IEG
INDEPENDENT EVALUATION GROUP

THE WORLD BANK

45400

# The Welfare Impact of Rural Electrification: A Reassessment of the Costs and Benefits

## An IEG Impact Evaluation

# RECENT IEG PUBLICATIONS

2006 Annual Report on Operations Evaluation
Annual Review of Development Effectiveness 2006: Getting Results
Addressing the Challenges of Globalization: An Independent Evaluation of the World Bank's Approach to Global Programs
Assessing World Bank Support for Trade, 1987–2004: An IEG Evaluation
Books, Buildings, and Learning Outcomes: An Impact Evaluation of World Bank Support to Basic Education in Ghana
Brazil: Forging a Strategic Partnership for Results—An OED Evaluation of World Bank Assistance
Bridging Troubled Waters: Assessing the World Bank Water Resources Strategy
Capacity Building in Africa: An OED Evaluation of World Bank Support
China: An Evaluation of World Bank Assistance
The CGIAR at 31: An Independent Meta-Evaluation of the Consultative Group on International Agricultural Research
Committing to Results: Improving the Effectiveness of HIV/AIDS Assistance—An OED Evaluation of the World Bank's Assistance for HIV/AIDS Control
Country Assistance Evaluation Retrospective: OED Self-Evaluation
Debt Relief for the Poorest: An Evaluation Update of the HIPC Initiative
A Decade of Action in Transport: An Evaluation of World Bank Assistance to the Transport Sector, 1995–2005
The Development Potential of Regional Programs: An Evaluation of World Bank Support of Multicountry Operations
Development Results in Middle-Income Countries: An Evaluation of the World Bank's Support
Economies in Transition: An OED Evaluation of World Bank Assistance
Engaging with Fragile States: An IEG Review of World Bank Support to Low-Income Countries Under Stress
The Effectiveness of World Bank Support for Community-Based and -Driven Development: An OED Evaluation
Evaluating a Decade of World Bank Gender Policy: 1990–99
Evaluation of World Bank Assistance to Pacific Member Countries, 1992–2002
Extractive Industries and Sustainable Development: An Evaluation of World Bank Group Experience
Financial Sector Assessment Program: IEG Review of the Joint World Bank and IMF Initiative
From Schooling Access to Learning Outcomes: An Unfinished Agenda—An Evaluation of World Bank Support to Primary Education
Hazards of Nature, Risks to Development: An IEG Evaluation of World Bank Assistance for Natural Disasters
How to Build M&E Systems to Support Better Government
IEG Review of World Bank Assistance for Financial Sector Reform
Improving Investment Climates: An Evaluation of World Bank Group Assistance
Improving the Lives of the Poor Through Investment in Cities
Improving the World Bank's Development Assistance: What Does Evaluation Show?
Maintaining Momentum to 2015: An Impact Evaluation of Interventions to Improve Maternal and Child Health and Nutrition Outcomes in Bangladesh
New Renewable Energy: A Review of the World Bank's Assistance
Pakistan: An Evaluation of the World Bank's Assistance
Pension Reform and the Development of Pension Systems: An Evaluation of World Bank Assistance
Poland Country Assistance Review: Partnership in a Transition Economy
The Poverty Reduction Strategy Initiative: An Independent Evaluation of the World Bank's Support Through 2003
The Poverty Reduction Strategy Initiative: Findings from 10 Country Case Studies of World Bank and IMF Support
Power for Development: A Review of the World Bank Group's Experience with Private Participation in the Electricity Sector
Putting Social Development to Work for the Poor: An OED Review of World Bank Activities
Small States: Making the Most of Development Assistance—A Synthesis of World Bank Findings
Social Funds: Assessing Effectiveness
Sourcebook for Evaluating Global and Regional Partnership Programs
Water Management in Agriculture: Ten Years of World Bank Assistance, 1994–2004
World Bank Assistance to the Financial Sector: A Synthesis of IEG Evaluations
The World Bank in Turkey: 1993–2004—An IEG Country Assistance Evaluation
World Bank Lending for Lines of Credit: An IEG Evaluation

All IEG evaluations are available, in whole or in part, in languages other than English. For our multilingual section, please visit http://www.worldbank.org/ieg

WORLD BANK INDEPENDENT EVALUATION GROUP

IEG

# The Welfare Impact of Rural Electrification: A Reassessment of the Costs and Benefits

## An IEG Impact Evaluation

2008
The World Bank
Washington, D.C.

http://www.worldbank.org/ieg

1818 H Street NW
Washington DC 20433
Telephone: 202-473-1000
Internet: www.worldbank.org
E-mail: feedback@worldbank.org



1 2 3 4 5 11 10 09 08 07



Cover photo: A woman in Bangladesh stands beside a household electric meter. Photo courtesy of NRECA International Programs.

ISBN-13: 978-0-8213-7367-5
e-ISBN-13: 978-0-8213-7368-2
DOI: 10.1596/978-0-8213-7367-5

**Library of Congress Cataloging-in-Publication Data have been applied for.**

World Bank InfoShop
E-mail: pic@worldbank.org
Telephone: 202-458-5454
Facsimile: 202-522-1500

Independent Evaluation Group
Knowledge Programs and Evaluation Capacity Development (IEGKE)
E-mail: eline@worldbank.org
Telephone: 202-458-4497
Facsimile: 202-522-3125

Printed on Recycled Paper

# Contents

## Tables

Electricity distributors at a mini hydroelectric plant in Sri Lanka. (Photo from the World Bank Photo Library.)

# Abbreviations

| | |
|---|---|
| CDD | Community-driven development |
| DHS | Demographic and Health Survey |
| DSM | Demand-side management |
| ERR | Economic rate of return |
| ESMAP | Energy Sector Management Assistance Program |
| GEF | Global Environment Facility |
| HAZ | Height for age |
| IBRD | International Bank for Reconstruction and Development (World Bank) |
| IEG | Independent Evaluation Group |
| klh | Kilo lumen hours |
| km | Kilometer |
| kWh | Kilowatt hours |
| LSMS | Living Standard Measurement Survey (Peru) |
| Norad | Norwegian Agency for International Development |
| O&M | Operations and maintenance |
| PAD | Project Appraisal Document |
| PPAR | Project Performance Audit Report |
| PV | Photovoltaic |
| RE | Rural electrification |
| REF | Rural Electrification Fund |
| RET | Renewable energy technologies |
| SHS | Solar home system |
| TFR | Total fertility rate |
| USAID | United States Agency for International Development |
| WAZ | Weight for age |
| Wp | Watt peak |
| WTP | Willingness to pay |

All dollar amounts are U.S. dollars unless otherwise indicated.

Villagers extending cables to provide village with electricity from hydro power.
(Photo from the World Bank Photo Library.)

# Acknowledgments

The report was prepared by Howard White (Task Manager), Nina Blöndal, Morgan Rota, and Anju Vajja, with inputs from Robin Banerjee, Mollie Fair, Tara Lonnberg, and Andrew Waxman under the supervision of Alain Barbu. Administrative support was provided by Soon Won-Pak, and the report was edited by William Hurlbut and Heather Dittbrenner. The external reviewers for the report were Andrew Barnett and Stein Hansen.

Thanks are due to the following for providing energy survey data and related documentation: Doug Barnes (the Philippines); Morten Larsen, Jie Tang, and Voravate Tuntivate (Lao People's Democratic Republic); and René Masse (Sri Lanka). Thanks are also due to Gustavo Angeles (Carolina Population Center, University of North Carolina) for running tabulations using data from the health facility survey for Nicaragua, and to Chris Edwards for advice at various stages of the analysis.

Director-General, Evaluation: *Vinod Thomas*
Director, Independent Evaluation Group, World Bank: *Cheryl Gray*
Manager, Sector, Thematic, and Global Evaluation: *Alain Barbu*
Task Manager: *Howard White*

Village home in Sri Lanka lit by solar energy. (Photo from the World Bank Photo Library.)

# Foreword

This report is part of the Independent Evaluation Group's (IEG) impact evaluation series. These studies fit under the category of "rigorous but relevant" evaluations, seeking to use a variety of data sources both to demonstrate impact and to deliver policy-relevant conclusions. This study is the first of the impact evaluations to combine evidence from a number of different countries; it uses data from a range of sources, both existing studies and reanalyses of existing survey data. Although the report touches on aspects of sector performance, it does not claim to be a comprehensive sector review.

A woman in Bangladesh beside a household electric meter. (Photo courtesy of NRECA International Programs.)

# Executive Summary

It has long been claimed that rural electrification greatly improves the quality of life. Lighting alone brings benefits such as increased study time and improved study environment for school children, extended hours for small businesses, and greater security.

But electrification brings more than light. Its second most common use is for television, which brings both entertainment and information. The people who live in rural areas greatly appreciate these benefits and are willing to pay for them at levels more than sufficient to cover the costs. However, the evaluation of these and other benefits (for example, in terms of public goods), as well as of their distribution, has been sparse.

This report reviews recent methodological advances made in measuring the benefits of rural electrification (RE) and commends them. It also notes that the understanding of the techniques shown in project documents is sometimes weak, and quality control for the economic analysis in project documents lacking. This study shows that willingness to pay (WTP) for electricity is high, exceeding the long-run marginal cost of supply.

Hence, in principle, RE investments can have good rates of return and be financially sustainable. But caveats are in order. The first caveat is that attention needs to be paid to ensuring least cost supply, including limiting system losses. Second, continued attention needs to be paid to achieving the right balance between financial sustainability and reaching the poor.

The World Bank has been financing RE for decades in Asia, and it has been expanding such activities in Latin America and Africa. Its support for RE has focused on outputs—building infrastructure and institutions. Yet outcomes have often been missing from project objectives; when present, they are assumed to follow automatically from the outputs. But the connection cannot be taken for granted.

Project design components to ensure that outputs do result in the intended outcomes are rare, though they are increasing. To give this results orientation further impetus, this assessment by the Independent Evaluation Group (IEG) examines anew the costs and benefits of RE for Bank-supported projects in several Regions of the world.

## Background to the Study

The World Bank has made loans for power generation, transmission, and distribution since its earliest years. By the 1980s it was lending substantial amounts for expanding coverage into rural areas. However, a 1994 IEG report, *Rural Electrification in Asia*, cast doubt on these investments, arguing that the rates of return were low because many of the claimed benefits were not realized and that the costs of these programs imposed a financial burden on the provider. Since that time, financial reforms have been implemented in a number of countries, and the RE portfolio has seen significant shifts in terms of project objectives and design.

In addition, in response to that IEG report, the Energy Sector Management Assistance Program (ESMAP) carried out a study in the Philippines to quantify a broader range of benefits from RE. Most notably, that study developed a new methodology for measuring the benefits of electric lighting that has been widely adopted in project appraisals, giving very acceptable rates of return. The main focus of IEG's current study is to review these claims and examine the extent to which changes in the portfolio have addressed earlier concerns regarding the limited poverty impact of lending to RE.

The study analyzed data from a range of sources, including IEG's own analysis of existing data sets for a dozen countries (three energy surveys, nine Demographic and Health Surveys, and two income and expenditure surveys) and a review of Bank and external studies. The analysis unpacks the causal chain from the provision of electricity to the various benefits it is claimed to bring, and quantifies these benefits where possible to address the balance of costs and benefits. The data were used to test the impact of RE on several variables, such as the quantity of lighting used, opening hours of clinics, female health knowledge, and income from home businesses.

## The Bank's Portfolio

The Bank's strategy for the energy sector has evolved considerably in the last 15 years. In 1993 two policy papers were published that gave greater emphasis to the role of the private sector and highlighted environmental concerns (World Bank 1993a, 1993b). A 1996 paper discussed the 2 billion poor people around the world lacking access to modern energy services and how the Bank may best meet their needs (World Bank 1996), and a 2001 sector board paper increased the emphasis on both poverty and the environment (World Bank 2001b). How have these strategy changes been reflected in the RE portfolio?

IEG identified 120 Bank-supported projects with RE activities since 1980, falling roughly equally into three categories: dedicated projects (such as Bangladesh Rural Electrification I, II, and III), energy sector projects with RE components (such as the Jordan Energy Development Project), and multisector projects with RE components (such as Brazil's Northeast Rural Poverty Alleviation Projects). A growing number of these projects are in Latin America, where RE is common in multisectoral community-driven development projects, and Sub-Saharan Africa.

Another recent trend is the growth of support for off-grid electrification, usually as a subcomponent of a larger project, as in the Southern Provinces Rural Electrification Project and follow-on Rural Electrification Project in Lao People's Democratic Republic. Most off-grid projects rely on renewable energy technologies, which have also become more prominent in the Bank's lending in the last 15 years.

Three-quarters of RE projects have objectives related to improving energy supply, and the same proportion has objectives related to institutional development. Only 60 percent have the objective of increasing welfare (including environmental benefits), and this objective is mostly stated in general terms, such as improving incomes. Moreover, this objective is most common in the multisectoral projects. Only 7 percent of dedicated RE projects and energy sector projects have an explicit poverty-reduction objective. Hence, poverty has not become a central concern of RE projects, and there is rarely any explicit consideration either of how the poor will be included or of any poor-specific activities. Similarly, although mention of gender in project documents has increased greatly in the last decade, these concerns rarely affect project design.

Where the Bank finances a series of dedicated projects it can make a substantial contribution to increasing RE coverage: in Indonesia coverage rose from 33 percent in 1991 to 85 percent by 2003, with about 45 percent of these additional connections being paid for with Bank financing. In Bangladesh, the number of rural connections grew from practically zero in 1980 to more than 4 million by 2002; 600,000 of these connections were made with Bank financing.

By and large, Bank-supported projects have successfully created the physical infrastructure for RE, although technical problems have often meant high system losses—which have reached as high as 50 percent in Albania and India (Rajasthan). These losses drive a wedge between the cost of generation and the cost of supply, thus undermining financial performance. Many Bank projects have components to address this problem of system loss, but not all have been successful.

There has been less success with institutional development, with the majority of unsatisfactory projects being rated such for this reason. The poor overall performance of the subsector—with just 68 percent of projects rated satisfactory from 1996 to 2006 (compared with 75 percent for the Bank as a whole)—mainly reflects institutional problems. These problems commonly relate to the lack of financial sustainability of the utility responsible for distribution, as tariffs are set below cost recovery. But the situation is changing; some countries have introduced higher tariffs and others, such as Lao PDR, are on track to do this. But there also remain a number of countries in which financial performance requires further attention.

## Who Benefits from Rural Electrification?

It is widely recognized that the larger share of benefits from RE is captured by the non-poor. IEG analysis shows that this continues to be the case, although the gap closes as coverage expands. Two factors underpin this anti-poor pattern in electrification: which communities get connected and which households can afford the connection once the grid is available.

In many countries communities to be connected to the grid are identified on a "least cost" basis, which favors which larger communities nearer to the existing grid, roads, and towns. The Bank has promoted this approach, which is often necessary to secure the financial viability of the RE program, in a number of countries. For example, the recent Peru Rural Electrification Project changed community prioritization from the government's "social criteria" to a least cost approach.

Although this is necessary for the financial health of the service provider, there is a clear trade-off with reaching the more disadvantaged. Hence, some countries include social variables in their eligibility criteria; in Bank-supported projects this has most often been the case for community-driven development projects that target the poorest areas. In other cases, such as the Ghana National Electrification Project, the Bank has acceded to the government's request to ensure geographically equitable coverage. In a small number of cases, RE funds have been used to offset the financial loss incurred by private companies that extend coverage to less advantaged rural areas.

Although off-grid connections can serve remote communities that may not be connected to the grid for some years, they do not necessarily reach the poor better than grid extension does. Bank support to off-grid electrification is typically through a private business model, so social concerns have to be weighed against financial viability.

In most countries, increases in coverage come from extensive growth (extending the grid to new communities) rather than intensive growth (connecting the unconnected in already electrified villages). Once electricity arrives in a village, the connection charge is a hurdle that prevents the poor from connecting to the grid, even though the benefits they would derive—and so their WTP—would exceed the cost of supply.

Even in villages that have been connected for 15–20 years, it is not uncommon for from 20 to 25 percent of households to remain unconnected (for example, in Lao PDR). The absence of credit markets means households cannot borrow to pay the connection charge. Only a very small number of Bank-supported projects have either extended credit to customers (for example, the Second Accelerated Rural Electrification Project in Thailand) or allowed the connection charge to be paid over a number of years. Because the poor do not connect, progressive tariff structures have proved to be regressive subsidy schemes—so better-targeted connection charges would be consistent with the Bank's priority of ensuring that the poor benefit directly.

The same point applies to off-grid schemes, which are more expensive to the consumer than grid electricity. In some countries, the subsidy provided to these schemes is tilted toward the smaller systems likely to be chosen by poorer households. For example, this is the case with the Philippines Rural Power Project. Also, credit or extended repayment periods for installation costs are more common for off-grid projects than for grid extension.

The poor who do connect benefit from a "lifeline tariff," a low tariff rate—commonly a fixed charge—for consumers who use below a certain level, usually 25 kilowatt hours (kWh) per month. But poor customer information means that many consumers unnecessarily restrict consumption to save money, when in fact it saves them nothing.

The full benefits of providing electricity to the poor are not being realized: first, poorer households are not enabled to connect to the grid, and second, consumers do not get information that allows them to obtain their maximum benefit. Bank-supported projects that claim to have the objective of bringing RE to the poor have typically neglected to include components that would help to achieve this objective.

## What Is Electricity Used for in Rural Areas?

The dominant use of electricity in rural households is lighting. All households use it for this purpose, and many use little electricity for anything else. The next most common use is TV. Lighting and TV account for at least 80 percent of rural electricity consumption and thus the bulk of the benefits delivered by electrification. Electricity is rarely used for cooking in rural areas, though East Asia is something of an exception with the use of rice cookers. Fans and irons are also used for a minority of consumption.

The pattern of use has implications for the benefits from RE. The potential benefits to be gained from displacing firewood or kerosene stoves are not realized in the vast majority of cases. Again, consumer education may enable these consumers to achieve a greater range of benefits.

Electricity is also used in community facilities—notably for the cold chain for vaccines, though this does not appear to affect immunization rates. A positive impact of RE on service provision comes from the greater willingness of health and education workers to stay in communities that have electricity.

The lack of large-scale productive uses for rural electricity remains a constraint on the financial viability of RE because of low load factors resulting from consumption being heavily concentrated in the evening peak hours.

RE does not drive industrial development, but it can provide an impetus to home businesses, even though few households use electricity for productive purposes. IEG's analysis shows that the number of enterprises grows as a result of electrification and that these enterprises operate for more hours. There is, therefore, a positive impact on household income. However, the broader literature has found these effects to be less than expected, except when there has been a specific program to promote productive uses of electricity. This is, then, another example of how an additional project component can help achieve the welfare objective.

## Benefits of Rural Electrification

IEG's review endorses the approaches advocated in the ESMAP study (2003) for measuring the benefits of lighting and TV; this involves measuring them as WTP for lumens (a measure of the quantity or intensity of lighting) in the case of lighting and hours of TV. There is a caveat that the shape of the demand curve matters (although the evidence as to its shape is still thin) and that assuming a linear demand curve, as in some studies, most likely results in an overestimation of project benefits. In one notable case, the claimed economic rate of return of 60 percent fell to 12 percent in IEG's recalculation.

It is also evident that some authors of project economic analyses have a weak grasp of the methodology, so the Bank's economic analysis does not match the quality of the available analytic work. Quality control mechanisms are not in place to stop weak analysis appearing in Board documents. But this view must be balanced with the observation that some project documents, such as that for the Peru Rural Electrification Project, are best practice examples of cost-benefit analysis.

The ESMAP approach yields a WTP of around $0.10–0.40 per kWh for lighting and TV alone. This figure is already well in excess of the average long-run supply cost, which is usually in the range of $0.05–0.12 kWh.

