	133.2	6.4
India	SAS	Third Rural Electrification	8205	LN 2165	795.0	300.0
Indonesia	EAP	Eleventh Power	8109	LN 2056	319.4	22.0
Indonesia	EAP	Rural Electrification	9002	LN 3180	524.7	329.0
Jordan	EMNA	Fourth Power	8104	LN 1986	86.6	4.1
Jordan	EMNA	Six Power	8605	LN	71.7	6.9
Lao PDR	SAS	Southern Provinces Electrification	8705	CR	32.6	6.8
Malaysia	EAP	Rural Electrification	8204	LN 2146	315.5	86.3
Mexico	LAC	Integrated Rural Dev. (PINDER III)	8106	LN 2043	506.0	8.1
Mexico	LAC	Decentralization and Regional Dev.	9103	LN 3310	1,362.7	27.9
Morocco	EMNA	Second Rural Electrification	9008	LN 3262	220.0	114.0
Pakistan	SAS	Private Tubewell Development	8903	CR 2004	50.3	12.6
Pakistan	SAS	Rural Electrification	8911	LN3148/ CR-2078	715.0	160.0
Philippines	EAP	Rural Electrification Revitalization	9112	LN 3439	118.5	91.3
Thailand	EAP	Second Accelerated Rural Ele.	8005	LN 1871	270.0	75.0
Thailand	EAP	Provincial Power Distribution	8305	LN 2312	51.6	29.8
Tunisia	EMNA	Third Power	8104	LN 2003	89.6	21.5
Tunisia	EMNA	Fourth Power	8406	LN 2455	83.0	13.8
Yemen Arab	EMNA	Regional Electrification (Power II)	8101	CR 1102	21.5	12.0
Subtotal		**28 projects**			**8,408.1**	**1,922.1**

a. The estimated Bank contribution is the sum of the related components (including contingencies) multiplied by the share of Bank lending in the total project financing.

B. Renewable Energy Projects/Components (millions of U.S. dollars)

Country	*Region*	*Project name*	*Date*	*Loan/ credit no.*	*Total project financing*	*Bank loan[a] amount*
Brazil	LAC	Alcohol & Biomass Energy Development	8104	LN 1989	5,115.0	250.0
Cyprus	EMNA	Energy Planning & Conservation	9109	LN 2286	5.2	3.6
Djibouti	Africa	Geothermal Development	8906	CR 2055	38.4	9.5
Djibouti	Africa	Geothermal Exploration	8405	CR 1488	16.6	6.0
Ethiopia	Africa	Petro. Exploration Promo & Geo Recon.	8305	CR 1386	9.5	2.2
India[b]	SAS	Renewable Resources Development	9211	LN3544/ CR 2449	250.0	138.0
Indonesia[c]	EAP	Twelfth Power	8211		1,470.9	154.8
Jordan	EMNA	Energy Development	8311	LN 2371	2.4	0.3
Kenya	Africa	Olkaria Geothermal Power Expansion	9006	LN 2237	41.6	12.0
Kenya	Africa	Geothermal Exploration	9212	CR 1486	34.3	24.5
Kenya	Africa	Geothermal Dev. and Energy Preinvest.	8812	CR 1973	59.6	40.7
Kenya	Africa	Olkaria Geothermal Power	7912	LN 1799	89.0	40.0
Mali	Africa	Biomass Alcohol & Energy Efficiency	8305	CR 1403	8.3	7.6
Mauritius	Africa	Sugar Energy Development	9203	LN 3458	55.1	18.3
Panama	LAC	Energy Planning & Petro. Explor. Prom.	8102	LN 1954	8.0	0.6
Philippines	EAP	Energy Sector Loan	8911	LN 3163-LN 3165	3,509.2	390.0
Philippines	EAP	Geothermal Exploration	9106	LN 2203	71.5	36.0
Philippines	EAP	Bacon Manito Geothermal Power	8805	LN 2969	227.0	100.0
Rwanda	Africa	Energy Sector Rehabilitation	9301	CR 2456	0.3	0.3
Yemen Arab	EMNA	Petroleum & Geothermal Exploration Prom.	8202	CR 1216	2.4	0.1
Yemen Arab	EMNA	Geothermal Exploration	8404	CR 1484	15.4	13.0
Subtotal		**21 projects**			**11,029.6**	**1,247.4**

a. The estimated Bank contribution is the sum of the related components (including contingencies) multiplied by the share of Bank lending in the total project financing.

b. The mini-hydro component is about US$20 million (including contingencies).

c. The Bank's contribution (International Development Association) to the small hydro component is US$70 million.

C. Fuelwood-Related Projects/Components (millions of U.S. dollars)

Country	*Region*	*Project name*	*Date*	*Loan/ credit no.*	*Total project financing*	*Bank loan[a] amount*
Bangladesh	SAS	Forest Resource Management	9205	CR 2397	58.7	30.5
Bangladesh	SAS	Mangrove Afforestation	8005	CR 1042	17.2	11.0
Bangladesh	SAS	Second Forestry	8510	CR 1634	36.0	17.0
Bhutan	SAS	Forestry Development	8403	CR 1460	6.8	5.5
Bhutan	SAS	Second Forestry Development	8803	CR 1900	31.3	3.6
Bhutan	SAS	Third Forestry Development	9306		8.9	5.4
Brazil	LAC	Minas Gerais Forestry Development	8711	LN 2895	100.0	7.2
Burkina Faso	Africa	Forestry	7912	CR 982?	17.5	14.5
Burundi	Africa	Second Forestry	8505	CR1620	17.0	11.3
Cameroon	Africa	Forestry	8112	LN 2092	35.5	2.8
Ethiopia	Africa	Forestry	8605	CR 1722	62.1	45.0
Ghana	Africa	Forest Resource Management	8811	CR 1976	64.6	32.1
Haiti	LAC	Forestry	8205	CR 1257	5.1	4.0
Haiti	LAC	Forestry and Environmental Protection	9109	CR 2301	29.0	26.1
India	SAS	Himalayan Watershed Management	8305	LN 2295	66.0	23.1
India	SAS	West Bengal Social Forestry	8109	CR 1178	43.5	29.0
India	SAS	Jammu/Kashmir & Haryana Social Forestr	8207	CR 1286	67.1	33.0
India	SAS	Watershed Dev. in Rainfed Areas	8311	CR 1424	45.5	8.9
India	SAS	Kerala Social Forest.	8407	CR 1514	54.5	31.8
India	SAS	National Social Forestry	8505	CR 1611	327.8	165.0
India	SAS	Maharashtra Forestry	9112	CR 2328	142.0	107.9
India	SAS	Karnataka Social Forestry	8311	CR 1432	56.6	27.0
India	SAS	Gujarat Community Forestry	7911	CR 961	76.0	37.0
Kenya	Africa	Forestry Development	9011	CR 2198	83.8	14.9
Malawi	Africa	Phase II of National Rural Dev. (Wood)	8002	CR 992	16.3	13.8
Malawi	Africa	Second Wood Energy	8602	LN 2670	19.6	16.7
Mali	Africa	Second Forestry	8512	CR1654	16.7	6.3
Nepal	SAS	Second Forestry	8306	CR 1400	24.0	18.0
Nepal	SAS	Community Forestry Dev. and Training	8003	CR 1008	24.8	17.1
Nepal	SAS	Hill Community Forestry	8905	CR2028	45.4	30.4
Niger	Africa	Second Forestry	8203	CR 1226	16.8	8.5
Nigeria	Africa	Second Forestry	8609	LN 2760	110.7	58.5
Philippines	EAP	Watershed Mgt. and Erosion Control	8006	LN 1890	75.0	31.3
Rwanda	Africa	Second Integrated Forestry	8705	CR 1811	20.1	13.8
Rwanda	Africa	Integrated Forestry and Livestock	8005	CR 1039	23.6	11.1
Senegal	Africa	Forestry	8101	CR1103	17.1	9.3
Sri Lanka	SAS	Forest Sector Development	8905	CR 2043	29.8	19.0
Tunisia	EMNA	Forestry Development	8707	LN	50.2	20.0
Uganda	Africa	Forestry Rehabilitation	8705	CR 1824	33.3	12.1
Zimbabwe	Africa	Rural Afforestation	8304	CR 1368	10.6	7.3
Subtotal		**40 projects**			**1,986.5**	**986.7**

a. The estimated Bank contribution is the sum of the related components (including contingencies) multiplied by the share of Bank lending in the total project financing.