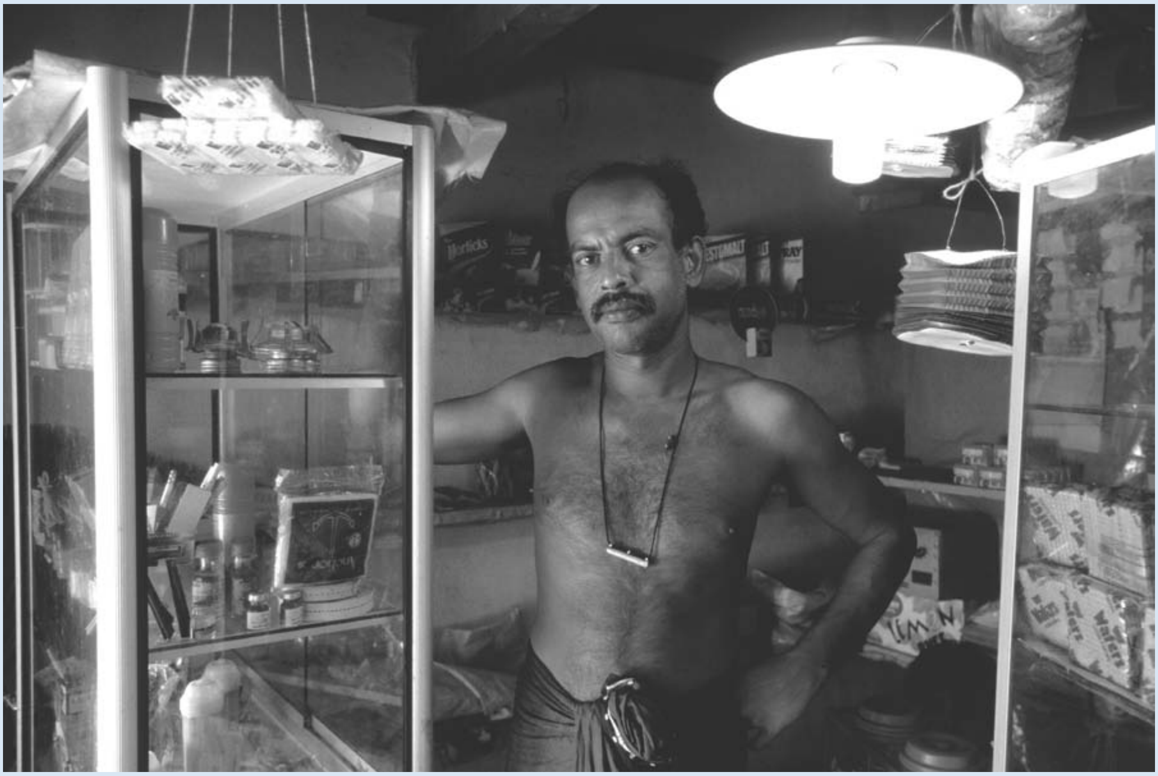
This study also considers education benefits (as did the ESMAP study) and health and fertility benefits. More studies are required to better understand these channels. Other benefits are harder to quantify. But many of them are most likely internalized by the household and so reflected in the WTP. The exceptions are public good benefits, such as street lighting, which increases security, and the so-called "global benefits" of reduced carbon dioxide emissions, where applicable. Including these benefits means the benefit for an average household consuming 30–40 kWh a month is about $60 per month per household. This level is sufficient to ensure an adequate rate of return for most grid-extension schemes.

Off-grid schemes fare less well because they have higher costs but lower benefits. Benefits are further reduced by technical issues, including supply problems. The economic rationale for funding off-grid components alongside grid extension when the latter has the higher economic rate of return is far from clear. Such a decision might be justified on social grounds, but the case is far from proven, especially when much lower subsidies would be required to reach the poor who are unconnected in electrified villages. An alternative argument to support these investments is that these are mostly small-scale programs to enable learning by doing, which, together with general cost reductions and technological developments, will eventually make off-grid electricity more competitive.

## Lessons Learned

It is difficult to generalize about RE, because both costs and benefits are context specific. However, some broad statements can be made.

- RE investments can generate sufficient benefits for the investment to be warranted from an economic standpoint—and they often have.
- The value of these benefits to households is above the average long-run supply cost, so cost-recovery tariff levels are achievable, even if politically unpopular in countries with a history of low tariffs.
- Analysis of feasible tariff levels can be informed by good quality economic analysis of the sort pioneered by the Philippines ESMAP study. But the quality analysis of that study is not uniformly replicated, as the quality of project-level analysis is uneven, with apparent weak quality control.
- The evidence base remains weak for many of the claimed benefits of RE. Tailor-made surveys, designed to test these benefits, need to be built into a greater number of Bank projects and designed to allow rigorous testing of the impact of electrification.
- Countries with low coverage rates—now mostly in Africa—still have to make investments in generation, transmission, and distribution, which implies relatively high average supply costs and low coverage, increasing slowly by extensive growth for some years to come. The principal challenge is to balance financial sustainability with growing coverage, requiring efficiency by limiting system losses. Grid connections will grow slowly, so many areas may be eligible for off-grid connections, but the logistics of maintaining technical quality will be challenging.
- Some countries in Asia and Latin America are reaching the limits of grid extension. Further increases in coverage require intensive growth, which requires instruments designed for that purpose, or off-grid schemes, which need design improvements if they are to be financially sustainable.
- There are project design options that have been uncommon but that would enhance project benefits. These include financing schemes for connection charges, consumer education, and support for productive uses.



Solar power generates electricity for village shop in Sri Lanka. (Photo from the World Bank Photo Library.)

# Chairperson's Summary: Committee on Development Effectiveness (CODE)

On December 17, 2007, the Informal Subcommittee of the Committee on Development Effectiveness considered a study entitled *The Welfare Impact of Rural Electrification: A Reassessment of the Costs and Benefits*, prepared by the Independent Evaluation Group (IEG)-World Bank.

## IEG Findings and Recommendations

The IEG report reviewed recent methodological advances made in measuring the benefits of rural electrification (RE) and commends them, while noting that the understanding of these techniques shown in project documents is sometimes weak and quality control for the economic analysis in project documents is lacking. One of the main findings was that RE investments could generate sufficient benefits to households and the value of these benefits was above the average long-run supply costs. IEG also noted that analysis of feasible tariff levels could be informed by good-quality economic analysis and endorsed the measurement approaches pioneered by the Philippines Energy Sector Management Assistance Program (ESMAP). IEG found that the Bank RE projects have become more explicitly focused on poverty reduction. However, complementary measures to ensure the highest poverty reduction and social impacts—such as educational campaigns, promotion of productive use, and smart subsidies—have been lacking in Bank projects.

## Overall Conclusions

Speakers welcomed the IEG impact evaluation and the methodology used for estimating measurable costs and benefits, particularly with regard to impact on the poor. Questions were raised about the Bank's support for development of the new sources of energy, particularly renewable energy. Members highlighted the importance of using targeted and well-focused cross-subsidies, which could increase the positive impact of RE on the poor. Speakers also underlined the need to strengthen cross-sectoral collaboration and promote local development initiatives. Members also stressed the importance of combining qualitative and quantitative methods while analyzing the impact of the Bank's programs.

## Main Issues

The following main issues were raised during the meeting.

***Impact Analysis.*** A number of speakers appreciated the methodology used in ESMAP. At the same time, a member underlined the importance of continued improvement of the analytical tools and asked management to ensure that staff would use such tools in day-to-day work. He also called for the rapid development and application of improved evaluation techniques to contribute to setting up informed and clear objectives and strategies in this sector. A member considered the scope of the IEG report narrow and would have preferred to see more in-depth analysis of the opportunity costs. He also remarked that development effectiveness of infrastructure projects should be evaluated by the nationwide economic impact, not by the Regional social impact. A speaker encouraged management to conduct an analysis of microscale positive effects that electrification has on small businesses.

***Use of New Technologies.*** Some speakers noted that the IEG report finding about higher costs but lower benefits of off-grid connection compared to grid extension was disputable. They also would have preferred to see recommendations that help the Bank develop its operations in renewable energy. In addition, a member remarked that the Global Environmental Facility grants can be used to promote use of new technologies for electrification in remote areas. *Management explained that grid and off-grid electrification is complementary, and in sparsely populated, remote, or mountainous areas the off-grid connection is the only solution. IEG clarified that there is often a trade-off between connecting, at a higher cost, better-off people in remote locations and poorer ones in nearer locations (including already connected villages) and that this trade-off needed to be made clear and a rationale provided.*

***Use of Subsidies.*** Several speakers commented on the need to further analyze subsidies, because the poverty dimension of RE can be addressed through cross-subsidization. A member noted that recently the International Finance Corporation (IFC) Board of Directors approved the Performance-Based Grants Initiative, authorizing the IFC to provide subsidies to the private sector to extend its infrastructure subsidies to the poor. He suggested the IFC share its experience in this area with the Bank. *Management clarified that the targeted subsidies for connection charges for low-income households, which the report advocates, face implementation difficulties in practice. These subsidies are more feasible in the countries with high electrification rates, where the cross-subsidies from industries and commercial and high-income customers are possible. Alternatives also adopted are using low-cost methods for household connections and financing to spread the connection cost over several months.*

***Community-Driven Mechanisms.*** Some speakers sought more information about the decision-making process in RE. They wondered whether such processes should be community driven with the involvement of local institutions and producer organizations. In this regard, a member underlined the importance of public awareness campaigns and noted that the poor should be made aware of the services available to them for the low basic tariffs. *IEG responded that in some Regions, particularly in Latin America, community-driven development programs provide financing for RE. Implementation of the community-driven RE programs also increases consumers' awareness of their potential benefits.*

## Other Issues

A member expressed disappointment that gender issues had not been more central to Bank projects. He also sought more information about the impact that access to television has on rural households. *Management agreed that the gender element is important in the electrification sector and stressed the importance of developing the appropriate mechanisms to incorporate gender dimensions in analytical and operational work. Regarding the impact of television, IEG clarified that the study had found that TV increased women's health knowledge and so had a fertility-reducing impact, but a similar effect was not found for radio.*

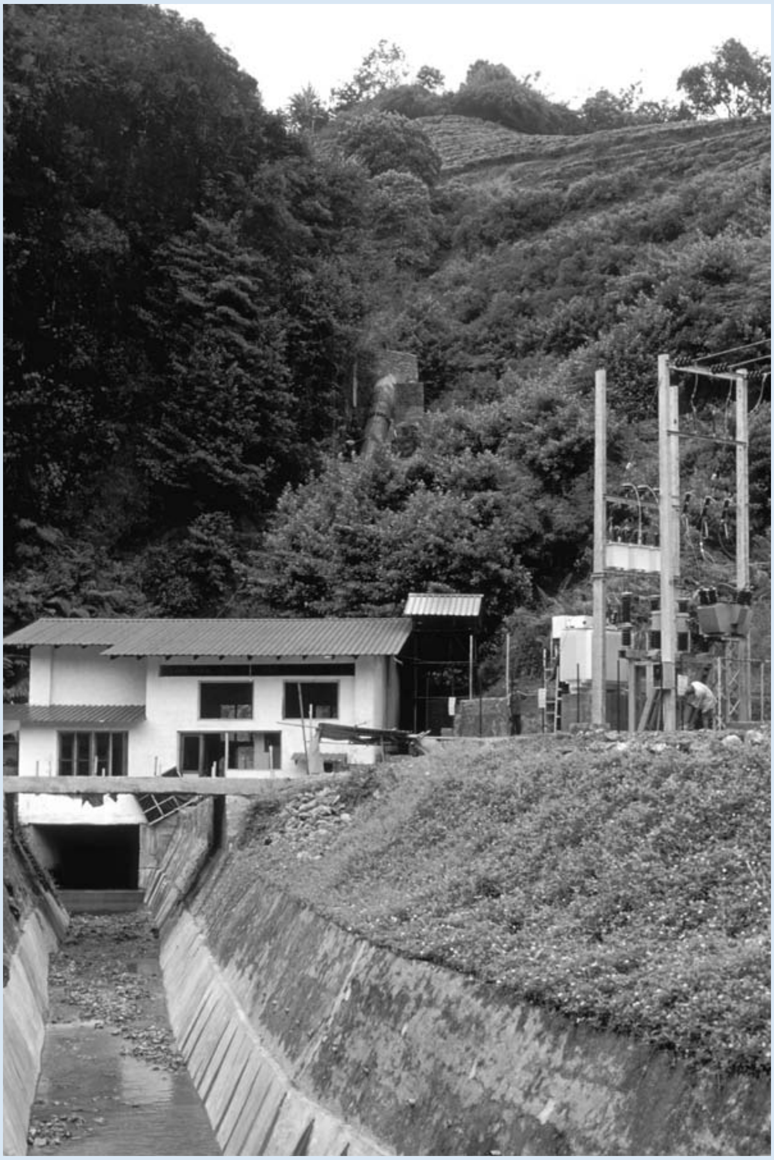
---

*Jiayi Zou, Chairperson*

# Chapter 1

## Evaluation Highlights

- A 1994 Independent Evaluation Group assessment found that rural electrification projects had lower economic rates of return than expected and benefited the non-poor.
- This evaluation calculates returns on rural electrification to determine whether the earlier finding still holds true.



Rural power station at a mini hydroelectric power station in Sri Lanka. (Photo from the World Bank Photo Library.)

# Introduction

The World Bank started as a lender for infrastructure investments, so some of its first loans were to the power sector, such as Loan 0005 for the Power and Irrigation Project in Chile, signed in 1948.[1] During the 1950s and 1960s the Bank was heavily involved in electrification projects around the world.

Examples include the first loan to Ghana in 1962 for the Volta Power Project, the 1957 Philippines Binga Hydroelectric Project, and two projects in Nicaragua in the 1950s (the Diesel Power and Thermal Power Projects). By the 1970s attention was turning to electrification of rural areas: cumulative investments had reached $10 billion by 1971, with another $10–15 billion expected to be disbursed during the 1970s.

## The Shifting Rationale and Returns to Lending for Rural Electrification

A 1975 paper entitled "Rural Electrification" (World Bank 1975) reviewed the rationale for Bank support to the sector.[2] The paper argued, "There is plenty of scope for successful investments in rural electrification (RE), provided that they are properly selected and prepared" (World Bank 1975, p. 3). The paper also recognized that these investments would often be loss making, at least initially. The up-front investment costs were very high, and rural demand was considerably lower than that in urban areas, resulting in low load factors and high unit costs.

However, marginal costs could fall rapidly as coverage expanded and once the main grid was established, so connecting neighboring areas could be relatively inexpensive. Project selection should rest initially on estimation of the economic rate of return (ERR), valuing benefits as the revenues from domestic consumption and the incremental value added from productive uses. The 1975 paper did acknowledge that stimulation of production by RE had in general been disappointing, albeit with exceptions. If these calculations did not provide an acceptable rate of return, then justification might be provided on the grounds of social benefits, although the paper recognized that electricity was not a basic need to be compared with clean water or health.

*Early analysis of RE suggested that its very high up-front costs would drop rapidly as connections expanded.*

At the time of the 1975 paper many Latin American countries had established countrywide networks linking major demand centers and were moving to connect smaller rural centers and outlying areas; Asian countries were then in the process of establishing systems to reach the major demand centers, and African countries were still at the stage of creating their own power-generation facilities. Hence, by the 1980s the focus of Bank lending for RE was in Asia, such as the Malaysia Rural Electrification Project (1982–1988) and the first two Bangladesh RE projects (Bangladesh RE I, 1981–1990, and RE II, 1985–1993).

However, a report published by the Independent Evaluation Group (IEG) in 1994 presented generally pessimistic findings regarding these projects. The study noted that—

- Ex post ERRs were much lower than those at appraisal, as many of the indirect and external benefits had not materialized. Notably, there was little impact on industrial development.

- RE projects ignored financial aspects. As had been recognized in the 1975 paper, unit investment costs for RE were much higher than those in urban areas because of lower population density and the low ratio of average demand to peak demand (rural use is concentrated in early evening, whereas urban demand is spread across the day). Cost recovery was low (between 10 and 50 percent), thus imposing a financial burden on electricity utilities or governments.
- The direct benefits of RE went to the nonpoor. Even with low tariffs, the poor cannot afford connection costs. The poverty-reduction benefits of RE were thus indirect and came through rising rural incomes; these effects were found to be limited.

*Early projects had lower ERRs than expected, and benefits went to the non-poor.*

In the decade following IEG's report, the Bank's strategy shifted toward a stronger poverty focus. This shift has been one factor behind changes in the portfolio, such as the development of off-grid programs.

In a more direct response to IEG's report, further technical work was carried out to identify and quantify the benefits of RE, most notably the seminal report by the Bank's Energy Sector Management Assistance Program (ESMAP), "Rural Electrification and Development in the Philippines: Measuring the Social and Economic Benefits," published in 2003. RE had long been claimed to have many diverse benefits for health, education, nutrition, security, and so on—one study provides a list of more than 50 discrete benefits (Saunier 1992). But there was little rigorous evidence regarding these benefits and no attempt at all to quantify them.

The ESMAP study of the Philippines changed that. Although the full range of estimates made in that report, which are discussed below, are quite data intensive, it developed techniques for measuring the main benefits from improved lighting and access to television, which have since been used in a number of appraisal documents. Application of these methods has resulted in very respectable rates of return, reaching levels as high as 95.3 percent for the Bangladesh Third Rural Electrification Project and 60.5 percent for the Lao People's Democratic Republic Southern Provinces Rural Electrification Project.

A primary intention of this report is to subject these new approaches to critical scrutiny. Does the 1994 IEG finding that ERRs from RE investments are too low still stand? Or do recent changes in the Bank's energy strategy, the nature of its support for RE, and methodological developments and evidence overturn that earlier position?

This question remains extremely relevant. The Bank has an active portfolio in the area. Meanwhile, coverage rates across most of Sub-Saharan Africa are extremely low, with RE rates of well below 5 percent in many countries (see attachment 1 of appendix I). Should the Bank support RE in these countries? Or are the returns to such investments insufficient to justify them?

## Evaluation Questions

For the purposes of this study, the broad question of the justification for RE lending is broken down into a number of evaluation questions, leading to the ultimate objective of calculating private and social rates of return from investments in RE. Following are specific questions:

- What is the rationale for World Bank support of RE?
- What has been the growth in the coverage of RE in countries receiving Bank support? To what extent has the Bank contributed to these connections? What is the distributional profile of those taking connections? What are the unit costs of connection by type of supply to the user and the supplier?
- What are the direct economic benefits from RE? Who gains these benefits? What are the indirect economic benefits (employment generation), and who gains them? How does the distribution of benefits change as coverage of electrification programs expands?
- What is the impact of RE on time use, and what are the welfare implications of these

changes for health, education, and increased leisure?

- How does RE affect the quality of health and education services?
- How do the aggregate private benefits and the public good benefits compare to the willingness to pay? What is the distributional profile of these benefits?
- What are the private and social rates of return from investments in RE?

## The Study Approach

This study adopted a multilayered approach to address these questions. First, a portfolio review was conducted to identify Bank lending for RE since 1980, allowing quantification of the scale of this support in both monetary terms and the number of beneficiaries. Second, 10 country case studies were compiled based on a desk review of Bank documentation and other documents on RE to capture the variety of experiences in different settings.[3] Third, a review of existing evidence on the impacts of RE was carried out. Fourth, analysis was made of Demographic and Health Survey (DHS) data for nine countries to examine the impacts of RE on health and family planning outcomes.[4] In addition, household income and expenditure surveys for two countries (Ghana and Peru) were analyzed to examine impacts on rural income generation. Fifth, RE-specific data sets were examined for Lao PDR, the Philippines, and Sri Lanka.[5]

The report combines an overview of the Bank's RE portfolio with an analysis of the impact of this lending. It does so using a theory-based approach, identifying inputs and outputs and then the outcomes (benefits) from those outputs and who receives them. The impact analysis is carried out on several levels, relying on the various survey data mentioned above. Most of this analysis is on single survey cross-sectional data, although panel data are available for two countries (Ghana and Peru).