Bibliography and References

The following is a full list of references cited in the text along with other pertinent publications. Also influential were the reports of the World Bank energy sector project missions and of the joint United Nations Development Programme/World Bank Energy Assessment Program and Energy Sector Management Advisory Program (ESMAP). Some are cited below, but as there are roughly 200 studies from 90 countries plus project appraisal reports for nearly 100 projects in more than 40 countries, they are too numerous to list here. A separate list of Energy Assessment and ESMAP studies that have dealt with general aspects or specifics of rural energy policies and projects, together with some World Bank studies has been prepared, and can be obtained on request from the World Bank's Energy and Industry Department.

Acker, Richard H., and Daniel M. Kammen. 1994. *The Quiet (Energy) Revolution: Analyzing the Dissemination of Photovoltaic Power Systems in Kenya.* Center for Energy and Environmental Studies Report No. 287. Princeton, New Jersey: Princeton University.

Agarwal, Bina. 1983. "Diffusion of Rural Innovations: Some Analytical Issues and the Case of Wood-Burning Stoves." *World Development* 11(4):359–76.

Ahmed, Kulsum. 1993. *Renewable Energy Technologies: A Review of the Status and Costs of Selected Technologies.* Technical Paper No. 240. Energy Series. Washington, D.C.: World Bank.

Ahmed, Kulsum, and Dennis Anderson. 1993. "Where We Stand with Renewable Energy." *Finance and Development* (June).

Ahmed, Raisuddin, and Cynthia Donovan. 1992. *Issues of Infrastructural Development: A Synthesis of the Literature.* Washington, D.C.: International Food Policy Research Institute.

Alam, Manzoor. Forthcoming. "Energy Transition in Hyderabad: Social and Economic Dimensions." Hyderabad, India: Institute for Energy and Environmental Studies, Hyderabad, India. Draft.

Alam, Manzoor, Joy Dunkerley, K.N. Gopi, William Ramsay, and E. Davis. 1985. *Fuelwood in Urban Markets: A Case Study of Hyderabad.* New Delhi, India: Concept Publishing.

Anderson, Dennis. 1987. *Economics of Afforestation: A Case Study in Africa.* Baltimore, Maryland: Johns Hopkins University Press.

Anderson, Dennis, and Robert H. Williams. 1994. *The Cost-Effectiveness of GEF Projects.* GEF Working Paper No. 6. Washington, D.C.: World Bank, United Nations Development Programme, and United Nations Environment Programme.

Arrow, Kenneth. 1962. "The Economic Implications of Learning-by-Doing." *Review of Economic Studies* 29(June):155–73.

Barnes, Douglas F. 1988. *Electric Power for Rural Growth: How Electricity Affects Rural Life in Developing Countries.* Rural Studies Series. Boulder, Colorado: Westview Press.

_______. 1990. *Population Growth, Wood Fuels, and Resource Problems in Sub-Saharan Africa.* Energy Series Paper No. 26. Washington, D.C.: World Bank, Industry and Energy Department.

_______. 1992. *Understanding Fuelwood Prices in Developing Nations.* Energy Series Paper No. 56. Washington, D.C.: World Bank, Industry and Energy Department.

Barnes, Douglas F., and Liu Qian. 1992. *Urban Interfuel Substitution, Energy Use, and Equity in Developing Countries: Some Preliminary Results.* Energy Series Paper No. 53. Washington, D.C.: World Bank, Industry and Energy Department.

Barnes, Douglas F., Keith Openshaw, Kirk R. Smith, and Robert van der Plas. 1994a. *What Makes People Cook with Improved Biomass Stoves? A Comparative International Review of Stove Programs.* Technical Paper No. 242. Energy Series. Washington, D.C.: World Bank.

Barnes, Douglas F., Jeffrey Dowd, Liu Qian, Kerry Krutilla, and William Hyde. 1994b. "Urban Energy Transitions, Poverty, and the Environment: Understanding the Role of the Urban Household Energy in Developing Countries." Washington, D.C.: World Bank, Industry and Energy Department. Draft.

Baumol, William J. 1995. "Environmental Industries with Substantial Startup Costs as Contributors to Trade Competitiveness." *Annual Review of Energy and the Environment* 20:71–82.