***The ultimate objective of this evaluation is to calculate private and public rates of return from RE investments.***

The challenge for most impact evaluations is to overcome possible selection bias. In the case of electrification, selection is very clearly on the basis of observables, most notably income and location.[6] When the selection criteria are observable, as in this case, then the regression-based approach adopted in this study overcomes selection bias. Hence, the regression-based approach is largely used to capture the impact of electrification compared with the counterfactual of no electrification. Some of the possible benefits examined in this study—for example, through media access to increased health knowledge and improved health and fertility outcomes—have not been previously explored. The report acknowledges weaknesses in the available data, calling where appropriate for more data collection specifically designed to examine these impacts.

# Chapter 2

## Evaluation Highlights

- Over the last 15 years the Bank's strategy has increasingly emphasized poverty and environmental issues.
- The objectives of Bank-supported projects have increasingly focused on welfare outcomes.
- The design of project components, however, has continued to focus on outputs.
- Where the Bank has had a continued presence, it has made a significant contribution to RE.
- Project performance has been low relative to the Bank-wide average, mainly because of poor institutional performance.

Villagers in Sri Lanka using solar panels to light houses. (Photo from the World Bank Photo Library.)

# World Bank Lending for Rural Electrification

Until the 1980s Bank lending in the energy sector was largely to public sector monopolies for power generation and supply. During the eighties, attention turned to institutional issues, aiming to improve economic efficiency and financial sustainability in the sector by encouraging least-cost planning, marginal-cost pricing, and other practices.[1]

The Bank also tightened its policies on environmental and resettlement standards and implementation arrangements. These changes were reflected in a power sector support strategy paper in 1983 and the power sector Operations Directive of 1987.

## The Bank's Evolving Energy Strategy

Two significant shifts occurred in the 1990s. First, there was a shift toward promotion of private sector participation in power generation and supply, as laid out in the policy paper "The World Bank's Role in the Electric Power Sector" (World Bank 1993b). The 2003 IEG report *Power for Development: A Review of the World Bank Group's Experience with Private Participation in the Electricity Sector* reviewed the experience with this policy; it concluded that, with the appropriate commitment from government, the expected benefits had been achieved. However, reform in many countries was in the early stages, and reforms in the distribution sector had lagged behind those in generation, possibly jeopardizing the latter. The report also pointed to the need to mainstream poverty and environmental concerns.

The second shift was increased attention to environmental issues. The publication of the *World Development Report* (World Bank 1992) on sustainable development marked a shift across the Bank; this was reflected in the energy sector by the publication of a second policy paper in 1993, "Energy Efficiency and Conservation in the Developing World." This focus on the environment has deepened over time, marked first by the publication of *Fuel for Thought: An Environmental Strategy for the Energy Sector* (World Bank 2000) and second with "protecting the environment" being listed as one of the four business lines of Bank energy lending in the document "The World Bank's Energy Program: Poverty Reduction, Sustainability, and Selectivity" (World Bank 2001b). This focus included programs to promote efficient energy use, fuel switching, and emissions trading.

In accordance with the re-establishment of poverty on the development agenda, the Bank's energy sector has paid increased attention to the fact that the poor have often been left out of the direct benefits of RE programs (IEG 1994). The 1996 publication *Rural Energy and Development: Improving Energy Supplies for Two Billion People* (World Bank 1996) set out the links between energy and poverty (operating through the high economic and health cost of biomass energy sources for poor households) and proposed steps in addition to market liberalization to enhance rural energy supplies and ensure that the poor would benefit. Finally, the 2001 sector board paper (World Bank 2001b) moved poverty closer to the center stage with "helping the poor directly" as the first of four priorities for Bank support to energy supply. The elaboration of measures related to this priority include "gender issues related to access to energy" (p. 23).

## The Portfolio

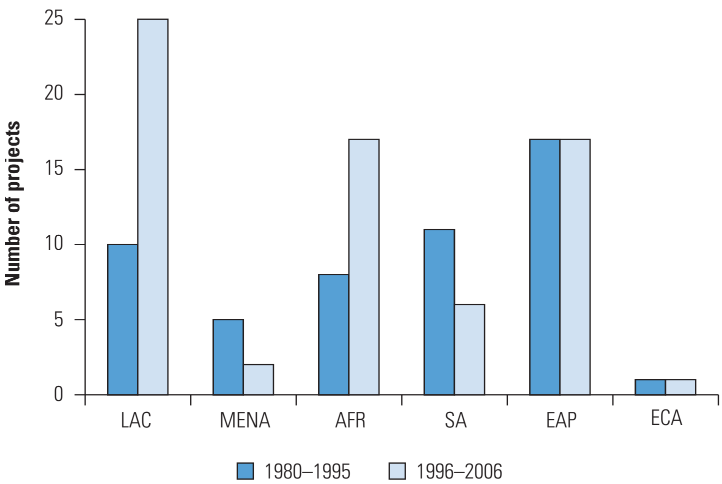
Bank support to RE is provided through dedicated projects, general energy projects with RE components, and multisector projects that include RE. Examples of dedicated projects include the three Bangladesh RE projects, which brought electricity to more than half a million households between 1982 and 2000, and the two RE projects in Indonesia, which reached more than 10 million households.

*Since 1980 the Bank has financed 120 projects that include rural electrification.*

RE components of larger energy projects may be very small, such as conducting a feasibility study or supporting development of a strategy, as in the Kenya Geothermal Development and Pre-Investment Project; or they may be large, as in the Ghana National Electrification Project, which installed distribution systems in both urban and rural areas. Finally, a project covering several sectors may include RE, most usually community demand-driven projects in which electricity supply is one option, such as the Brazil Northeastern Rural Poverty Alleviation Program.

A review of the portfolio since 1980 identified 120 RE projects,[2] with roughly a third falling into each of the three categories: 42 (35 percent) were dedicated RE projects, 44 (37 percent) were larger energy projects with RE components, and 34 (28 percent) were multisector projects that included RE components. It is not always possible to identify the amount of the loan or project budget allocated to RE. A lower estimate is given by taking the dedicated projects only, amounting to $798.3 million from 1980 to 2006. An upper estimate was reached using the total budget of all 120 projects, which comes to $5.97 billion; these amounts are equivalent to 0.14 and 1.6 percent, respectively, of the Bank's total lending over this period.

**Figure 2.1: A Growing Number of Rural Electrification Projects Are in Latin America and Sub-Saharan Africa**




*Source:* IEG portfolio review.

*Note:* Figures refer to year of approval. AFR = Africa; EAP = East Asia and Pacific; ECA = Europe and Central Asia; LAC = Latin America and the Caribbean; MENA = Middle East and North Africa; SA = South Asia.

A large and growing proportion of RE projects are in the Latin America and Caribbean and Sub-Saharan Africa Regions, with a falling share in South Asia and East Asia; many projects in Latin American and the Caribbean are multisectoral, community-driven development (CDD) projects (see figure 2.1). There are very few RE projects in the Middle East and North Africa and Europe and Central Asia Regions.

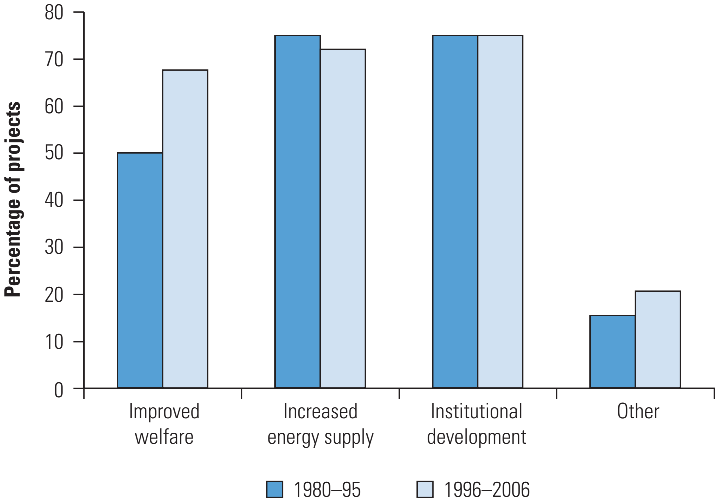
This pattern broadly reflects coverage rates, which are high in the Regions in which there are fewer projects. However, there are many countries, notably in Africa, with low coverage rates where the Bank is not supporting RE. And substantial investments are still needed to reach the many millions of unconnected households in South Asia. Although there are a number of new energy projects in African countries—such as Ethiopia, Tanzania, and Uganda—the scale of the Bank's investments in the sector does not match the challenge, suggesting the need for a review of the priorities in the Bank's lending program against the availability of funds.[3]

## Objectives

Objectives can be broadly classified into four categories:

- *Improved welfare:* This includes objectives such as "enhancing Madagascar's prospects for economic recovery and growth by ensuring an adequate supply of electricity in the medium term, for both businesses and households" (Madagascar Energy Sector Development Project) and to "improve welfare, enhance income-earning capacity, and help alleviate poverty" (Vietnam Rural Energy Project). Included in this category are environmental objectives, such as "reduce deforestation and increase access and diversify choice to renewable and cleaner fuels to the household and [small and medium enterprise] sectors" (Benin Energy Services Delivery Project).
- *Improved energy supply:* This category includes objectives such as "helping to bring about an improvement in supply and distribution of electricity over the medium term" (Guinea-Bissau Energy Project) and "expand rural electricity service in seven central and southern provinces of Lao PDR, where economically justified, through grid extension and off-grid electrification" (Lao PDR Southern Provinces Rural Electrification Project).
- *Institutional development:* This includes objectives such as "strengthen government capacity to implement its national RE strategy" (Nicaragua Off-Grid Rural Electrification) and "support transformation of [electric cooperatives] through institutional and operational improvements" (Philippines Rural Power Project).
- *Other objectives not related to electrification:* These objectives are from the multisectoral projects with RE components. Examples include "increasing the capacity of communes for decentralized and participatory planning and management of development activities" (Vietnam Community-Based Rural Infrastructure) and "foster the sound management of water resources" (Cape Verde Energy and Water Sector Reform and Development Project).

**Figure 2.2: Increased Energy Supply and Institutional Development Account for the Largest Share of Objectives (percentage of projects given objectives in each category)**




*Source:* IEG portfolio review.
*Note:* Categories do not total 100 because each project can have objectives in more than one category.

Analysis of the 120 projects shows that three-quarters have objectives related to increasing energy supply (73 percent) and institutional development (75 percent), compared with 60 percent that include improving welfare among their objectives. The percentage for the first two categories has been constant across the study period, but there has been a marked increase in projects with welfare objectives (figure 2.2; appendix table B.5). Before 1995 only half of all projects mentioned welfare objectives, but since 1995 two-thirds (68 percent) do so; this increase is driven by the increase in multisectoral projects, which are more likely to have welfare objectives than are energy projects.

The objectives were classified into subcategories under these four main headings (see appendix table B.3 for full details). The most common welfare objective is to increase growth or incomes, which is found in 30 percent of all projects, followed by environmental effects (in 23 percent), reducing poverty (22 percent), and a general statement of improving welfare (21 percent). However, the poverty-reduction objective is mostly associated with multisector projects; just

7 percent of dedicated RE and energy sector projects include poverty reduction among their objectives.

*There has been a marked increase in projects that have the objective of improving welfare.*

Increased access is the most common objective under increased energy supply, either in general (30 percent) or for rural areas (24 percent). Improving efficiency is also a common objective, mentioned for nearly one-third (29 percent) of projects. The most common institutional development objective is "institutional development," either in general (34 percent of projects) or for the utility company (23 percent), followed by promoting private sector involvement (28 percent).

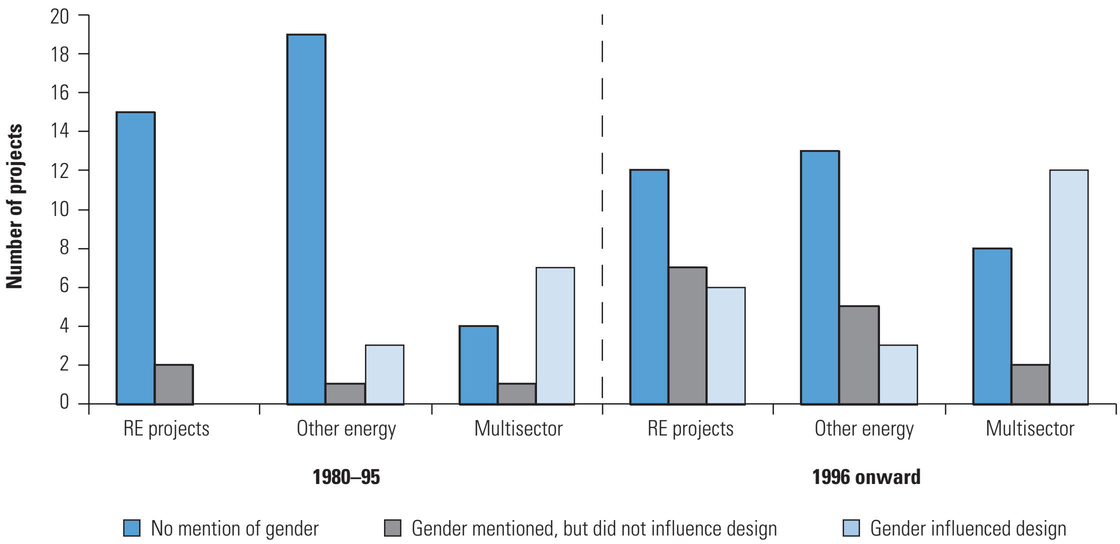
*Though the focus on welfare outcomes has increased, a focus on outputs continues to dominate the portfolio.*

Another notable shift is the increase in the attention paid to gender. Traditionally, energy projects have paid no explicit attention to gender issues—even though men and women may use electricity differently. This was true of the appraisal reports for 83 percent of energy projects in the period 1980–95 (figure 2.3).

The situation has changed somewhat: from 1997 to 2006 just under half (48 percent) of appraisal documents for energy projects mention gender, although there has been a clear impact on design for just 20 percent. More recent projects oriented toward providing modern energy services, rather than focusing solely on electricity connections, are the most usual exceptions to the neglect of gender. For example, the Energy Access Project in Ethiopia includes training and technical assistance for the women to promote sustainable management and exploitation of woodfuel plantations. In Uganda, the Energy for Rural Transformation Project has promoted gender-specific TV and radio communications to raise health awareness.

Multisectoral projects are far more likely to contain a gender aspect, with gender influencing the design of more than half all such projects. In addition, the monitoring and evaluation systems of such projects are more likely to focus on gender-specific effects on impact than energy sector proj-

**Figure 2.3: Gender Issues Are Increasingly Taken into Account but Still Affect the Design of Only a Minority of Energy Projects**




*Source:* IEG portfolio review.

*Note:* RE = rural electrification.

ects do (with some notable exceptions, such as the Benin Energy Services Delivery Project and Nepal Power Development Project).

Indeed, evaluations of multisectoral projects have found benefits from women's involvement in the selection, prioritization, execution, and operation and maintenance of subprojects (for example, Peru Second Social Development and Compensation Fund Project), although not all projects have managed to address gender-related weaknesses in project design during implementation (for example, the Panama Social Investment Fund Project).

The main conclusion from this discussion is that projects have historically focused on objectives related to outputs (energy supply and institutional development) rather than to outcomes (welfare). This focus is changing, though not much more than one-fifth (22 percent) of projects have explicitly included poverty reduction among their objectives. Similarly, a growing number of project appraisals mention gender, but it only has an influence on project design in a minority of cases. This relatively low percentage may reflect recognition that the poor frequently do not benefit directly from electrification, but as coverage rates increase, this topic deserves some more attention—see chapter 3—especially as directly benefiting the poor is now a priority in the Bank's energy lending.

## Project Design: Analysis of Components

The nature of the objectives has implications for project design. Project design is analyzed by classifying project components and subcomponents, which fall under four broad headings:

- *Building infrastructure:* This includes, for example, "distribution networks to electrify about 120 rural villages and small towns that at present lack electricity service, through extension of existing transmission and subtransmission facilities" (Colombia Village Electrification Project) and "… to support investments in small power generation, decentralized grids and stand-alone RET systems, most notably [photovoltaic] systems" (Philippines Rural Power Project).
- *Institutional development:* This includes, for example, "operational support, training, and technical assistance to the Rural Electrification Agency to enable the agency to carry out the RE program" (Senegal Electricity Services for Rural Areas project) and "development of the institutional framework and regulations for rural provision of electricity service on and off grid … and capacity building for demand-driven and decentralized identification, planning and development of projects" (Peru Rural Electrification Project).
- *Electrification financing:* This includes, for example, "provide medium and long-term financing to private sector firms, [nongovernmental organizations], and cooperatives for solar home system and village hydro pre-grid electrification, grid-connected mini-hydro schemes and other renewable energy investments" (Sri Lanka Energy Services Delivery Project).
- *Other:* This category includes components related to consumers, including demand-side management, and other activities, including resettlement.

***Project components and subcomponents focus on building infrastructure, institutional development, and electrification financing.***

Not surprisingly, most projects (82 percent) contain infrastructure components, and 85 percent have institutional development components (appendix table B.6).[4] The most common infrastructure component is grid expansion, present in 63 percent of projects, followed by renewable energy (in 32 percent). Institutional development is most commonly supported by technical assistance for general management (71 percent), engineering (26 percent), or financial/ commercialization (19 percent).

The two main developments in the portfolio in the last decade have been an increase in projects utilizing renewable energy technologies (RETs), such as solar, wind power, and hydropower, and support to off-grid schemes. Promotion of RETs is in line with the growing emphasis on environmental protection in the Bank's energy strategy: of the 120 projects, 13 percent of those from 1980 to 1995 utilized RETs, compared with nearly half (46 percent) from 1996 onward (see appendix table B.4).[5]

Support to off-grid electrification has grown quickly in recent years: there were only two such projects prior to 1995, but 31 since then. Although off-grid systems in the developing world often rely on diesel generators, Bank support for off-grid connections has been linked to RETs: three-quarters of all Bank off-grid projects have promoted photovoltaic energy (usually solar home systems, SHS), nearly half (47 percent) micro hydro, and one-third (31 percent) wind power (see appendix table B.26).

Where there has been a choice of technologies, SHSs have been the dominant one. For example, in Lao PDR, the Bank-financed off-grid program provided electricity to 46 villages, all but one of which opted for SHS. In contrast, just two projects (6 percent) promoted diesel power, one of which was the Lao PDR Southern Provinces Rural Electrification Project.

*Off-grid electrification has been growing rapidly.*

The increased focus on RETs has been driven by two factors. First, the cost of these technologies has decreased substantially since the 1970s, so they have become least cost energy solutions, at least in areas difficult to reach with the grid. Projections in *Rural Energy and Development: Improving Energy Supplies for Two Billion People* (World Bank 1996) suggested that, if cost reductions for RETs continued, then by 2020 they will in general be as cheap as conventional methods of power generation, a conclusion made more likely by the higher price of oil in recent years. Second, during the 1990s the Bank began to take environmental issues more seriously; they now have a prominent position in the Bank's energy strategy.

The greater economic feasibility of RETs has also given a boost to off-grid programs. A second reason for the growth of off-grid investments is the explicit attention now being given to providing modern energy services to the poor, who live disproportionately in remote areas beyond the reach of the grid.

Usually support for off-grid activities is a component of a larger project—this is true for 28 of the 33 off-grid projects; in many cases these activities are pilot projects (appendix tables B.10 and B.11). In such cases the relative budget share is often small. For example, under the Lao PDR Southern Provinces Rural Electrification Project, the off-grid component was 6 percent, compared with 76 percent for grid expansion, rising to 17 percent under the follow-on Rural Electrification Project.[6] These off-grid components have often attracted cofinancing from the Global Environment Facility (GEF), which has provided $270 million to Bank-supported RE projects.

## Outputs and Outcomes

The ratings for RE projects on completion are slightly lower than those for other Bank projects.[7] Before 1995, 73 percent of projects were rated as satisfactory (highly satisfactory, satisfactory, or moderately satisfactory), which is comparable to the 74 percent for the Bank as a whole (appendix table B.2). But since 1995 the percentage has slipped slightly to 68 percent, whereas the Bank's overall performance has improved modestly. Ratings are lower for energy sector projects (that is, excluding multisector), with the figures for the two periods being 70 and 64 percent, respectively.

The principle reasons given for unsatisfactory ratings are poor institutional performance; this was cited for 11 of the 16 projects rated unsatisfactory or highly unsatisfactory.[8] In some cases institutional problems undermine physical implementation (failure to meet physical targets was a problem in 5 of 16 unsatisfactory projects), but many projects manage to implement their infrastructure components even while the service provider is ailing. This was so for a number of cases, such as the first and second Brazil Electorbras Power Distribution projects, the Philippines Transmission Grid Reinforcement Project, and, in Lao PDR, the Provincial Grid Integration Project and the follow-on Southern Provinces Rural Electrification Project. It is possible to sustain service expansion despite weak underlying financial performance when concessional finance is being used to fund the expansion, but it will not prove sustainable in the long run.

So there is a largely positive story to be told regarding the physical achievements of Bank-supported RE projects, although with an important caveat regarding technical problems in some cases. In particular, where the Bank has a continued presence through a series of dedicated projects, it can make a substantial contribution to increasing the country's electrification rate. From 1993 to 2004, coverage in Lao PDR rose from 14 to 45 percent as an additional 325,000 households got electricity; Bank-supported projects supplied 90,000 of these households (28 percent).

In Bangladesh the number of rural connections grew from close to zero in the early 1980s to more than 4 million by 2002 (and is now growing at the rate of 700,000 households a year) (Barnes 2007). The three Bank-supported RE projects financed more than 600,000 of these connections, or 15 percent of the total.

Most notably, the RE rate in Indonesia rose from 33 to 85 percent between 1991 and 2003, as approximately 11 million households got new electricity connections. Between 1991 and 2000 the first and second Indonesian RE projects brought electricity to more than 10 million households; the Bank's support of a "time slice" of the Indonesian program means that Bank finance paid for about half of all the new connections in this period.

The scale of Bank support can also be measured by outputs, although these figures are underestimates because the data are not available for all projects. Bank projects have brought electricity to more than 130,000 villages, reaching nearly 20 million households, supplied more than 600,000 kilometers (km) of new lines, and installed more than 500 substations (appendix tables B.15 and B.16).

However, success in increasing access has been marred by technical problems in some countries. System losses are both technical (electricity "evaporates" during transmission and distribution) and nontechnical, which is a euphemism for theft through illegal connections. The percentage of nontechnical loss can vary widely between countries—for example, from 3 percent of total system losses in Vietnam to 30 percent in Mozambique. In developed countries, total system losses are less than 10 percent (for example, 7 percent in the United States). Better-performing low- and middle-income countries achieve similar figures (for example, Thailand)—but many lie in the range of between 20 and 50 percent (for example, Albania and Rajasthan at the upper end).

***Ratings for RE projects are low relative to other projects—and are getting worse.***

Because system losses are electricity bought or generated for which no revenue is collected, they represent a loss to the utility, a loss in potential benefits to consumers, and a source of excess environmental costs. RE programs are likely prone to these losses—long transmission and distribution lines are most likely to suffer both technical and nontechnical losses, with the problem declining as the network gets "filled in." But the problem is also one of poor system construction, which should be addressed through better design and supervision.

Explicit attention to the issue in Bank projects can help reduce losses: one-quarter of the Bank's RE projects had either a rehabilitation or system loss component (see appendix table B.4). For instance, the Jordan Energy Development Program (1984–91) succeeded in reducing transmission line losses from 16 to 12 percent. But not all projects have been successful. For instance, in the third Bangladesh RE project (1990–2000), despite reduction of system losses being an objective, the percentage of system loss stayed nearly steady, 16.8 percent in 1990 and 16.2 percent in 2000; in the Pakistan RE project, where reduced system losses was also an objective, the percentage actually increased from 23 to 26 percent between 1990 and 2000.

***Where the Bank has had a continued presence, it has made a substantial contribution to increasing countries' RE rates.***

In the 1980s and early 1990s many electricity supply agencies were experiencing financial problems, which undermined sustainability, as operations and maintenance (O&M) was weak and sometimes hindered implementation of planned grid extension. In some cases these problems were tackled both through the Bank's adjustment lending and the conditionality attached to power sector investment loans. A recent study states that 70 countries have undertaken power sector reform since the early 1990s (Besant-Jones

2006), though in several cases it is too early to judge the success of these changes (as also suggested in the 2003 IEG review). And in some cases, provision has been made for private sector participation in generation without addressing underlying structural issues.[9]

But several countries have made progress, which is demonstrated by the changing focus of Bank-supported RE projects. There has been a marked decline in tariff conditionality, that is, requirements to raise or review electricity tariff rates, in Bank loans since 1995. Bank loans required a review of tariffs in 35 percent of projects before 1995 and in only 14 percent after. The decline in required increased tariff rates is even more striking—from 17 percent of projects to 9 percent. As utility financial management has improved, the necessity of Bank conditionality in this area has declined. A Bank study (Komives and others 2005) found that current tariff levels were insufficient to cover O&M in less than a third (29 percent) of low- and low middle-income countries, whereas in a quarter (24 percent) they were sufficient to cover O&M and make a contribution to capital cost (see appendix table B.22).

*Financial performance is certainly better than it was a decade ago, but in many countries progress is still needed.*

But it should also be noted that a more comprehensive approach to the issue of financial sustainability is required, focusing not just on tariff reform, but also on explicit recognition of the possible need for subsidies (including cross-subsidies) and improving system design and revenue collection. The story in relation to financial performance is thus an uneven one: the picture is certainly better than it was at the time of the last IEG review, but in many countries progress is still needed.

# Chapter 3

## Evaluation Highlights

- Electrification favors the non-poor, although more of the poor are included as the grid is extended.
- Emphasis has been given to extending the grid to areas where it will cost least and communities can most afford it.
- A majority of households that are going to connect do so in the first three years that the grid is available.
- Project benefits would be greater if explicit attention were paid to extending the grid to those least able to connect and to ensuring that poor customers use electricity efficiently.

Solar panels in Mali provide rural power. (Photo from the World Bank Photo Library.)

# Who Benefits from Rural Electrification?

It is widely recognized that the immediate benefits of RE seldom go to the poor. IEG's analysis supports the finding that the poor are less likely to have access to electricity. But the analysis also shows that distribution improves as coverage expands.

## The Distribution of Electrification

In 1992 in Bangladesh, the poorest 40 percent of rural households accounted for just 7 percent of all electrified rural households, but this share increased to 17 percent by 2004 (see figure 3.1). For Ghana these figures are 5 percent for 1988 and 23 percent for 2003.[1]

The share of the poor in electricity consumption is lower still if the level of consumption is taken into account: although there are substantial variations by country, the expenditure by the poor on electricity is typically one-half to two-thirds that of the non-poor (Komives and others 2005, annex B.2). Figure 3.2 plots the share of electricity consumption against the population share for the Philippines and Lao PDR. In the former, the bottom 40 percent accounted for just 14 percent of the electricity consumption; in the latter, that figure was 15 percent.

The rural poor are less likely to have grid connections for two reasons. First, in nearly all countries, communities are ranked by a number of criteria that usually favor the better-off communities. Second, within a community connected to the grid, there will be some households that cannot afford to connect. Despite the fact that energy expenditures are typically less for electrified households, the connection fee acts as a barrier, preventing the poorest from switching to the lower-cost source.

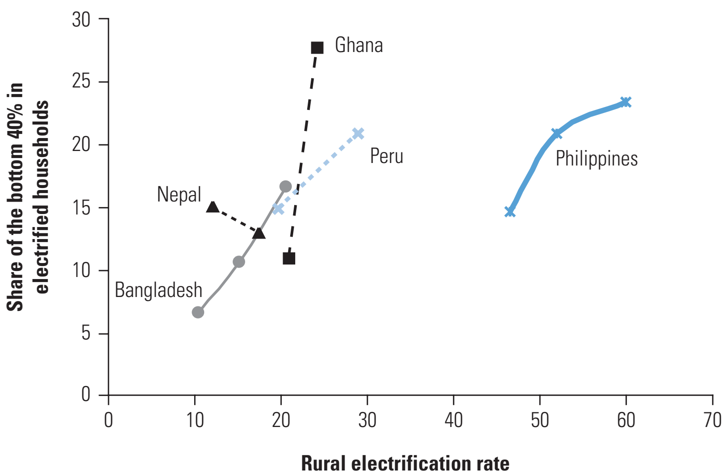
## Which Communities Get Electricity?

Of the 120 projects, information is available for 29 on how the communities to be electrified are to be chosen. These eligibility criteria can be classified as follows:

- *Cost-effectiveness:* Criteria are developed to identify which communities it will be most cost effective to connect. These criteria typically include distance to the existing grid, population size, affordability (average community income), and productive potential. This approach was widely promoted in the 1960s by the US Agency for International Development (USAID) under the name the Demand Assessment Model, for example, in El Salvador and Guatemala. The Bank used a similar approach later, sometimes adopting earlier work by USAID, such as in Bangladesh. For example, the Cambodia Rural Electrification and Transmission Project combined most of these factors in its decision that villages should be within 40 kilometers (km) of the existing grid, be reasonably accessible by road, have development potential from agriculture or handicrafts, and be able to pay their electricity bills.

The Pakistan Rural Electrification Project selected communities with I/K ratios greater than 24, where I is the population size and K the distance to the nearest medium voltage wire.

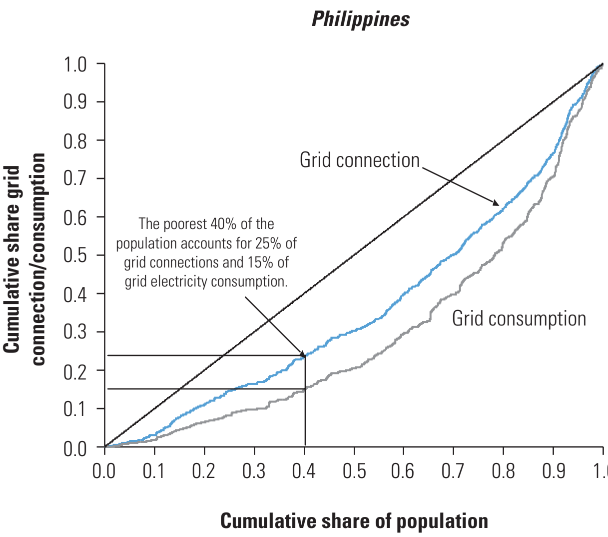
**Figure 3.1: Pattern of Electrification Favors the Non-Poor, but This Bias Generally Reduces over Time as Electrification Coverage Expands**

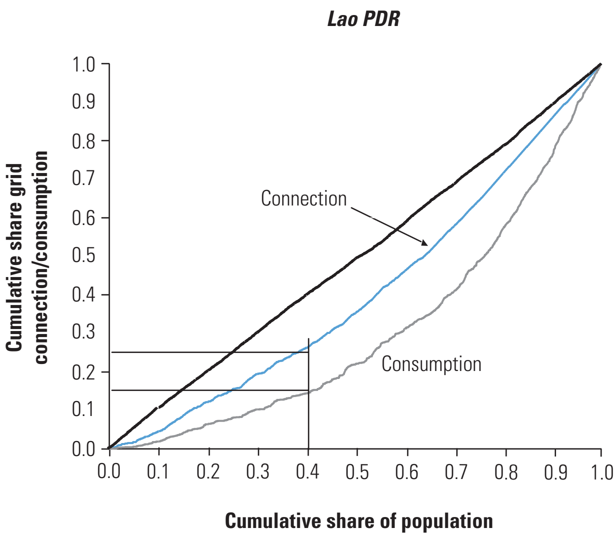



The graph plots the share of the poorest 40 percent against the RE rate for five countries at different points in time. In all but one case (Nepal), as coverage expands, so does the share of the bottom 40 percent—when there is universal coverage, their share will reach 40 percent.

*Source:* Appendix C.

**Figure 3.2: Share of Poor of On-Grid Electricity Consumption Is Low (Lorenz curves for rural electricity consumption)**




*Source:* Appendix C.

Cost-effectiveness allocation rules make communities with many poor people less likely to be connected, sometimes explicitly, as when the Indonesian government targeted those within 10 km of the district capital and a poverty rate of less than 20 percent, compared with the national average of 45 percent (Meier 2001).

- *Social allocation:* The decision rule includes poverty or other social indicators, giving a preference to the more deprived areas. One example is the eligibility criteria for the North East Rural Poverty project in Brazil, which included low socioeconomic indicators, a poor natural resource base, and communities of fewer than 7,500 people. Alternatively, the decision rule may strive for geographical balance, which will also favor areas that would not satisfy strictly economic criteria.
- *Combined allocation rule:* This takes into account both financial viability and social considerations. Examples include the eligibility criteria under the Infrastructure for Territorial Development Project in Chile and the Honduras Rural Infrastructure Project; both included high poverty incidence but also productive potential. The Vietnam Rural Energy Project included affordability and productive potential but also communes in the government's list of the poorest communes and those that had made great contributions to, or suffered from, the war.

A cost-effectiveness approach is justified on the grounds of financial sustainability. By going first to communities that cost the least to reach and where load factors will be highest, RE does not put undue strain on the utility's finances.

The minority of projects (17 percent) that do use a social allocation rule are mostly multisectoral projects, that is, CDD projects targeting poor communities that include electrification among their possible subprojects. In the Brazil Northeast Rural Development Project, 28 percent of communities selected electrification—and an ex post evaluation suggests that this has been successfully implemented with the expected benefits (see box 3.1). Under such projects the community is usually responsible for the cost of grid connection, but the infrastructure is managed by the utility.

**Box 3.1: Successful RE through a Multisectoral CDD Project**

In Ceara, a Brazilian state, more than 1,500 rural communities were electrified through a multisectoral CDD project. As part of the project, communities were directly involved in selecting, preparing, and overseeing the implementation of electrification subprojects, which in turn were executed by private firms contracted by the community associations. Under this arrangement 91,000 families were connected and power provided for street lighting as well as schools, village shops, and small-scale processing units at an average cost of about $425 per family.

*Source:* World Bank 2001a.

***Common eligibility criteria for connection include cost-effectiveness, social allocation, and use of a combined allocation rule.***

On the other hand, a growing number of projects have adopted a combined approach to allocation. But this is not an unambiguous trend; the case of the Peru Rural Electrification Project is a recent example in which there was a strictly cost-efficient decision rule, the government favoring this approach to prevent the political interference that plagued the previous social allocation (box 3.2).

More socially oriented allocations have been assisted for both grid and off-grid connections through Rural Electrification Funds (REFs), which sometimes (though not always) have the intention of subsidizing connections to less-well-off communities. The best known fund has been that in Chile (see box 3.3), which was not a Bank-supported initiative. The Bank has supported such funds through the Uganda Energy for Rural Transformation Project and the Nicaragua Off-grid Rural Electrification Project. But to date, such funds have only been employed in a minority of cases, and sometimes with a different focus, such as to support private sector development.

In addition, growing support for off-grid electrification may favor less-well-off communities, because these projects benefit those that do not

**Box 3.2: Selection of Projects under the Peru Rural Electrification Project**

The Peru Rural Electrification Project stresses efficient provision of rural electricity. One means of achieving this end is to change the current approach of selecting areas for electrification, which the government was basing largely on social grounds. Under the project, the emphasis is being shifted to prioritizing cost-effectiveness by selecting first those communities that are near existing distribution systems. The appraisal report showed that if communities are selected this way rather than by using the ordering chosen by government, the $92.4 million subsidy to be provided by the project could finance the electrification of 150,000 households compared with 100,000 under the government's existing program.

*Source:* World Bank 2006.

satisfy the criteria for grid connection. This approach is formalized in the "least cost frontier." The smaller the community and the further it is from the existing grid, the more expensive the grid connections are. Using data on connection costs, a cost-effectiveness frontier can be constructed between grid connection and photovoltaic (PV) sources of energy. Various Bank documents present this analysis, for example, for Brazil, the Philippines, Vietnam, and Senegal.

*Off-grid solutions may favor less-well-off communities.*

One of these reports states that PV is competitive for communities larger than 45 households when the distance to the grid is more than 11.5 km. That distance decreases to 6.5 km if systematic PV rural electrification by a regional operator works with local nongovernmental organizations (NGOs) that have lower overheads. The Vietnam example plots the cost of grid extension (which is a function of population size and distance) against average consumption: at a typical consumption level of 30 kilowatt hours (kWh) per month, SHS is the least cost option if grid extension costs more that $600 per household. However, these programming approaches are not adopted in all cases (and are only explicitly presented in one project appraisal document). Other projects use a more rule-of-thumb approach to identifying communities for off-grid connections; for instance, in Lao PDR those communities that will not be connected to the grid for at least 10 years are eligible.

But three caveats are needed regarding the poverty focus of off-grid connections. First, the scale of off-grid investments remains small compared with those in grid extensions, so the number of connections from the latter is far greater. Hence, the number of disadvantaged households reached through off-grid systems will remain relatively small.

Second, affordability considerations must also be present for off-grid supplies, particularly as the favored model is one of private sector supply. For example, the project appraisal document (PAD) for the Nicaragua Off-Grid Rural Electrification Project explicitly states that the need for commercial viability means that the project cannot exclusively target the poor. In Lao PDR, communities identified as eligible are subject to an affordability assessment, with 80 percent of households having to sign up before an off-grid scheme can be introduced.

Finally, although off grid is least cost for those communities receiving it, it costs more than grid extension to other areas, where there may also be concentrations of poor. For the one country for which comparable data are available (Sri Lanka), connections to SHSs are less equitably distributed than are those to the grid (see appendix H). Hence, off-grid investments are not necessarily the most pro-poor allocation of funds.

The emphasis in RE projects has been on extending the grid to areas where it will cost least to do so and to communities that can best afford it. This emphasis can be seen as necessary because many electricity utilities were in poor financial health. Indeed, the report *Rural Electrification in Asia* (IEG 1994) criticized the Bank for failing to consider the financial consequences of RE for electricity supply companies and the governments that subsidize them.

But in some countries circumstances are changing. The financial situation of utilities has improved, and electricity is now being provided to those communities that meet the cost-effectiveness criterion. Hence, social considerations are creeping into sector projects through combined allocation rules, and multisector projects have shown that RE can be viable even among communities selected as being the poorest (see box 3.1).

### Box 3.3: Chile Rural Electrification Fund

Chile's RE program, launched in 1994, included the creation of a special REF that links subsidies to output targets. This fund is used to competitively allocate one-time direct subsidies to private distribution companies to cover part of their investment costs in RE projects. Local operators apply for a subsidy by presenting their proposed project; these in turn are scored against a checklist of objective criteria, including cost-benefit analysis, operator investment commitment, and social impact. The central government allocates subsidy funds to the regions based on the number of unelectrified households and the progress each region has made in RE during the preceding year.