Bensel, Terrence G. 1994. "Commercial Woodfuel Markets, Smallholder Tree Cultivation and the Environment in Cebu Province, Philippines." In John B. Raintree and Hermina A. Franciscom, eds., *Marketing of Multipurpose Tree Products in Asia.* Bangkok, Thailand: Winrock International.

Bhatia, R. "Photovoltaic Street Lighting in India." 1988. In A.S. Bhalla and Dilmus James, eds., *New Technologies and Development.* Boulder, Colorado: Lynne Rienner Publishers.

Bhatia, Ramesh K., and Nikhil Desai. 1995. "Rural Energy Policy Analysis." *Rural Energy Planning: A Government Enabled Market-Based Approach.* Kuala Lumpur, Malaysia: Asian and Pacific Development Centre.

Binswanger, Hans P. 1994. "Agricultural and Rural Development: Painful Lessons." Simon Brandt Address delivered at the 32nd annual meeting of the Agricultural Economics Association of South Africa, Pretoria. September 21.

Binswanger, Hans P., and Pierre Landell-Mills. 1995. *The World Bank's Strategy for Reducing Poverty and Hunger: A Report to the Development Community.* Environmentally Sustainable Development Studies and Monographs Series No. 4. Washington, D.C.: World Bank.

Brodman, Janice. 1982. *Rural Electrification and the Commercial Sector in Indonesia.* Center for Energy Policy Research, Discussion Paper D–73L. Washington, D.C.: Resources for the Future.

Butler, Edward, Karen M. Poe, and Judith Tendler. 1980. *Bolivia: Rural Electrification.* AID Project Impact Evaluation Report No. 15. Washington, D.C.: Agency for International Development.

Cabraal, Anil, and Mac Cosgrove-Davies. 1995. "Best Practices for Photovoltaic Household Electrification Programs: Lessons from Experiences in Selected Countries." The Asia Alternative Energy Unit. Washington, D.C.: World Bank.

Cernea, Michael M. 1981. "Land Tenure and the Social Implications of Forestry Development Programs." Staff Working Paper No. 452. Washington, D.C.: World Bank.

_______, ed. 1985. *Putting People First: Sociological Variables in Rural Development*. New York: Oxford University Press.

_______. 1989. *User Groups as Producers in Participatory Afforestation Strategies*. Discussion Papers No. 70. Washington, D.C.: World Bank.

_______. 1992. "A Sociological Framework: Policy, Environment, and the Social Actors for Tree Planting.: In N.P. Sharma, ed., *Managing the World's Forests: Looking for Balance between Conservation and Development*. Des Moines, Iowa: Kendall/Hunt Publishing Company.

Child, Frank C., and Hiromitsu Kaneda. 1975. "Links to the Green Revolution: A Study of Small-Scale Agriculturally Related Industry in the Pakistan Punjab." *Economic Development and Cultural Change* 23(2): 249–75.

Cleave, John. 1974. *African Farmers: Labor Use in the Development of Smallholder Agriculture*. New York: Praeger.

Cleaver, Kevin M. 1993. *A Strategy to Develop Agriculture in Sub-Saharan Africa and a Focus for the World Bank*. Technical Paper No. 203, Africa Technical Department Series. Washington, D.C.: World Bank.

Current, Dean, Ernst Lutz, and Sara J. Scherr. 1995. "The Costs and Benefits of Agroforesty to Farmers." *The World Bank Research Observer* 10(2):151–80.

Deng, Keyun, Zhang Zhengmin, and Robert M. Wirtshafter. 1995. "Developing China's Rural Energy Potential: The Integrated Rural Energy Development Program." Washington, D.C.: World Bank, Industry and Energy Department. Draft.

Doolette, J.B., and William Magrath, eds. 1990. *Watershed Development in Asia: Strategies and Technologies*. Technical Paper No. 127. Washington, D.C.: World Bank.

ESMAP (Energy Sector Management Assistance Program). 1990. *Indonesia: Urban Household Energy Strategy Study*, 2 vols. Nos. 107A–B/90. World Bank/United Nations Development Programme (UNDP) Energy Sector Management Assistance Program Series. Washington, D.C.: World Bank.