*Sources:* Jadresic 2000; Tomkins 2001.

## Which Households Get Electricity?

The second factor behind low connection rates for the poor is that, once electricity becomes available in a community, the poor may not be able to afford the service; high connection charges are a frequent barrier. For example, in Lao PDR an estimated 30 percent of the population cannot afford the $100 connection charge.

This pattern is at best only partially overcome by the development of off-grid electricity sources. Remote communities are among the poorest and most expensive to connect to the grid, so they will be the last to be reached under schemes that set the order in which communities are connected on the basis of cost-effectiveness. Off-grid sources provide the opportunity to bring electricity to these communities. It may be the case that unit costs in these schemes are lower than those of bringing the grid to these communities (see table 3.1), but they are invariably higher than the price of electricity for those who can access the grid.[2]

So the second barrier of cost still prevents many from accessing off-grid services: in Namibia households must have an annual income of at least $2,500 to be eligible for an SHS. Off-grid activities in Lao PDR, supported by the Bank's Southern Provinces Rural Electrification Project and the Rural Electrification Project, undertake an affordability survey of a village before deciding whether to provide services to the community. In some projects this barrier is reduced somewhat by tilting the program subsidies to smaller systems that are more likely to be chosen by poorer consumers. For example, under the Philippines Rural Power Project, a P8000 subsidy was provided to help meet the connection cost for 20- to 30-watt peak (Wp)[3] systems, P5000 for 31- to 50-Wp systems, and nothing for systems higher than 50 Wp.

***Emphasis has been given to extending the grid to areas where it will cost least and communities can most afford it.***

These cost differentials mean that those who can afford to do so connect to the grid once it becomes available. Analysis of data from Lao PDR shows that around 60 percent of households connect within the first year; the vast majority of households that will connect do so in the first three years of the grid reaching the community (figure 3.3). In the Philippines a smaller percentage connect in the first year but still account for half of all those who connect in the first 20 years; the connection rate is 50 percent after three years, but it has still not reached 80 percent after 20 years. In Thailand 25 percent of households in electrified villages remained unconnected after more than 20 years (Green 2005). In India 90 percent of villages have electricity, but only 40 percent of rural households have access (ESMAP 2002).

***High connection charges are a frequent barrier to connecting the poor.***

So evidence from several countries shows that extending coverage to the remaining households takes some years—in communities with electricity for more than 10 years, between 15 and 20 percent remain without electricity connections. Countries that are expanding their RE rates are

**Table 3.1: Relative Price of Grid, Off-Grid, and Kerosene ($/kWh) for Selected Countries**

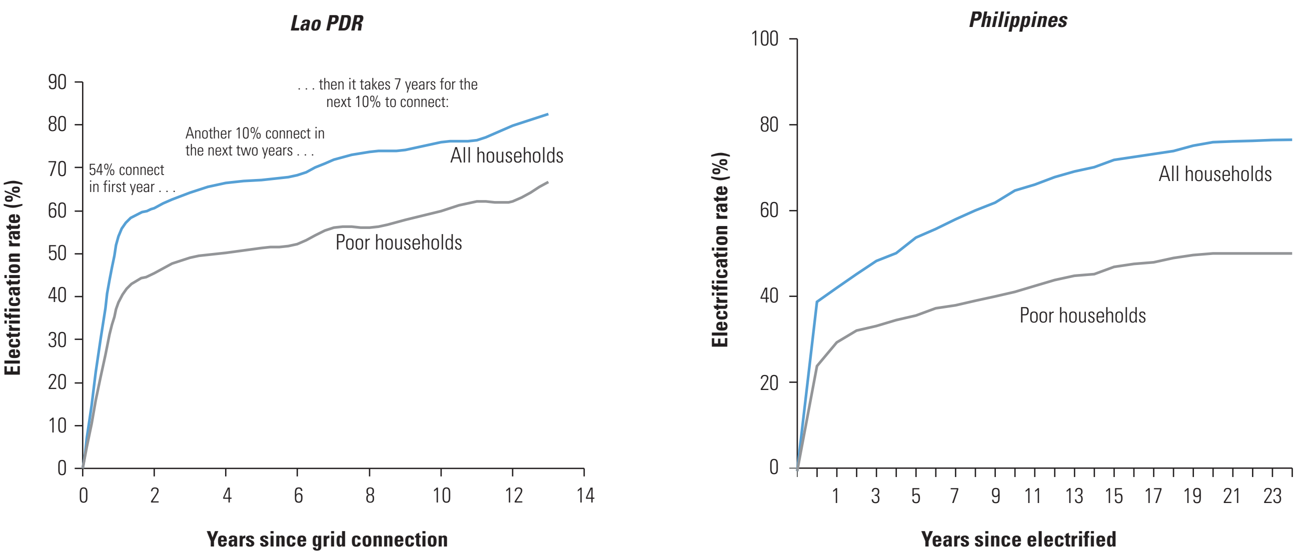
| | Grid | Off-grid (SHS) | Kerosene | Off-grid: Grid | Price ratio Kerosene: Grid | Kerosene: Off-grid |
|---|---|---|---|---|---|---|
| Indonesia | 0.0580 | 0.0137[b] | 0.0370[b] | n.a. | n.a. | 2.7 |
| Philippines | 0.0075 | n.a. | 0.3600 | n.a. | 48.0 | n.a. |
| Nicaragua[a] | 0.0040 | 0.0350 | 0.3300 | 8.75 | 82.5 | 9.4 |
| Honduras | n.a. | 0.0400 | 0.5000 | n.a | n.a. | 12.5 |
| Bolivia | n.a. | 0.0400 | 0.4800 | n.a. | n.a. | 12.0 |
| Mozambique | 0.0400 | 0.0400[b] | 0.1000[b] | n.a. | n.a. | 2.5 |
| Peru | 0.0100 | n.a. | 0.5700 | n.a. | 57.0 | n.a. |
| Lao PDR | 0.0003 | n.a. | 0.1950 | n.a. | 650.0 | n.a. |
| Senegal | n.a. | 0.0220[b] | 0.2358[b] | n.a. | n.a. | 10.7 |
| Malaysia | 0.0800 | n.a. | 0.5800 | n.a. | 7.25 | n.a. |

*Source:* Project documents.
*Note:* n.a. = not available.
a. Grid is mini grid.
b. Cost per klh, not kWh.

largely doing so by extending electricity to previously unconnected communities; it is only when a high proportion of communities are covered that intensive growth takes over.[4]

IEG analyzed data from four countries[5] and found that only in the Philippines, where more than half of the population lives in electrified communities, does the majority of the increase in

**Figure 3.3: A Large Proportion of Households Connect to the Grid Immediately after It Becomes Available . . . But Some Remain Unconnected after Many Years**




*Source:* REP I baseline data.

*Source:* ESMAP 2003.

**Box 3.4: India's Experience with the Single Point Light Connection Scheme: Kutir Jyoti**

Under Kutir Jyoti, a social welfare program by the Indian government for families below the poverty line, India's Rural Electrification Corporation supplied state electricity boards with a full subsidy to cover the cost of low-voltage connections for households below the poverty line. More than 5.8 million households in rural areas have benefited, although it has proven difficult for the utilities to sustain this level. The increased kilometers of line exposed the utilities to the risk of theft and the cost of upkeep, making the scheme expensive and threatening the financial position of the state electricity boards. Consequently, utilities became reluctant to promote RE, and the number of villages being electrified dropped from 100,000 during 1985–90 to 11,000 between 1997 and 2002. In response, the government reformulated its RE scheme, keeping a single point light component whereby free connections would still be available to households below the poverty line, but increasing the government's share of the cost burden for new infrastructure to 90 percent; the other 10 percent still fell to the state power utility.

*Sources:* Bhattacharyya 2006a, 2006b; http://recindia.nic.in/rggvy.htm.

coverage come from intensification (see appendix C). But in Bangladesh, Nepal, and Peru the bulk of increased coverage comes from grid extension to new communities.

The focus on extensive growth has been deliberate policy in some countries. A sector review in Indonesia that laid the basis for the First and Second Rural Electrification Projects stated, "Initial connection rates are assumed to be 33 percent and 50 percent of village households for average and above average income villages, respectively. These connection rates increase to 60 percent and 75 percent, respectively, by the 20th year of electrification" (World Bank 1986). That is, the connection rate will grow slowly over time as incomes rise with growth and electricity becomes affordable to a greater proportion of the village. But even after 20 years, between 25 and 40 percent of households in the village will remain unconnected.

This pattern exists despite the fact that once a village is electrified, the marginal cost of electrification of each additional household is low. As explained in the appraisal report for Indonesia's Second Rural Electrification Project: "Given the relatively low levels of household electrification today, the marginal costs of intensification—the incremental cost of connecting one additional household within a village that already has access to electricity—are substantially lower than the marginal cost of extensification, the cost of extending the 20 kV network to an un-electrified village" (World Bank 1995). Under this project the average cost per new connection in already connected villages is a third of that in newly connected villages ($53 per household versus $157 per household).

*A majority of households that connect do so in the first 3 years that the grid becomes available. Even after 20 years, some 20 percent of households are still not connected.*

The appraisal report for the Accelerated Electricity Access Rural Expansion Project in Ethiopia contains a graph showing how the marginal cost of connection falls rapidly as more households connect. If tariff levels are sufficient to cover O&M, then the provider will lose little by providing these connections. Even if O&M is not covered, the government may feel the social benefits warrant subsidizing these final connections—such as the single lightbulb schemes in several Indian states (box 3.4).

An alternative argument is an economic one that a monopoly supplier should practice price discrimination to maximize profits, charging a lower price to those who have a higher elasticity of demand. The problem for the supplier is usually to identify a consumer's "type"—but that is readily done in this case. "Late connectors" are those who cannot afford the higher connection fee (and so have a higher elasticity), so a connection tariff differentiated across time from the village

**Box 3.5: Overcoming the Connection Cost Barrier**

Meeting the high cost of connection can be eased by allowing households to spread payments, either by adjusting the tariff to an installment basis or by providing credit for this purpose. Two countries have taken the former route.

During the Second Rural Electrification Project in Morocco rural consumers were allowed to pay the connection charge in monthly installments of 40 dirhams over a seven-year period (coming to a total of 3,360 dirhams). The Ethiopian Electric Power Corporation introduced a similar program, with the connection charge paid over a five-year period (with no interest); it later reduced this to two years because of the financial burden of the program for the utility. It is estimated that the five-year plan boosted the take up in electrified villages by 20 percent and the two-year plan by 10 percent. The Bank has not financed this subsidy, but under the forthcoming Electricity Expansion Project II is seeking funding from the Global Partnership on Output-Based Aid for this purpose.

The Electricity Access Rural Expansion in Thailand piloted a credit program. Loans were made available one year after the village had been connected to the grid, with interest charged at one percent the local rate paid by the utility. However, the scheme was discontinued because it was found not to be sufficiently encouraging.

being connected would increase the benefits from the project and the profits to the supplier.

However, few Bank projects have taken this issue on board. Connection costs benefit from a blanket subsidy, as the charges are rarely sufficient to meet the investment cost. Neither the connection charge nor the tariff structure, however, is constructed in such a way as to target these benefits toward the poor (see box 3.5). It is, however, true that the tariff structures of many countries have contained cross-subsidies from commercial or urban domestic consumers to rural customers; the Cambodia Rural Electrification and Transmission Project has created an REF that is an explicit cross-subsidy mechanism to help finance RE. But at the same time, in neighboring Lao PDR, the Bank urged the government to increase real tariffs most rapidly for the lowest “lifeline” rate so it would reach cost recovery levels.

However, Bank staff in Lao PDR are now explicitly considering the issue of late connectors. Similarly, the Ethiopia Accelerated Access (Rural) Expansion Project includes a study of possible connection subsidies for rural areas. An alternative to an outright subsidy is a loan to meet connection charges: two Bank projects—Thailand Second Rural Electrification and Ethiopia Accelerated Access (Rural) Expansion—provided credit to rural consumers to meet the $98 connection fee. In two other countries—Morocco and Senegal—the connection charge is repaid over a longer period (15–20 years in Morocco).

In contrast, in off-grid programs, subsidy schemes are common. Although households may have to pay some up-front costs, it is not the whole installation cost, which is typically in the range of $200–$500 (appendix table B.30). The cost is partially subsidized, credit is available, payments are spread over several years, or a combination thereof exists. Of 33 projects with off-grid components, 22 specified having subsidies in the project documents. Of those, 86 percent specified an up-front capital cost subsidy, usually declining over time and using an output-based aid approach (see appendix table B.31).

Seven projects employed credit support facilities for off-grid energy. For example, in Indonesia the SHS program provided credit to enable private providers to offer their customers the option of spreading out the cost of the SHS over several years. In Sri Lanka, the Renewable Energy for Rural Economic Development Project also provided credit to solar dealers and microfinance organizations but did so in conjunction with a subsidy phased out over five years.

Likewise, Bank projects in both Nicaragua and Honduras employ a combination of microfinance and subsidies to reach the most remote users. Finally, in Lao PDR, there is an up-front payment of around $50, but most installation charges are spread across monthly payments of $1 over 10 years.

## The Distribution of Benefits from Electrification

Because consumption patterns favor the better off, subsidies to electricity providers also go disproportionately to the better off. Evidence from a number of national-level studies shows that electricity subsidies are invariably less well distributed than a random allocation of funds would be, though performance improves as coverage increases and can be improved through geographic targeting or means testing in the subsidy scheme. However, connection subsidies perform much better, having a positive distributional impact.

Apparently progressive tariff structures may actually mean the poor pay more per kilowatt hour if there is a minimum monthly payment. The poor also end up paying more because they are more likely to be disconnected and subsequently face reconnection charges, especially as the constant monthly payment does not match the seasonal fluctuations in rural income. Payment problems are exacerbated if tariff structures are not transparent or are improperly understood, so consumers may make poor choices or unnecessarily reduce their consumption (see the examples from South Africa and Zanzibar in box 3.6)—a problem exacerbated by bills that are complicated even for those who are literate and numerate.

These examples illustrate the importance of consumer education that will both stimulate demand and ensure that consumers derive maximum benefit at least cost, which also, of course, increases the return to the project. Such issues have typically been ignored in Bank projects, though they have begun to emerge in recent years in demand-side management (DSM) components.

DSM comprises activities designed to influence the customer's timing and amount of electricity use in a way that will simultaneously increase customer satisfaction and produce beneficial changes in the utility's load shape. For example, the Mali Household Energy and Universal Access Project sought to promote use of low-energy consumption lamps and energy-efficient air coolers at the household level to reduce peak hour power use and lower electricity bills. In addition, the project included grassroots information campaigns to raise awareness about efficient energy use. Another example is the Vietnam System Efficiency, Equitization, and Renewables Project, which sought to achieve system peak reduction of 120 megawatts by implementing several DSM measures, including promotion of energy-efficient lamps and time-use meters for large and medium-size customers.

***Some progressive tariff structures actually mean the poor pay more per kilowatt hour.***

### Box 3.6: Poor Communication of Tariff Structures Can Disadvantage the Poor

The Zanzibar State Fuel and Power Corporation applies a flat rate tariff up to 50 kWh per month. However, many consumers are unaware of this, partly as their monthly bills vary because of irregular meter readings. On average, villagers consume only 25 kWh per month, even though they could double their consumption and not pay any more. One villager decreased his electricity usage to just 3 kWh a month—equivalent to burning one lightbulb for 1.5 hours per day—in a futile attempt to save money.

In Tambo, South Africa, consumers had a choice between a connection fee of 200 rand (R) and a metered charge per kilowatt hour, or a lower connection fee of R10 and a fixed monthly charge of R15. Given actual consumption levels, most households would have been better off taking the first option, but most opted for the second because they could not afford the R200 connection charge and were not sure how much they would use. To make matters worse, many low-income consumers cannot always afford the R15 a month and so are disconnected and have to pay the R10 again to be reconnected.

*Sources:* Winther 2005; James 1997.

## Concluding Comment

The direct benefits of RE programs have traditionally gone to the non-poor. This continues to be the case, but the poor gain a greater share of benefits as coverage increases. The distribution of benefits is affected both by the manner of selecting communities to be electrified and by the connection cost barrier preventing poor households in electrified villages from connecting.

Because RE programs have historically been a financial burden on utility companies, strategies such as identifying the most cost-effective expansion pattern help relieve this burden. However, as programs become established with a secure financial footing, then smart subsidies can be used—including funds to subsidize connections to more remote communities and connection charge subsidies for late connectors—to increase the volume of benefits and improve their distribution.

# Chapter 4

## Evaluation Highlights

- Most connections in rural areas are residential.
- The most common uses of electricity are lighting and television; there is some resistance to using electricity for cooking.
- Electrification has beneficial impacts for clinics and for the attraction and retention of skilled staff in schools and health centers.
- Although some countries have seen greater productive use of RE, it has not led to industrial rural development.

Rural home powered by Sri Lankan village hydroelectric scheme. (Photo from the World Bank Photo Library.)

# What Is Electricity Used for in Rural Areas?

The energy ladder refers to the phenomenon of households and firms—and so, in aggregate, countries—shifting from low-efficiency fuels to high-efficiency ones as income per capita increases. Biomass fuels such as dung and fuelwood are at the bottom of the energy ladder and electricity at the top.

Electricity should be differentiated by how it is generated, because, for example, solar and hydropower are less polluting than thermally generated electricity. Figure 4.1 (panel A) shows the energy ladder from cross-country data; the greater reliance of poorer countries on biomass fuels and, conversely, the greater amount of electricity use per capita in higher-income countries are evident. The same point applies intracountry, as shown in figure 4.1 (panel B), whereby the non-poor are less reliant on inefficient fuels than are the poor.

Moving up the energy ladder has implications for the benefits of RE. More efficient fuels pollute less. Moreover, for basic fuels, the transformation of matter into energy takes place in or near the home, so the pollution is not only more concentrated but also nearer to the user. Moving up the energy ladder therefore has positive environmental and health effects.

In addition, more efficient fuels are cheaper per unit of energy consumed. Ironically, however, the poor are least able to afford these cheaper fuels because of the connection charge barrier. But even for the better off, moving up the energy ladder takes time and is differentiated by end use.

## What Types of Connection Are There?

Connections can be residential, industrial, agricultural (usually irrigation), or commercial (retail and restaurants), or they can be for public and social facilities and for street lighting. Bank projects nearly always support residential connections, with a small number of exceptions being focused on agricultural connections. Of the 120 projects reviewed, end uses are identified in the project documents for 75, and all but three of these include residential connections (the three exceptions are Mexico Renewable Energy for Agriculture, Pakistan Private Tubewell Development, and Brazil Irrigation Subsector Project). However, only a minority (11 percent) of the 72 projects undertaking residential connections are restricted to those end uses. Most projects also seek to supply business, agriculture, and so on; the proportion of agricultural connections has fallen over time, as these were a strong feature of Asian projects whose share in the portfolio is falling (figure 4.2).

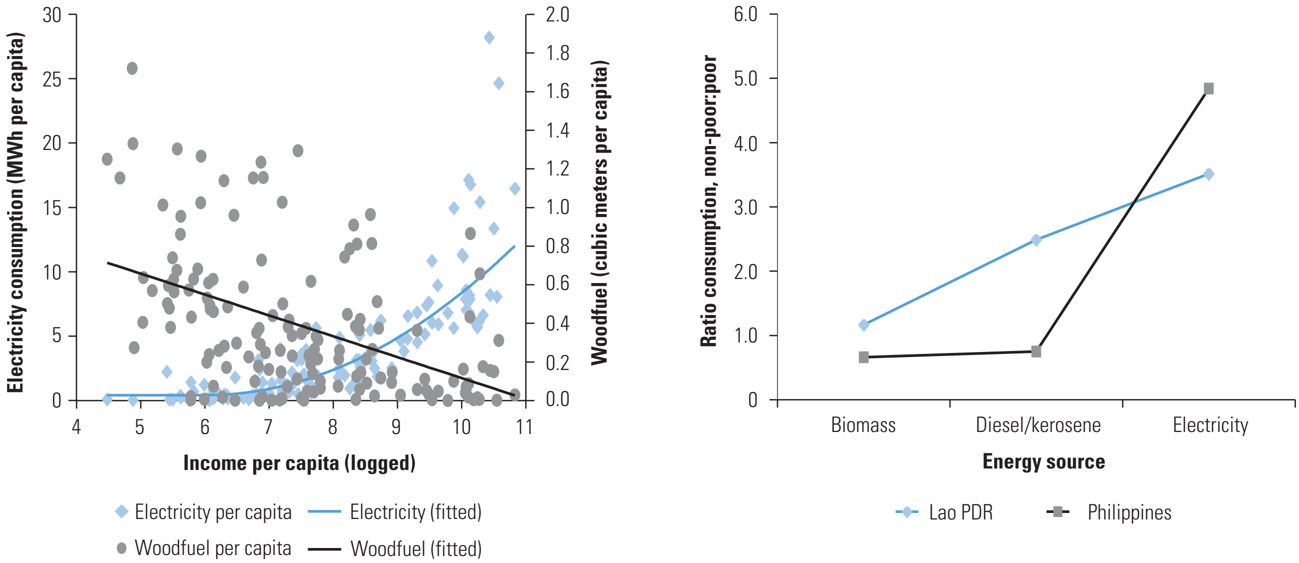
*The poor are the least able to take advantage of moving up the energy ladder from biofuels to electricity because of the connection charge barrier.*

However, in terms of the number of connections, it is residential connections that usually dominate. Data from selected projects (appendix table B.22) show that more than 95 percent of connections are residential. For example, under the Tunisia Fourth Power Project, the RE component was to make 35,000 new domestic connections and to connect 1,500 water pumping stations and 50 small industrial or commercial customers.

**Figure 4.1: The Energy Ladder**

(A) Poor countries use less-efficient biomass fuels, whereas richer ones rely more on electricity.

(B) The poor are lower down the energy ladder (ratio of consumption of the non-poor to poor).

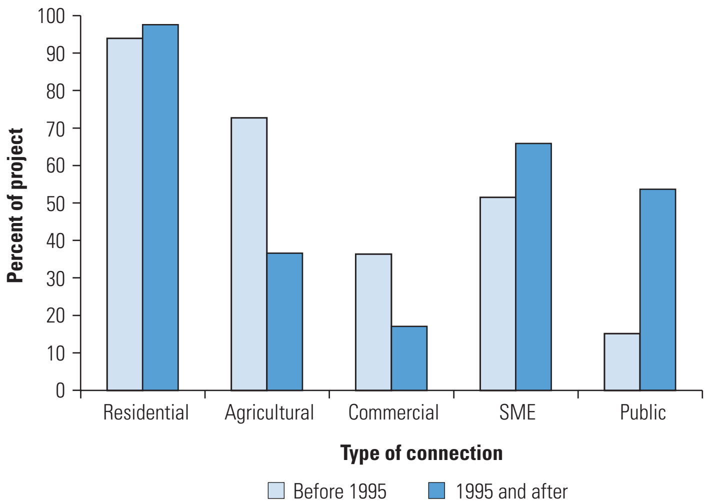



*Sources:* World Development Indicators, FAO statistics.

*Note:* Mwh = Megawatt hours.

*Source:* IEG analysis of survey data.

**Figure 4.2: Nearly All Projects Provide Residential Connections, but also Other Connections for Productive Purposes**




*Source:* IEG portfolio review.

*Note:* SME = small and medium enterprise.

In contrast, nonresidential users typically demand more energy: data presented for the Second Indonesian Rural Electrification Project show nonresidential customers on Java consume on average nine times as much as residential customers (417 kWh per month versus 45 kWh per month)—suggesting that residential consumption is two-thirds of total consumption. Data reported for the Thailand Second Rural Electrification Project show residential consumption to be 78 percent of the total.

## Domestic Uses of Electricity

There is also an energy ladder in the pattern of electricity use. The bottom rung is lighting, the basic purpose to which RE is put in all homes. Electricity provides more and better lighting at lower cost than the next available alternative, kerosene lamps, for most households.

The next most common use of electricity is television: on average, close to half of all electrified homes in rural areas have a television (see appendix D, figure D.1.B). A similar proportion of *all* homes have radios, ownership of radios not being related to grid connection because they can be powered by batteries. However, grid electricity is cheaper than battery power, so households connected to the grid are likely to listen for longer. For example, in the Philippines those connected to the grid used the radio for 105 hours a month, compared with just 13 hours for nonelectrified households.

Television may be viewed at home, in the home of a friend or relative, or in a public place such as a bar. In some cases, the government may use mobile TVs for public education. Viewing television outside the home is most common for teenage children, and it is more common for men than for women. Women's ability to watch elsewhere is limited by restrictions on their mobility, especially in the evening, and especially in conservative societies (such as Zanzibar and Bangladesh)[1] and by husbands feeling shamed because they cannot provide for their family if women have to go to another's house to watch (Mensah-Kutin n.d.), writing about Ghana.

So although in principle any benefits from television may spill over to nonelectrified households, such a spillover is context specific and cannot be taken for granted. IEG analysis of DHS data for nine countries showed that though 60 percent of women in a household with a television watched almost every day, this was so for only 10 percent of women in houses without their own TV (appendix figure D.2).

***The use of electricity also progresses up a ladder, from lighting through television to other small appliances and then to refrigeration, cooking, and air conditioning.***

Electricity is used for cooking only in a small minority of homes, less than 1 percent in most countries (appendix table D.2). Asian countries are a partial exception, because rice cookers are a common acquisition in electrified homes, thus partially displacing the demand for wood or other cooking fuels. Refrigerator ownership is low, with fewer than one in five electrified homes having one; that proportion is higher in middle-income countries.

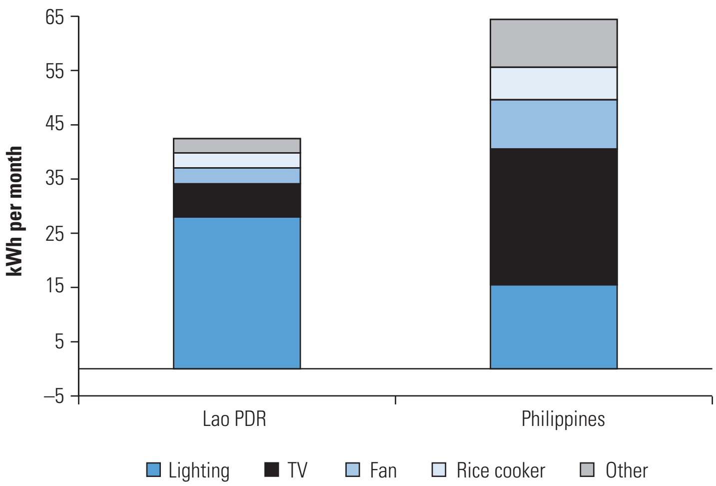
This pattern of end use is evident in the pattern of energy use found in energy surveys. In Lao PDR lighting accounts for 66 percent of electricity use among households connected to the grid; but that figure is only 24 percent in the Philippines, which has been connected longer.[2] This share is higher for the poor, reaching 72 percent in Lao PDR. The most important household item in the Philippines is TV, accounting for on average 39 percent of electricity consumption; it is second most important in Lao PDR, where it accounts for 14 percent (see figure 4.3).

The finding that electricity is not used for cooking comes from a wide range of data in a variety of countries (see appendix D). One reason is cost: households are conscious of the rapidly spinning wheel of the electricity meter if a heating ring is turned on. But tradition also plays a part: people say they prefer the taste of food cooked over wood or charcoal. In other places, cooking with electricity is said to be dangerous, either because poor connections mean that it actually is or because of fear of spirits (angering the kitchen gods in Lao PDR) or witchcraft (neighbors giving the evil eye to those acquiring electrical appliances in Zanzibar).[3]

***Resistance to the adoption of electricity for cooking is partly economic and partly social. Overcoming that resistance requires consumer education.***

That there is some resistance to adopting new electricity-based technologies is not unique to

**Figure 4.3: Pattern of Consumption in Rural Households (distribution total kWh)**




*Source:* IEG analysis of survey data.
*Note:* kWh = kilowatt hour.

**Box 4.1: The Cold Chain**

Vaccines are sensitive to both heat and cold and so need to be kept between 2° and 8°C from the point of manufacture to the point of use. The system for doing this is called the cold chain.

To maintain a store of vaccine, health clinics need refrigerators, which are most easily and cheaply operated by electricity but may also run on gas or, less reliably, on kerosene. A cold box can keep vaccines at the required temperature for between two and seven days and is needed in case of interrupted power supply or equipment maintenance. They can also be used to supply health posts without refrigeration, provided the vaccine is to be used immediately, as would be the case for a National Immunization Day.

developing countries. The mass RE programs of the 1930s in the United States and the United Kingdom both ran into substantial resistance, based on opposition to "urban values"—beliefs about possible harmful effects and conflicts over land use (Kline 2002; Luckin 1990). Consumer education regarding electrification, discussed in chapter 3, can help overcome this resistance and so increase program benefits.

## Community Uses

Health facilities can benefit directly from RE in two ways: by having longer opening hours and by having equipment that requires electricity. These links have not been subject to previous empirical investigation. IEG analysis of health facility survey data for two countries—Bangladesh and Kenya—found that electrified clinics are indeed open for, on average, one hour longer each day.

*Electrified clinics are open longer and, with refrigeration, can offer less-costly immunization; this does not necessarily lead to a higher immunization rate.*

The most commonly claimed benefit for health clinics for electrification is that it helps preserve the cold chain (see box 4.1) for vaccines; again, this claim has not been tested. IEG examined the data for six countries (appendix table D.5) and found that the cold chain was significantly stronger in electrified clinics than in those without electricity. But the proportion of clinics offering immunization services did not differ between the two groups.

So RE can help bring down the cost of providing immunization services and be a part of the routine services offered by a clinic. But it does not increase the extent to which such services are offered or (for the one case where the causal chain could be followed that far) the immunization rate.

Of course these benefits are not dependent on the grid, or even a dedicated RE project. For example, the Bank-supported social fund in Zambia provides solar power to all clinics it constructs. The same project also constructs a house with solar power for the health worker, which points to an underappreciated benefit from RE: the positive effect it has on attracting and retaining skilled staff. Two studies—one of health workers in Bangladesh and one of teachers in Ghana—find a clear and significant link from electrification to reduced absenteeism (see box 4.2) (Chaudhury and Hammer 2003; IEG 2004).

## Productive Uses

The data above show that the vast majority of rural connections are residential, though some programs have had a stronger productive focus than others. The most notable example is India, whose RE program was strongly linked to the promotion of high-yield varieties of crops and the spread of irrigated agriculture, facilitated by electric water pumps with subsidized or free electricity.

Support for industrial development has been limited, even in countries that do have rural-based industries. During the 1980s Sri Lanka began a phase of rapid growth of garment and textile exports. In the early 1990s, the 300 Factories Program sought to spread the employment and income benefits from the export sector to rural areas by providing incentives for producers to locate in rural areas. Despite the relatively high level of RE in Sri Lanka, these factories continue to use their own diesel generators because the electric power supply is not sufficiently reliable. A similar story can be told about Bangladesh, which has seen rapid growth in textile production, with many factories in semirural locations. But these manufacturers again rely on their own power supply rather than trusting the grid. So it cannot be argued that RE led, or even facilitated, industrial rural development.

Small-scale enterprises, including home businesses, are more plausibly influenced by the availability of electricity. As shown in the next chapter, there is evidence of RE increasing both the number of businesses and the hours they are open.

Relative lack of productive uses means that electricity consumption is heavily concentrated in the peak evening hours, resulting in a low load factor (the load factor is the ratio of average consumption to the total possible consumption). From a financial point of view it is preferable that demand be evenly spread throughout the day (because installed capacity has to meet maximum demand, but is idle for much of the time with a low load factor). The financial viability of RE is therefore linked to promoting productive uses.

**Box 4.2: Electrification and Worker Absenteeism in the Social Sector**

Two studies provide evidence of how RE can reduce absenteeism in the social sector.

Surprise visits to health facilities in Bangladesh were used to collect data on absenteeism. It was found that health workers were significantly more likely to live in the same community as the facility if the rate of electrification was greater—and that living locally greatly reduced the probability of the worker being absent from the facility for the whole day.

IEG's impact study of support to basic education in Ghana estimated a multivariate model of the determinants of teacher absenteeism. A teacher's living conditions, including whether his or her home had electricity, affected the incidence of absenteeism and teacher morale. During fieldwork for the study, the chair of the school committee in a community without electricity—where only one of the four teachers allocated to the school had taken up his post—complained: "What teacher will come here and live in a place with no electricity?"

*Sources:* Chaudhury and Hammer 2003; IEG 2004.

# Chapter 5

## Evaluation Highlights

- Connections to RE lower the price of operating lighting and TV.
- The impacts of RE on indoor air quality, health, and knowledge, and fertility reduction are quantifiable and significant.
- RE has some long-term impact on home businesses.
- Off-grid solutions have demonstrable environmental benefits.
- Willingness to pay is high and exceeds the average supply cost where grid connection is feasible.
- Reducing consumption by high-end users through higher tariffs can have a net welfare benefit.
- Off-grid investments usually have a lower rate of return than grid extension because the costs are more and the benefits less.

A Sri Lankan village shop at dusk, lit by solar lamps. (Photo from the World Bank Photo Library.)

# The Benefits of Rural Electrification

The main domestic uses of electricity are lighting and TV. In the Bank's economic analysis, the valuation of the benefits of lighting have typically been based on the willingness to pay (WTP), which is calculated on the basis of the cost of lighting using the existing source, usually a kerosene lamp.

## Domestic Uses: Lighting and TV

Older analyses instead compared the cost of kilowatt hours from a diesel generator with that from the grid. This approach changed with the ESMAP study of the Philippines, which instead measured lighting as lumens consumed (see box 5.1).

The approach is illustrated in figure 5.1, which shows the demand for lumens. Electricity supply lowers the cost of energy to the user, resulting in an increase in consumer surplus, which is the difference between what consumers are willing to pay and what they actually do pay. Data from an energy survey give two points on the demand curve: price of lumens and the quantity consumed using either kerosene as the source ($P_k$,$Q_k$) or electricity ($P_e$, $Q_e$). Using these two points, the demand curve can be interpolated.

The amount the consumer is willing to pay for a quantity Q is the area under the demand curve from 0 to Q. Hence, the consumer is willing to pay A + B + D for consumption of $Q_k$, but actually pays just B + D (= $P_k$ $Q_k$), leaving a consumer surplus of A. Once electricity becomes available, the consumer surplus is A + B + C, so the increase in consumer surplus as a result of electrification is B + C. This consumer surplus has two parts: that arising from the reduction in the price of the $Q_k$ units already being consumed and the consumer surplus associated with the new consumption, $Q_e - Q_k$.

The benefit to the consumer is B + C. It is common in project analysis to also include areas D and E, sometimes referring to the whole area B + C + D + E as WTP; that is not quite correct, as WTP includes area A also. It is perfectly acceptable to include areas D and E. This is the amount paid by the consumer, which is simply a transfer payment to the utility and so a neutral flow for economic analysis.[1] The cost side of the analysis will capture the cost of consumption. Assuming that the average cost of supply ($C_e$) is less than tariff rate, there will be a positive producer surplus, which is being captured in this calculation (figure 5.2). The alternative is to deduct the payments (D + E) from consumers and add them to producers, so when summing across all flows these payments/receipts cancel out.

***Electricity supply reduces the cost of energy to the user.***

The calculation of WTP clearly depends on the shape of the demand curve, which determines the extent of area C (see appendix H for more discussion). The evidence base for the shape of this curve is still thin. Currently the most satisfactory approach is to take two points on the curve, as in figure 5.1, and assume a constant elasticity (or log linear) demand curve. This approach has been

### Box 5.1: Shedding Light on Lumens

A lumen is a measure of light emitted: a candle emits around 12 lumens, a kerosene lamp from 30 to 80 lumens, and a 60-watt lightbulb 730 lumens. So by using a single 60-watt lightbulb for four hours a day for one month (30 days), a household is consuming 88 kilolumen hours (klh) (=4 x 30 x 730/1,000). Electricity consumption is 7.2 kWh per month (=4 x 60 x 30/1,000).

Suppose electricity costs the consumer $0.05 per kWh; then she has a monthly lighting bill of $0.36, equivalent to a cost of $0.004 per klh. In contrast, burning a kerosene lamp for four hours a night yields just 6 lumens but costs about the same as the monthly electricity bill, giving a cost of $0.06 per klh. Moving from kerosene to electricity cuts the cost by more than a tenth and increases consumption more than tenfold.

*IEG found four approaches to consumption used in ERR calculations.*

used in a number of Bank studies, such as the PAD for Peru Rural Electrification. Some more recent studies rely on more points on the curve (where a range of fuel options is available, say kerosene, car batteries, and electricity) to estimate a kinked demand curve. However, other studies have assumed a linear demand curve, which results in an overestimation of WTP and so of total project benefits, sometimes by a substantial magnitude (see appendix H).

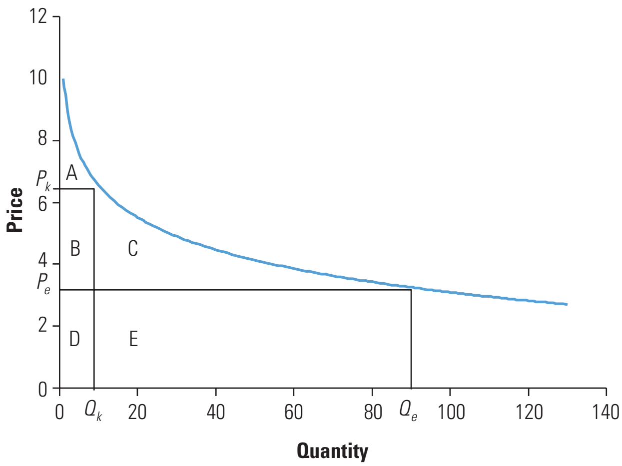
A selection of results is reported in table 5.1, showing an average household WTP of $9–16 a month. These figures are comparable for both grid and off-grid sources. The latter might be expected to be lower, given that the level of service is lower; the similar size of the WTP estimates partly reflects the means by which the demand curve is estimated.[2]

Electrification projects are among those that still routinely report an ERR. More than 80 percent of the 120 projects did so, and most of the exceptions were multisector projects.

IEG examined the ERR calculations for 13 projects.[3] The following approaches were found to be used:

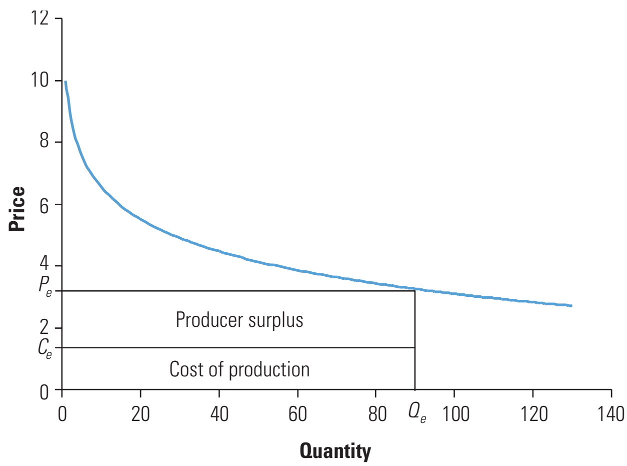
- Estimate WTP assuming a nonlinear demand curve or a linear demand curve but taking only a percentage of the estimate for area C to allow for overestimation. This approach conforms to best practice. It was used in 5 of the 13 cases examined, including Peru Rural Electrification and Senegal Electricity Services for Rural Areas Projects.
- Estimate WTP assuming a linear demand curve. This approach results in an overestimate of project benefits. In one case the ERR fell from

### Figure 5.1: Consumer Surplus




*Note:* $P_e$ = price of electricity from the grid; $P_k$ = price of kerosene; $Q_e$ = quantity of electricity used from the grid; $Q_k$ = quantity of kerosene consumed.