_______. 1991a. *Bolivia Prefeasibility Evaluation Rural Electrification and Demand Assessment*. Report No. 129/91. World Bank/UNDP Energy Sector Management Assistance Program Series. Washington, D.C.: World Bank.

_______. 1991b. *India Mini-Hydro Development on Irrigation Dams and Canal Drops Pre-Investment Study*, 3 vols. Nos. 139A–C/91. World Bank/UNDP Energy Sector Management Assistance Program Series. Washington, D.C.: World Bank.

_______. 1991c. *Haiti Household Energy Strategy*. Report No. 143/91. World Bank/UNDP Energy Sector Management Assistance Program Series. Washington, D.C.: World Bank.

_______. 1994a. *Photovoltaic Power to the People: The Kenya Case.* World Bank/UNDP Energy Sector Management Assistance Program Series. Washington, D.C.: World Bank.

_______. 1994b. "Ecuador: Energy Pricing, Subsidies and Interfuel Substitution." World Bank/UNDP Energy Sector Management Assistance Program. No. 11798–EC. Washington, D.C.: World Bank, Industry and Energy Department. Draft.

_______. Forthcoming. "Energy for Rural Development in China: An Assessment Based on a Joint Chinese/ESMAP Study in Six Counties." World Bank/UNDP Energy Sector Management Assistance Program. Washington, D.C.: World Bank, Industry and Energy Department.

Feinstein, Charles, and Robert van der Plas. 1991. *Improving Charcoaling Efficiency in the Traditional Rural Sector.* Energy Series Paper No. 38. Washington, D.C.: World Bank, Industry and Energy Department.

Fitzgerald, Kevin B., Douglas Barnes, and Gordon McGranahan. 1990. *Interfuel Substitution and Changes in the Way Households Use Energy: The Case of Cooking and Lighting Behavior in Urban Java.* Energy Series Paper No. 30. Washington, D.C.: World Bank, Industry and Energy Department.

Fleisig, Heywood. 1995a. "Limits to Lending for Movable Property in Latin American Countries: Possible Implications for Mexico." Remarks prepared for Conference on Commercial Relations: Secured Transactions and Registry Systems, Hermosillo, Mexico, March 17.

_______. 1995b. "The Right to Borrow." *Viewpoint* (World Bank, Energy and Industry Department) (44).

Floor, Willem. 1995. "Niger Household Energy Project." *Energy Notes* (World Bank, Industry and Energy Department) (2).

Floor, Willem, and Robert van der Plas. 1991. *Kerosene Stoves: Their Performance, Use, and Constraints.* Energy Series Paper No. 47. World Bank, Industry and Energy Department, Washington, D.C.

Foley, Gerald. 1991. *Electricity for Rural People.* London: Panos Institute.

_______. 1992. "Rural Electrification in the Developing World." *Energy Policy* 20(2):145–52.

_______. 1995. *PV Applications in the Rural Areas of the Developing World.* Energy Sector Management Assistance Program. Washington, D.C.: World Bank.

GEF (Global Environment Facility). Various years. *Quarterly Operational Reports.* Washington, D.C.

_______. 1995. *Annual Report.* Washington, D.C.

_______. 1996. *Operational Strategy.* Washington, D.C.

Government of Madagascar, Unité de Planification Energie Domestique. 1994. *Document Preparatoire à l'Evaluation du PPED (Programme de Planification Energie Domestique).* Antananarivo.

Government of Tanzania, Ministry of Water, Energy and Minerals. 1992. *Dar es Salaam Improved Charcoal Stoves Pilot Project: Final Report.* Dar es Salaam.

Gregersen, Hans, Sydney Draper, and Dieter Elz, eds. 1989. *People and Trees: The Role of Social Forestry in Sustainable Development*. EDI Seminar Series. Washington, D.C.: World Bank.

Gutiérrez, Luis. 1995. "The Social Impact of Raising Tariffs to Economic Levels." Paper presented at the Johannesburg Symposium on Power Sector Reform and Efficiency Improvements in Sub-Saharan Africa. World Bank Industry and Energy Department, Washington, D.C.

Hosier, Richard H. 1993. "Urban Energy Systems in Tanzania: A Tale of Three Cities." *Energy Policy* 21(5):510–23.

Hosier, Richard H., and W. Kipondya. 1993. "Urban Household Energy Use in Tanzania: Prices, Substitutes and Poverty." *Energy Policy* 21(5):454–73.

Hoskins, Marilyn. 1980. "Community Participation in African Fuelwood Production, Transformation, and Utilization." In *Energy in Africa*. Washington, D.C.: U.S. Agency for International Development.

Interdisziplinäre Projekt Consult GmbH. 1990. "Dissemination Strategies for Solar Home Systems in Developing Countries: Learning from GTZ's Experience." Report prepared for the Energy Division of the German Agency for Technical Cooperation. Frankfurt.

Inversin, Allen R. 1994. *New Designs for Rural Electrification: Private-Sector Experiences in Nepal*. Washington, D.C.: National Rural Electric Cooperative Association.

Isham, Jonathan, Deepa Narayan, and Lant Pritchett. 1995. "Does Participation Improve Performance? Establishing Causality with Subjective Data." *The World Bank Economic Review* 9(2):175–200.

Johansson, Thomas B., Henry Kelly, Amulya K.N. Reddy, and Robert H. Williams, eds. 1993. *Renewable Energy: Sources for Fuel and Electricity*. Washington, D.C.: Island Press.

Karekezi, Stephen, and Dominic Walubengo. 1989. *Household Stoves in Kenya: The Case of the Kenya Ceramic Jiko*. Nairobi: Kenya Energy and Environment Organization.

Kessler, Judd L., Janet Ballantyne, Robert Maushammer, and Nelson Romero Simancas. 1981. *Ecuador: Rural Electrification*. AID Project Impact Evaluation Report No. 21. Washington, D.C.: U.S. Agency for International Development.

Kozloff, Keith, and Olatokumbo Shobowale. 1994. *Rethinking Development Assistance for Renewable Electricity*. Washington, D.C.: World Resources Institute.

Kulkarni, Ashwini, Girish Sant, and J.G. Krishnayya. 1994. "Urbanization in Search of Energy in Three Indian Cities." *Energy* 19(5):549–60.

Kumar, Shubh, and David Hotchkiss. 1988. *Consequences of Deforestation for Women's Time Allocation, Agricultural Production, and Nutrition in Hill Areas of Nepal*. Research Report No. 69. Washington, D.C.: International Food Policy Research Institute.

Leach, Gerald. 1987. *Household Energy in South Asia*. London and New York: Elsevier.

_______. 1992. "The Energy Transition." *Energy Policy* 20(2):117–23.

Leach, Gerald, and R. Mearns. 1988. *Bioenergy-Issues and Options in Africa.* A Report for the Royal Norwegian Ministry of Development Cooperation. London: International Institute for Environment and Development.

Lewis, W. Arthur. 1969. *Some Aspects of Economic Development.* Aggrey-Fraser-Guggisberg Memorial Lectures. Tema, Ghana: Ghana Publishing Corporation.

Liebenthal, Andres, Subodh Mathur, and Herbert Wade. 1994. *Solar Energy: Lessons from the Pacific Island Experience.* Technical Paper No. 244. Energy Series. Washington, D.C.: World Bank.

Mandel, David H., Peter F. Allgeier, Gary Wasserman, Gerald Hickey, Robert Salazar, and Josephine Alviar. 1980. *The Philippines: Rural Electrification.* AID Project Impact Evaluation Report No. 15. Washington, D.C.: U.S. Agency for International Development.

Mason, Melody. 1990. "Rural Electrification: A Review of World Bank and USAID–Financed Projects: Background Paper." Washington, D.C.: World Bank, Energy and Industry Department. Processed.

Mendes, Matthew S., and Marcia M. Gowen. 1995. "Financing Rural Energy Services." *Rural Energy Planning: A Government Enabled Market-Based Approach.* Kuala Lumpur, Malaysia: Asian and Pacific Development Centre.

Menezes, L.M. 1995. "India's Rural Energy Programs." Paper presented at Donors Roundtable on Energy and the Environment, World Bank, Washington, D.C., May 24–25.

Milukas, Matthew V. 1993. "Energy for Secondary Cities: The Case of Nakuru, Kenya." *Energy Policy* 21(5):543–58.

Ministry of Agriculture, Government of China/ESMAP. 1992. "Energy for Rural Development in China: An Assessment Based on a Joint Chinese/ESMAP Study in Six Counties." Report prepared for the Symposium on Rural Energy in China, Beijing, November 2.