### Figure 5.2: Producer Surplus




*Note:* $C_e$ = average cost of supply; $P_e$ = price of electricity from the grid; $Q_e$ = quantity of electricity used from the grid.

**Table 5.1: Willingness to Pay Calculation for Lighting**

| | Grid | | | | Off-grid | | | |
|---|---|---|---|---|---|---|---|---|
| | Lao PDR | Peru | Philippines | Indonesia | Bolivia | Honduras | Mozambique | Nicaragua |
| Quantity (lumen hours/month) | | | | | | | | |
| Nonelectricity | 20 | 4.6 | 4.1 | 8.8 | 7.0 | 5.5 | 48.7 | 2.4 |
| Electricity | 435 | 363 | 204 | 38 | 90 | 115 | 122 | 125 |
| Price ($/lumen hour) | | | | | | | | |
| Nonelectricity | 0.20 | 0.57 | 0.36 | 0.55 | 0.48 | 0.50 | 0.10 | 0.33 |
| Electricity | 0.00 | 0.01 | 0.01 | 0.10 | 0.04 | 0.04 | 0.04 | 0.04 |
| Expenditure ($/month) | | | | | | | | |
| Nonelectricity | 3.90 | 2.62 | 1.48 | 4.80 | 3.36 | 2.75 | 4.87 | 0.78 |
| Electricity | 1.31 | 3.63 | 1.53 | 3.81 | 3.60 | 4.60 | 4.87 | 4.36 |
| WTP | | | | | | | | |
| Total | 11.20 | 16.16 | 7.36 | 11.08 | 12.24 | 13.68 | 9.73 | 9.01 |
| Per klh | 0.03 | 0.04 | 0.04 | 0.29 | 0.14 | 0.12 | 0.08 | 0.07 |
| Per kWh | 0.81 | 1.11 | 0.47 | 0.71 | 3.02 | 3.37 | 2.06 | 1.90 |
| Average kWh | 13.81 | 14.50 | 15.50 | 15.50 | 4.06 | 4.06 | 4.74 | 4.74 |

*Sources:* Calculations based on figures in project documents.
*Note:* klh = kilolumen hours; kWh = kilowatt hour; WTP = willingness to pay.

60 percent in the project Implementation Completion Report to just 12 percent when the correct approach was used (and for the off-grid component of that project the ERR fell from 26 percent to 1.5 percent); this approach was also used in 5 of the 13 cases.

- Estimate WTP based on the alternative energy source, and then value the whole of expected energy consumption with electricity at that level. This approach neglects the downward sloping demand curve, resulting in a substantial overestimate of project benefits. The only example found was Peru Rural Electrification, but the analysis also underestimated benefits, as costs were double counted.
- Estimate benefits as the cost savings on current consumption levels (that is, area B in figure H.1). This approach underestimates project benefits because it ignores additional consumer surplus from new consumption (area C). Several older projects used this approach, such as Malawi Power V.

There has been a change in appraisal methods over time, with more recent studies adopting the ESMAP approach. However, this approach has been unevenly applied, with the understanding of the approach among some task managers being weak.[4] There is more than one case of inappropriate application of the approach, resulting in an overestimation of project benefits. This suggests a failing of the quality control mechanism of reports that go to the Board—indeed, many project documents contain insufficient information for the analysis to be replicated, though these data are sometimes available in separate documents.

But lighting is only one use of electricity, albeit the main one from a domestic perspective. If other benefits are not also captured, then the return to the project might be underestimated. This has indeed been the case for many projects.

Recent studies use the lumen-based approach to value the WTP per kilowatt hour and value all sales

**Table 5.2: Willingness to Pay Calculation for TV**

| | Lao PDR | Mozambique | Peru | Philippines |
|---|---|---|---|---|
| Modern supply source | Grid | SHS | Grid | Grid |
| Q units | hours | hours | kWh | hours |
| Quantity: car battery | 55 | 36.5 | 4.2 | 41.3 |
| Quantity: electricity | 106 | 91.25 | 11 | 129 |
| Price: car battery | 0.032 | 0.050 | 1.04 | 0.22 |
| Price: electricity | 0.001 | 0.025 | 0.18 | 0.0125 |
| Exp(cb) | 1.78 | 1.83 | 4.37 | 9.09 |
| Exp(e) | 0.11 | 2.28 | 1.98 | 1.61 |
| Elasticity | –5.30 | –0.76 | –1.82 | –2.52 |
| Intercept | 17.79 | –0.27 | 2.65 | 7.86 |
| B[a] | 1.72 | 0.91 | 3.61 | 8.57 |
| C[a] | 0.39 | 1.87 | 2.91 | 4.92 |
| Total | 2.11 | 2.79 | 6.52 | 13.49 |
| WTP | | | | |
| Total | | | | |
| Per month | 2.22 | 5.07 | 8.5 | 15.11 |
| Per hour | 0.021 | 0.056 | 0.06 | 0.12 |
| Per kWh | 0.26 | 0.69 | 0.77 | 1.46 |

*Sources:* Calculations based on figures in project documents.
*Note:* TV uses 80 watts per hour (that is, 0.08 kWh per hour).
a. See figure 5.1.

*The price of operating a TV is lower and the amount of usage is higher with a grid connection.*

at that amount. That is, all sales are valued at the WTP for electricity for lighting. Such an approach may yield either an underestimate or an overestimate, depending on the WTP for other end uses. Where possible, it is preferable to measure the benefits from these end uses separately.

An approach similar to that based on the demand curve can be used to calculate the benefits from television, where the unit of consumption is hours of television watched per month. In the absence of a grid connection, TVs are operated using car batteries, which will provide the price and quantity against which to compare grid electricity. As with lighting, the price is lower and the quantity higher with a grid connection (see table 5.2), although the change in quantity is not as marked as with lighting.

*Household electrification was found to have a significant impact on health outcomes in Bangladesh.*

For two of the cases, the WTP for a kilowatt hour is greater for lighting than for TV (for example, in Peru WTP is $0.77 per kWh for TV usage, compared to $1.11 per kWh for lighting—the WTP for a kilowatt hour for lighting is almost twice that for TV). But for the Philippines the WTP for TV is higher than for lighting.

## Health Benefits

The health benefits from RE operate through a number of channels:

- Improvements to health facilities
- Better health from cleaner air as households reduce use of polluting fuels for cooking, lighting, and heating (Hutton and others 2006)
- Improved health knowledge through increased access to television
- Better nutrition from improved knowledge and storage facilities from refrigeration.

Each of these benefits is explored here. The findings support the view that there are health benefits from RE, including fertility reduction (next section)—but the survey instruments were not designed with the intention of examining these issues and so should be seen as suggestive; further research and evaluations are needed to strengthen the evidence base.

### *Indoor air quality*

The use of traditional solid fuels such as fuelwood crop residue and dung exposes people—especially women and young children—to indoor air pollution, with consequent health risks: principally acute lower respiratory infections, but also low birth weight, infant mortality, and pulmonary tuberculosis. A review of existing studies showed that exposure to indoor cooking using traditional methods increased the risk of premature death by a factor between two and five. These diseases caused by indoor air pollution cause between 1.6 and 2 million excess deaths each year,[5] more than half of them among children younger than five. This figure accounts for 2.7 percent of the global burden of disease. There is also a fire risk. In addition, fuel collection imposes a costly time burden of up to 8 hours a week (appendix D), once again usually mainly on women.

In principle, RE can tackle both of these issues, promoting better health through reduced indoor air pollution and reducing the time burden on women of fuel collection. However, in practice, these benefits have been little realized because (as shown in the previous chapter) electricity is largely not used for cooking in rural areas.[6]

But improvements in indoor air quality can also come about through changes in lighting source. Kerosene lamps emit particles that cause air pollution; these are measured by the concentration of the smallest particles per cubic meter (PM10). Burning a liter of kerosene emits PM51 micrograms per hour, which is just above the World Health Organization 24-hour mean standard of PM10 of 50 micrograms per cubic meter. But these particles do not disperse, so burning a lamp for four hours can result in concentrations several times the World Health Organization standard.

The extra risk of respiratory sickness from exposure to these levels of PM10 is captured in the hazard ratio (the relative probability of the exposed versus unexposed being sick), which is 3.5. Lost adult work days average 3 per year, and the additional under-five mortality is 2.2 per 1,000. So substituting electric lighting for kerosene lamps has a quantifiable health benefit of $2.50 per household.

**Box 5.2: The Health Risk of Candles**

The health risks from candles have only recently been appreciated, since a 1999 Australian study showed that the lead used in candle wicks results in air lead concentrations at levels far in excess of established safety standards. Burning a candle for a few hours in an enclosed room results in lead concentrations sufficient to cause fetal damage or to harm the mental development of children.

Since the Australian study was done, many developed countries have banned the use of lead in wicks, but these bans do not affect candles made for developing county markets.

*Where RE can help is in the replacement of kerosene lamps with electric lamps, a change that reduces indoor air pollution.*

A second, relatively unrecognized health benefit from RE comes from displacing candles (see box 5.2). However, candles are not used for lighting that much. They do have nonlighting uses, such as for ceremonial purposes—but these are not affected by electrification, so these effects are not captured in this study.

### *Knowledge and fertility reduction*

IEG's impact evaluation of health outcomes in Bangladesh (IEG 2005) found a significant impact of household electrification on mortality. One possible channel for this effect is that access to media improves health knowledge. Chapter 4 demonstrated the link between electrification and access to television. IEG analyzed DHS data for eight countries to examine how access to media (radio, TV, and newspapers) affects women's health knowledge (see appendix G for full details).

The causal chain for the first possible health impact is as follows:

- Access to electricity increases time spent watching TV and listening to the radio.
- Increased access to media increases awareness of health issues.

- This increased awareness results in changed health behavior.
- Changed behavior improves health outcomes and reduces fertility.

*Access to television significantly increases women's knowledge of health and family planning.*

The link between electrification, TV ownership, and TV viewing was demonstrated in chapter 3. It was also shown that the access to TV in villages where not all people have a TV cannot be taken for granted. Multivariate analysis of the determinants of women's knowledge of health and family planning provides very strong evidence that access to television significantly increases this knowledge; this variable is significant in all but one of the 11 cases examined (see appendix G).

The household electrification variable is not significant but becomes so when television is dropped from the equation, which shows that television is the channel through which electrification affects health knowledge. But the percentage of households that have television is significant in only one case (Ghana), so, in general, the channel of other households having television does not operate. As noted above, women are the least likely to view television in someone else's home.

The next step is to examine the extent to which knowledge affects practice. Two health practice variables are examined: use of modern contraceptives and child immunization. The contraceptive knowledge variable was significantly, positive in all 11 equations estimated. For immunization status, the knowledge variable was significant, with the expected sign in 53 of the 55 estimated equations. The link between knowledge and practice is thus firmly established.

The final step is the link between knowledge and outcomes. In seven of the nine cases, the health knowledge variable has a significant negative impact on fertility. The household electricity variable is also significant and negative in seven cases. What are the possible reasons for this latter finding?

A possible reason is that electricity reduces coital frequency by increasing waking hours, both because there is more light and because TV and radio provide an "alternative to sex" for recreation. However, the data do not support this point of view. TV watching only significantly affects sexual activity in one of the eight cases, and household electricity is never significant. To the contrary, electrification indirectly increases sexual activity, as coital frequency is higher for women using modern contraception, the knowledge of which comes in part from TV.

These results can be used to estimate the impact electrification has on fertility (table 5.3). The total effect is the combination of the direct impact from the fertility equation and the indirect impact via higher knowledge (which is the knowledge coefficient from the fertility equation multiplied by how electricity affects knowledge, taken as the coefficient on the household electricity variable in the absence of the media variables). These calculations show a median impact of a reduction in fertility of 0.6 children as a result of electrification.

However, the link between electrification and mortality does not appear strong; the results are not robust. Immunization and knowledge are both significant in a few cases, but not overwhelmingly so, as earlier links in the chain are.

Nutrition is an outcome that may also be affected by knowledge, both because health knowledge proxies for nutrition knowledge and because ill health (notably diarrhea) is a major factor in poor nutrition. In addition, electricity may positively affect nutrition by allowing refrigerated food storage.

Two nutrition measures are used to evaluate the effect of nutrition: the height for age z score (HAZ) and the weight for age z score (WAZ). The z score is a standardized measure; being more than two z scores below the reference value constitutes being undernourished; being more than three scores below constitutes severe undernourishment. HAZ is taken as a measure of long-run nutritional status; WAZ indicates short-run status. The conditioning variables are similar to those used in the mortality equations. These are in turn similar to those used throughout this analysis but with more

**Table 5.3: Fertility Impact of Electrification**

| | Bangladesh | Ghana | Indonesia | Morocco | Nepal | Nicaragua | Peru | Philippines | Senegal |
|---|---|---|---|---|---|---|---|---|---|
| Knowledge equation | | | | | | | | | |
| Electrification status | 0.28 | 0.38 | 0.02 | –0.10 | 0.17 | 0.10 | 0.23 | 0.16 | 0.08 |
| Child ever born: TFR equation | | | | | | | | | |
| Electrification status | –0.02 | –0.08 | –0.08 | –0.11 | –0.09 | 0.04 | –0.01 | –0.16 | –0.16 |
| Knowledge variable | –0.02 | –0.03 | –0.01 | –0.07 | 0.02 | –0.04 | –0.03 | –0.03 | 0.00 |
| TFR at age 50 | 5.83 | 6.35 | 4.63 | 6.32 | 5.98 | 7.25 | 6.57 | 5.54 | 7.42 |
| Impact of electrification | 5.68 | 5.77 | 4.26 | 5.67 | 5.46 | 7.51 | 6.45 | 4.63 | 6.23 |
| Reduction | –0.15 | –0.58 | –0.37 | –0.65 | -0.52 | 0.26 | –0.11 | –0.91 | –1.19 |
| Reduction (only significant variables) | 0.00 | –0.07 | –0.37 | 0.00 | –0.52 | –0.03 | –0.05 | –0.91 | –1.19 |

*Source:* Appendix H.
*Note:* TFR = total fertility rate.

demographic variables, because there is possible competition for resources between siblings.

The knowledge variable affects HAZ in four of the six countries for which data are available; it affects WAZ in three of the six. There is also an indirect effect, with immunization status affecting nutrition in two of the six countries.[7] Data on households owning a refrigerator were available for four countries: the coefficient was significantly positive on HAZ in two of the four countries and in just one of the four for WAZ. There is thus evidence that electrification improves child nutritional status, but the channels are not operating in all countries.

Is it possible to put a value on these effects? Valuing fertility decline is a difficult matter. A straightforward economic (Beckerian) approach is to assume that families wish to avert births with a negative net present value, so the benefit of averted births is the avoidance of incurring this negative net present value. This approach was used to calculate the benefits of family planning programs in the 1970s, including by Bank analysts. However, it has fallen out of favor—at the Bank there is no requirement to perform cost-benefit analyses for social sector interventions. Anyway, conceptually it is clear that parents want to have children even when they have a huge negative net present value (the United States is a clear example—child-raising costs are very high and the pecuniary advantages negligible).

*Calculations show that electrification results in fertility reduction.*

An alternative approach is to take the value of fertility reduction to be the cost of achieving the same decline in fertility through a reproductive health intervention. To take a successful example, approximately $5 billion was spent on the Bangladesh family planning program, bringing the total fertility rate down from around seven to three children per family. As a conservative estimate, at least half of this fertility decline is attributable to the family planning program (see IEG 2005). The number of averted births from this fertility decline was 60 million. Hence, the cost of a one-child reduction in fertility is $167 per averted birth. So the fertility-reduction benefit of RE is approximately $100 per household. However, only 10 percent of the RE impact was through clearly identifiable channels, so a lower limit of the RE impact is $10 per household.

## Time Use

Electrification can affect time use in a variety of ways: watching TV, greater participation in community activities and socializing, reducing time spent on household work or shifting it to the evening, increasing time spent reading or—for children—doing homework, and extending hours of home businesses. These additional activities are made possible by the longer waking hours electricity makes possible, with households reporting they stay up, on average, an additional one to two hours.

The main use of this additional time is watching TV; indeed, time spent watching TV is greater than the increased time available, suggesting that it cuts into other activities (table 5.4). One such activity is reduced time on housework—the Philippines study found that women spent one hour less on such tasks as a result of electrification. But other studies have suggested that women's work burden can actually increase, as household activities can be carried out in the evening, allowing more working hours on other activities.[8] Indeed, the latter may be one explanation for increased business hours, which are found in IEG's analysis of data from Ghana and the Philippines (but not in Peru).

## Education Benefits

The main channels through which electrification may affect education are (1) by improving the quality of schools, either through the provision of electricity-dependent equipment, or increasing teacher quantity and quality; and (2) time allocation at home, with increased study time, though the availability of TV may decrease that time (but at the same time it may also possibly provide educational benefits).

Children in electrified households have higher education levels than those without electricity. The ESMAP Philippines study (ESMAP 2003) finds almost a two-year difference (8.5 versus 6.7 years). However, this is a single difference estimate that does not allow for other factors such as parental education, household income, and school facilities. But IEG's analysis of DHS data for nine countries also found that electricity has a direct impact on rural education once these factors are controlled for. What are the reasons for this impact?

**Table 5.4: Hours Watching TV by Electrification Status**

| | |
|---|---|
| Lao PDR | Car battery: 1.78 hours/day |
| | SHS: 2.20 hours/day |
| | Grid: 3.55 hours/day |
| | Regression estimate: 1.26 hours/day = 37.8 hours/month |
| Philippines | Car battery: 1.85 hours/month |
| | Grid: 129 hours/month |
| | Regression estimate: 2.25 hours/day = 67.5 hours/month |

*Sources:* ESMAP 2002; IEG analysis of survey data for Lao PDR.

In low-income countries rural schools often lack basic equipment, such as furniture and adequate textbooks—the presence of electricity does not affect these important constraints.[9] The failure of teachers to take up posts in remote locations and frequent absenteeism from such postings are problems in many countries, and the evidence presented in the last chapter, albeit for just one country, supports the argument that the availability of electricity makes rural positions more attractive to teachers. This is thus one possible reason for the higher education levels, with improved school quality encouraging students to stay on longer or enabling them to do so as their grades improve from better teaching.

The other possible explanation is that increased study time at home results in better grades, so children stay in school longer. There is indeed evidence that electricity increases study time (by approximately an hour an evening in the case of the Philippines—see appendix G), but no study follows the causal chain through to improved results and higher educational attainment.

## Productive Uses

A general conclusion from analysis of RE programs is that the impact on productive activities is limited. But three caveats are needed to this conclusion. The first is that some irrigation programs (and Bank projects) have focused on RE for irrigation programs, and—in India, at least—were linked to the spread of Green Revolution technologies (see Barnes 1988; Binswanger and Khandker 1993).

Second, in cases where there has been a complementary program to assist productive uses of electricity, there has been more success—an early example being USAID support in Colombia in the 1960s. However, only a minority of Bank-supported projects have had such components.