Molnar, Augusta. 1986. "Social Forestry Experience in India and Nepal: A Review of Community Woodlots, the Involvement of Women, and the Introduction of Wood-Saving Devices in the Various Projects." Report to the World Bank.

Munasinghe, Mohan. 1987. *Rural Electrification for Development: Policy Analysis and Applications.* Boulder, Colorado: Westview Press.

Newcombe, Kenneth. 1984. *An Economic Justification for Rural Afforestation: The Case of Ethiopia.* Energy Department Paper No. 16. Washington D.C.: World Bank.

O'Keefe, Phil, and Barry Munslow. 1989. "Understanding Fuelwood II: Starting with the People." *Natural Resources Forum* 3(1):11–19.

OTA (Office of Technology Assessment). 1991. *Energy in Developing Countries.* OTA-E-486. Washington, D.C.: U.S. Government Printing Office.

_______. 1992. *Fueling Development: Energy Technologies for Developing Countries.* OTA-E-516. Washington, D.C.: U.S. Government Printing Office.

Pearce, David, and Michael Webb. 1987. "Rural Electrification in Developing Countries: A Reappraisal." *Energy Policy* 15(8):329–38.

Peskin, Henry M., and Douglas Barnes. 1994. "What Is the Value of Electricity Access for Poor Urban Consumers?" Background paper for the World Bank's *World Development Report 1994*.

Ramakrishna, Jamuna. 1991. "India's National Improved Stoves Program." Energy Sector Management Assistance Programme. Washington, D.C.: World Bank, Industry and Energy Department. Draft.

Ramani, K.V. 1995. "Approach to Rural Electrification." *Rural Energy Planning: A Government Enabled Market-Based Approach*. Kuala Lumpur, Malaysia: Asian and Pacific Development Centre.

Ramani, K.V., A.K.N. Reddy, and M.N. Islam, eds. 1993. *Rural Energy Systems in the Asia-Pacific: A Survey of Their Status, Planning and Management*. Kuala Lumpur, Malaysia: Asian and Pacific Development Centre.

_______. 1995. *Rural Energy Planning: A Government Enabled Market-Based Approach*. Kuala Lumpur, Malaysia: Asian and Pacific Development Centre.

Reddy, Amulya K.N., and B. Sudhakara Reddy. 1994. "Substitution of Energy Carriers for Cooking in Bangalore." *Energy* 19(5):561–71.

Sen, D., and P.K. Das. 1987. *The Management of People's Participation in Community Forestry: Some Issues*. Social Forestry Network Paper No. 4d. London: Overseas Development Institute.

Smith, Kirk. 1987. *Biofuels, Air Pollution, and Health: A Global Review*. New York: Plenum Press.

_______. 1988. "Air Pollution: Assessing Total Exposure in Developing Countries." *Environment* 30 (10):16–35.

_______. 1991. "The Health Effects of Biomass Smoke: A Brief Survey of Current Knowledge." Energy Sector Management Assistance Programme. Washington, D.C.: World Bank, Industry and Energy Department. Draft.

_______. 1993. "Fuel Combustion, Air Pollution, and Health: The Situation in Developing Countries" *Annual Review of Energy and the Environment* 18:529–66.

Smith, Kirk R., S. Gu, K. Huang, and D. Qiu. 1993. "One Hundred Million Improved Cookstoves in China: How Was It Done?" *World Development* 21(6):941–61.

Soussan, John, Phil O'Keefe, and Barry Munslow. 1990. "Urban Fuelwood: Challenges and Dilemmas." *Energy Policy* 18(6):572–82.

Spears, John. 1986. *Measuring the Impact of Forests and Farm Trees on Water Availability, Soil Fertility, Crop and Livestock Yields, with Special Reference to Africa*. Washington D.C.: World Bank. Agricultural Projects Department.

Teplitz-Sembitzky, Witold, and Gunter Schramm. 1989. *Woodfuel Supply and Environmental Management*. Energy Series Paper 19. Washington, D.C.: World Bank, Industry and Energy Department.

Thomson, James. 1981. "Public Choice Analysis of Institutional Constraints on Firewood Production Strategies in the West African Sahel." In *Public Choice and Rural Development*. Washington, D.C.: Resources for the Future.

Torres, Silvia. 1993. "Beneficiary Assessment of the Mizque-Aiquile Subproject." Electrification for Alternative Development Project. La Paz, Bolivia: National Rural Electric Cooperative Association. Processed.

Tuntivate, Voravate Tig, and Douglas F. Barnes. 1995. "Rural Electrification in Thailand: Lessons from a Successful Program." Washington, D.C.: World Bank, Industry and Energy Department. Draft.

Turvey, Ralph, and Dennis Anderson. 1977. *Electricity Economics*. Baltimore, Maryland: The Johns Hopkins University Press.

Tyler, Stephen. 1994. "Household Energy Use and Environment in Asian Cities: An Introduction." *Energy* 19(5):503–508.

Unnayan Shamannay (in association with Development Design Consultants). Forthcoming. *Socioeconomic Impact Evaluation of the Rural Electrification Program in Bangladesh.* Washington, D.C.: U.S. Agency for International Development.

van der Plas, Robert. 1994. "Solar Energy Answer to Rural Power in Africa." *Finance and Private Development* (World Bank) 6.

_______. 1995. "Burning Charcoal Issues." *Energy Notes* (World Bank, Industry and Energy Department) 1.

van der Plas, Robert, and A.B. de Graaff. 1988. *A Comparison of Lamps for Domestic Lighting in Developing Countries.* Energy Series Paper 6. Washington, D.C.: World Bank, Industry and Energy Department.

van der Plas, Robert, and Willem Floor. 1996. "Market-Driven Approach Can Illuminate Lighting Options for Rural Areas." *Power Engineering International* (March/April).

Von Pischke, J.D., Dale W. Adams, and Gordon Donald. 1983. *Rural Financial Markets in Developing Countries.* Baltimore, Maryland: The Johns Hopkins University Press.

Wade, Herbert. 1991. "Photovoltaic Rural Electrification Projects in the Pacific Region and Lessons Learned." Report prepared for the World Bank, Pacific Regional Energy Assessment. Tahiti, French Polynesia: South Pacific Institute for Renewable Energy.

Whittington, Dale, Donald T. Lauria, and Xinming Mu. 1991. "Paying for Urban Services: A Study of Water Vending and Willingness to Pay for Water in Onitsha, Nigeria." *World Development* 19(2–3):179–98.

World Bank. 1975. *Rural Electrification*. Policy Paper. Washington, D.C.

_______. 1978. *Forestry*. Policy Paper. Washington, D.C.

_______. 1987. *Tropical Forest Action Plan.* Washington, D.C.

_______. 1990. *World Development Report 1990: Poverty*. New York: Oxford University Press.

_______. 1991. *The Forest Sector*. Policy Paper. Washington, D.C.

_______. 1992. *World Development Report 1992.* Washington, D.C.

_______. 1993a. *Energy Efficiency and Conservation in the Developing World.* Policy Paper. Washington, D.C.

_______. 1993b. *The World Bank's Role in the Electric Power Sector.* Policy Paper. Washington, D.C.

_______. 1993c. *World Bank Atlas 1994.* Washington, D.C.: The World Bank.

_______. 1994a. "Rural Electrification in Asia: A Review of Bank Experience." Operations Evaluation Department, Report No. 13291. World Bank, Washington, D.C. June.

_______. 1994b. *World Development Report 1994: Infrastructure for Development.* New York: Oxford University Press.

_______. 1994c. "Review of Implementation of the Forest Sector Policy." Washington, D.C.

_______. 1994d. "Power and Energy Efficiency: Status Report on the Bank's Policy and IFC Activities." Joint World Bank/International Finance Corporation seminar, presented to the Executive Directors, July 7. Washington, D.C.: Energy and Industry Department.

_______. 1995a. "Lending for Electric Power in Sub-Saharan Africa." Washington, D.C.: Operations Evaluation Department.

_______. 1995b. *World Bank Participation Sourcebook.* Environment Department, Social Policy and Resettlement Division. Washington, D.C.: The World Bank.

_______. 1995c. *Global Economic Prospects and the Developing Countries.* Washington, D.C.

World Bank/United Nations Development Programme. Forthcoming. *India Rural Energy Study.* Washington, D.C.: World Bank.