Finally, considering home enterprises, the effects are greater than those from medium and large firms, although these enterprises may be small indeed, such as renting out refrigerator space (see box 5.3).

IEG's analysis of household survey data does find evidence of a positive impact of RE on home businesses. The finding is strongest for the 15-year panel data from 1988 to 2003: the number of home businesses grew significantly more in communities that became electrified than in either those communities that did not or those that were already electrified in 1988 (appendix F). Similar evidence was not found in the other panel data set (Peru), but the year between surveys occurred at a time when rural areas were experiencing considerable unrest. In addition, the presence of electricity extends the work hours of home businesses, and this increases the net income from these activities.

## Global Benefits

RE largely involves transmission and distribution, so, unlike power-generation projects, it has limited direct environmental impact. To the extent that electrification promotes increased energy consumption, it increases $CO_2$ emissions, though these are at least partially offset by the fuel displaced. Grid-extension projects have not entered into these calculations, so the net balance of cost and benefits cannot be reported here but would be a useful area for further analysis.

Off-grid activities are an exception, because Bank support for off-grid energy supply mainly relies on RET, the most common being SHSs (see appendix table B.26). Installation of RET generation capacity displaces existing nonrenewable energy sources, mostly kerosene, thus creating an environmental benefit. The main benefit is averted $CO_2$ emissions, the value of which should be included in the benefit stream.

Bank project documents value this amount in one of four ways, the first two being the most common:

**Box 5.3: Micro Home Enterprises**

Electrification may bring the chance for small business activities that help defray the costs of electrification. In Ghana, the woman of the household prepares snacks to be sold to people who come to her house to watch television in the evenings. In South Africa, households sell cold drinks and rent out refrigerator space.

- GEF funding is taken as the international community's WTP for reduction in global $CO_2$ emissions; that is, the total value of reduced emissions equals the GEF contribution to the project. The value per ton of $CO_2$ avoided is based on an estimate of the amount of $CO_2$ avoided divided by the amount of GEF funding. Examples include Argentina Renewable Energy in Rural Markets Project, China Renewable Energy, Indonesia Solar Home Systems, and Honduras Rural Electrification.

*Off-grid renewable energy activities have positive environmental benefits.*

- As an alternative approach, global environmental benefits are estimated using GEF incremental costs. One example is the Nicaragua Off-Grid Project, where GEF's incremental cost for minigrids is based on a Prototype Carbon Fund WTP of $7 per ton of $CO_2$. The same approach was used in the Bolivia Decentralized Infrastructure for Rural Transformation Project.
- Avoided emissions are calculated and valued at carbon prices currently observed in the carbon market. Using this approach, the Senegal Electricity Services for Rural Areas Project values 1 ton of avoided $CO_2$ emissions at $4.50 per ton.
- The emission factor from the project (which for the Mexico Carbon Fund Project is 0.584 tons of $CO_2$ emissions/MWh) is calculated, and then the value of $CO_2$ reductions at the price of energy sales to the grid ($0.057 per kWh).

The most common methods are based on GEF's decision of how much to allocate to the project.

GEF's country allocations are based on a two-part formula: the potential for reducing $CO_2$ emissions (the product of the baseline emissions and the rate of reduction over the previous decade) and an institutional quality measure of the capacity to implement environmental programs. How much money a project gets from GEF depends on the country allocation and the number of projects. Hence, the GEF-based estimation of environmental benefits is not project specific and thus bears no relation to the actual level or value of carbon emissions averted.

*Calculation of $CO_2$ emissions averted is done in several different ways, resulting in ERRs that are not comparable.*

Application of the method results in different valuations of the worth of averting $CO_2$ emissions from project to project. This figure varies as well, because different documents use different approaches. As the benefit is a global one, it should be expected that a ton of $CO_2$ emissions saved carries the same value regardless of the source. Using a variety of methods to arrive at different values per ton of $CO_2$ undermines the comparability of the resulting ERRs.

## Adding Up the Benefits

Table 5.5 summarizes the data for selected countries for which a range of benefits have been quantified. These benefits are as follows:

- Benefits from lighting and TV/radio, calculated as WTP.
- Education benefits from higher educational attainment by the children of electrified households, which results in higher future earnings. The present value of these incremental future earnings is calculated and imputed to a monthly figure.[10]
- Time saved from household chores (additional leisure time), valued at the opportunity cost of labor, that is, the average wage.[11]
- Productivity of home business includes total net revenue from new businesses and incremental revenue to existing businesses. Because the results are for the average household, they have to be adjusted to reflect the proportion of households with a home business.[12]
- Similarly increased agricultural productivity calculated as incremental revenue. This figure was only calculated for the Philippines, where it was found to be zero.
- Improved health comes from the value of reduced mortality as a result of improved indoor air quality from reduced reliance on kerosene lamps, which has a monthly annuity value of \$0.02.
- Reduced fertility coming from knowledge from channels accessed using electricity, valued at the cost of achieving fertility reduction through reproductive health programs. The lower limit of these benefits was placed at \$10, which is equivalent to a monthly "annuity" of \$0.08.
- Public goods benefits, such as increased security, have not been estimated in any of the cases, but are listed for completeness. Global benefits from reduced $CO_2$ emissions apply only to off-grid components. As argued in the text, calculations should also reflect the net environmental impact of increased energy consumption as a result of grid extension, but this has not been calculated in any Bank studies.

Obtaining the total benefits from RE is difficult for two reasons. First, some of the benefits are difficult to put a value on. The rationale for the ESMAP study of the Philippines was that it was the resulting systematic undervaluation of the benefits from electrification that made these projects appear unattractive investments. Accordingly, the study valued a broader range of benefits, showing these to be substantially in excess of those from lighting alone (see table 5.4). However, the second problem is that there can be double counting.

Double counting can occur because households' WTP for lighting or TV includes the value they attach to longer waking hours, better indoor air quality, greater study time, and the informational benefits flowing from watching television. Project documents often calculate the benefits based on WTP for lighting and sometimes TV, noting that these are underestimates because there are many other benefits not included. In fact, though, many *are* included in the household's valuation of its WTP. It is only the public good elements of household consumption that are not included, which might include, for example, knowledge benefits

**Table 5.5: Rural Electrification Benefits (US$ per household per month)**

| Benefit | Philippines | Peru | Lao PDR | Bolivia |
|---|---|---|---|---|
| Lighting | 7.36[a] | 16.16 | 5.60 | 12.24 |
| TV | 15.11 | 8.5 | 2.22 | 4 |
| Radio | (included in TV) | Not estimated | Not estimated | Not estimated |
| Education | 12.46 | Not estimated | Not estimated | Not estimated |
| Time saved for household chores/increased leisure | 5.30 | 5.5 | 5.5 | 5.5 |
| Productivity home business: existing business | 6.30 | 0.0 | 3.40 | Not estimated |
| Productivity home business: new business | 5.25 | 0.0 | 2.35 | Not estimated |
| Improved health | 0 | 0.02 | 0.02 | Not estimated |
| Reduced fertility | Not estimated | 0.08 | 0.08 | Not estimated |
| Increased agricultural productivity | 0 | 0 | Not estimated | Not estimated |
| Public good benefits (including security) | Not estimated | Not estimated | Not estimated | Not estimated |
| Reduced pollution (global benefits)[b] | Not estimated | 0.24 | 0.15 | 0.20 |

*Source:* IEG data.

a. IEG estimates for the Philippines differ from those by ESMAP (2002) because that study used a linear demand curve.

b. Applies to off-grid beneficiary households only. Assumes 0.6 ton of $CO_2$/MWh priced at $8/ton of $CO_2$.

to outsiders watching the household television, household members spreading this knowledge by word of mouth (though IEG's analysis suggests these are very much second-order benefits), or public benefit from an external light.

Even if the health and fertility benefits are additional, their monthly value is quite small. However, this study is the first to quantify these, so these estimates should be treated with caution until further data and analysis are available to strengthen the evidence base. In contrast, the education benefit is sizeable. Again, further research is needed to fully understand this channel. For those households that do have a home business, there appears to be a reasonable income impact from RE.

Table 5.5 shows that there are other, unquantified, benefits. Project documents typically speak of ERR estimates being conservative because they omit some benefits. Of course, total consumption is being valued at the household WTP for lighting, and there are not missing benefits but a mispricing of some output, with an unknown bias on the ERR. But if the benefits are truly omitted, then the omission is not serious if the ERR is above the threshold anyway, which is usually the case.

*Calculating the total benefits of electrification is difficult because some benefits are difficult to value and there is a potential for double counting.*

Total household WTP depends on the extent to which it is believed other benefits are internalized in the WTP for lighting and TV. Assuming they are so internalized, with an allowance for unaccounted benefits, gives a WTP of $10–30 per household per month (excluding home business benefits), corresponding to around $0.20–0.60 per kWh, depending on whether other benefits are internalized in the WTP. Assuming these benefits are not internalized adds up to another $30 to this amount (though the Philippines study derived rather higher figures), giving a range of $40–70 per household per month (or around $1.00 and higher per kWh).

## How Do the Benefits Compare with the Costs?

Actual connection costs vary between $150 and $2,000 per household, depending on the location and size of the community; costs are even less in already connected communities. The estimate of household benefits at a midpoint of $50 a month equals $600 a year, meaning that the break-even point is between one and three years and that discounting net benefits over, say, a 20-year period will give a good rate of return. Put another way, the household WTP is well above the average supply cost. Rural grid connections can indeed be good investments, though each investment is context specific regarding both costs (generation and supply costs vary widely and depend on tackling technical issues, most notably system losses) and benefits (which vary according to alternative energy sources, potential for productive use, and so on).

*New approaches convincingly demonstrate that WTP is high and generally exceeds the average supply cost where grid connection is feasible.*

What the new approaches have convincingly demonstrated is that the WTP for RE is high and almost invariably exceeds the average supply cost for areas in which grid connection is considered feasible (see figure 5.3). The immediate implication of this finding is that the ERR will exceed the financial rate of return, a state of affairs that points to the policy conclusion that the financial rate of return can be raised by increasing tariffs if a stronger financial rate of return is needed.

*Reducing consumption of the high-end consumers through a higher tariff will raise consumption of the low-end consumers, providing a net welfare benefit.*

But assuming that return is sufficient for sustainability, then the policy conclusion is that the project ERR can be raised through a cross-subsidy-based redistribution. The argument is a simple utilitarian one: the marginal benefit to the low-level consumer exceeds that to the high-end consumer; reducing the consumption of the latter by charging a higher price to raise the consumption of the former results in a net welfare gain.

The strength of this argument is reinforced by the fact that low-income households may be willing to pay but cannot afford to. The connection fee is typically $100. Although this comes to a less than $0.03 a day ($0.78 a month) if amortized over 20 years, and thus is well within the affordability of even most poor households, the absence of credit markets means these households are not in a position to spread the payment in this way. The two solutions are to fill the gap in the credit market and to subsidize the connection fee for poorer households. As argued earlier, the market can be segmented by the connection lag, allowing an increase in both the utility's financial performance and the economic return to the project.

But, as this report stresses, decision making is context specific. Many African countries have yet to embark on RE. In these cases, connection costs will be high, and many areas may not be connected to the grid for some years. The emphasis in the coming years will be on putting in place the basic infrastructure for grid connections with an eye on financial sustainability, which will imply relatively low community connection rates, increasing coverage by extensive rather than intensive growth.

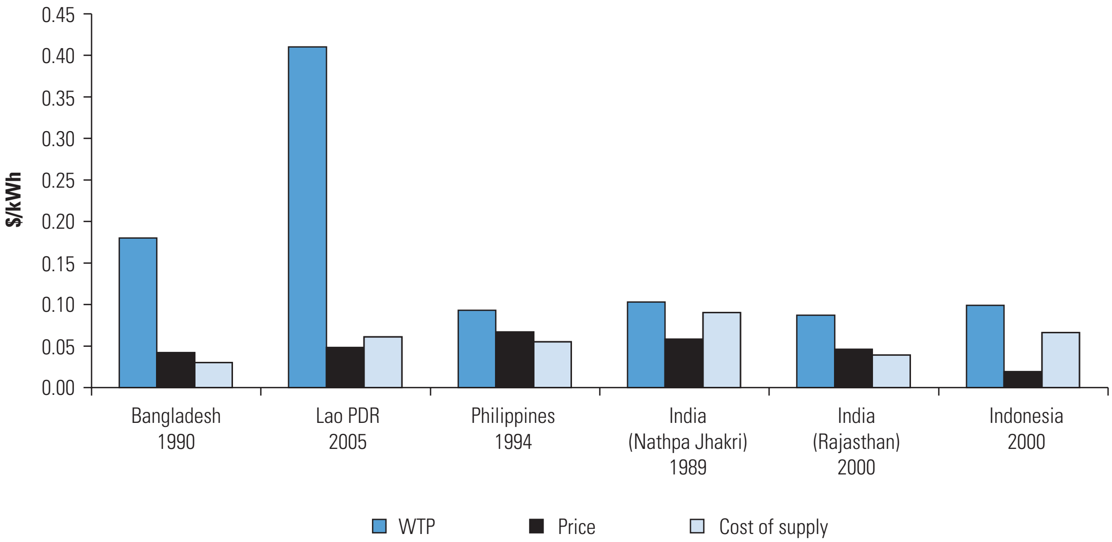
At the same time, there will be areas beyond the reach of the grid that will be suitable for off-grid connections. In these schemes the subsidy element can be tilted toward the bottom end to increase connection rates. A second group of countries, mostly in Asia, is still struggling to establish the financial sustainability of its grid programs. The analysis shows that the market can bear tariff increases, though these may be politically unpopular.

But there is another group of countries that has put the utility on a sound financial footing and is in a position to reap the full potential benefits of RE. These benefits will be realized by shifting to intensive growth, which is made possible by reduced or monthly connection charges for late connectors, increasing and diversifying patterns of electricity use through consumer education, and providing support to productive uses.

## Off-Grid Connections

The rate of return to RET investments can be expected to be lower than that in grid electricity be-

**Figure 5.3: Willingness to Pay Exceeds Supply Cost**




*Source:* Project documents and IEG calculations.
*Note:* kWh = kilowatt hours; WTP = willingness to pay.

cause, at present, the costs are usually higher and the benefits lower. To clarify the statement on costs: the cost of providing electricity to the community should be lower using a RET than connecting that community to the grid (otherwise it should be part of a grid-extension program), but the cost per kilowatt hour will likely be greater than the cost for those who are connected to the grid. The benefits are lower because the capacity is less, so off-grid connections support fewer appliances and possibly provide fewer hours of lighting. But of course the choice for these communities is not between grid and off-grid, but among grid, kerosene, and car batteries.

For example, the IEG analysis of survey data for Sri Lanka showed that the median household total wattage of all lightbulbs used is 360 watts for grid-connected households and just 60 watts for SHS users.[13] In addition, households with SHS own practically no electrical appliances other than a TV, whereas a large proportion of grid-connected households own a range of appliances including water heaters, irons, and grinders. The same survey found that satisfaction with quality and quantity of electricity supply is much lower for households connected by SHS: nearly all (92 percent) of such households say they need more kilowatt hours to cover their needs, which is the case for less than a third of grid-connected households.

*Africa generally is far from having the infrastructure needed to build a rural grid, and many Asian countries still struggle with financial sustainability of their grids.*

In addition, off-grid projects have suffered from technical problems resulting from lack of technical capacity in rural areas and the logistical difficulties of servicing equipment (see box 5.4). These problems mean systems fall into disuse or run below planned capacity, further reducing the return. For example, IEG reanalyzed the rate of return for off-grid investments under the Lao PDR Southern Provinces Rural Electrification Project; the review by Bank operational staff estimated the ex post ERR to be 26 percent. But allowing for the technical problems reduced the return to 16 percent (which fell to –9.4 percent once the revaluation of consumer surplus, discussed at the beginning of this chapter, was applied).

**Box 5.4: Technical Problems Reduce the Benefits from Off-Grid Investments**

More than 6,000 households were given off-grid connections under the Southern Provinces Rural Electrification Project in Lao PDR, virtually all of them SHSs. This went beyond the appraisal target by nearly one-third.

However, a survey undertaken in Vientiane Province in 2006 revealed a number of operational problems. More than 80 percent of SHSs were not working properly or were working at a low level of service. The large majority of controllers were no longer working: 40 percent were simply missing, and most of the remainder had been bypassed so the panel was connected directly to the battery. The resultant power fluctuations shorten battery life (which was only two to three years anyway), as does excess use by connecting too many lights or appliances. As a result, nearly all batteries were past their useful life, with more than half being more than four years old. Most households have not replaced these batteries (which cost $20–50), but continue to charge them, getting just 30 minutes to an hour's electricity a day, which is a great reduction in project benefits.

In Thailand, 59 micro hydroelectricity schemes have been implemented. Of these, only 25 remain in operation. Most of those that are now defunct ceased operation when the grid reached the village. There are a number reasons for the preference for grid electricity: (1) the lower cost to villagers, which is heavily subsidized but also does not require community management, which micro hydro does; (2) technical problems with micro hydro, in part arising from the last reason; and (3) "a tragedy of the commons" whereby households consume "excess electricity" by using rice cookers and heaters, causing shortages.

*Source:* Greacan 2003.

*In all cases where projects have both grid and off-grid components, the ERR is greater for the grid component.*

This statement is supported by looking at Bank projects that contain both grid and off-grid components (appendix table B.20). In virtually all cases, the ERR for grid connections is greater than that for the off-grid component. This observation raises a question about the use of the results of economic analysis. If a project has one component with a high return and another with a low return, the policy implication is that funds should be diverted to the high-return activity until the rates of return are equalized.

It might be argued that off-grid investments serve other environmental or social objectives, but these should be explicitly factored into the analysis by the valuation of environmental benefits and by using social weights (reflecting policy makers' preferences) for different groups. An alternative argument might be that these are small programs that enable learning by doing, which, together with technological developments, will improve competitiveness. This argument is not, however, found in the project documents.

# Chapter 6


Rural Chinese village with electric poles. (Photo from the World Bank Photo Library.)

# Conclusion and Lessons Learned

## Answering the Evaluation Questions

### *What is the rationale for Bank support of RE?*

Why does the Bank support RE? The policy paper "Rural Electrification" (World Bank 1975) argued that investments had to be justified by the benefits to consumers and increased production. If the resulting return on investment (ERR) was insufficient, a case might be made on social grounds. However, it should be recognized that electricity is not a necessity like water or health, although it does benefit consumers and results in increased production. In contrast, the two 1993 policy papers, which were not specifically concerned with RE, proceed straight to their core subject matter without offering a rationale for energy investments.

More recent policy papers have stressed the links between energy and poverty. Most notably, *Rural Energy and Development* (World Bank 1996) documented the time burden and adverse health implications of relying on biomass fuels. The 2001 sector board paper begins with the bolder statement: "Efficient and clean energy supply is central to the reduction of poverty through many and varied linkages, as well as being important for economic growth."

Alternatively, project documents can be examined to understand the rationale for Bank lending. The majority of projects take the benefits as self-evident, as the objectives are restricted to the outputs of improved access or institutional development. A minority of RE projects have welfare objectives, the most common of which are increasing growth and a general improvement in welfare (cited in the objectives of 21 percent and 19 percent of energy projects—that is, excluding multisectoral investments—respectively; appendix table B.3). A final perspective is given by the benefits included in the project analysis.

Quantification of benefits is most commonly restricted to lighting benefits, with a small number of analyses including TV viewing. Other benefits are sometimes mentioned but not quantified.

The largely private quantified benefits appear rather distant from the broad claim that clean energy is central to poverty reduction and economic growth. This is especially so because the poor are still excluded from direct benefits, and few Bank projects have taken explicit steps to include them.

In summary, the economic case for investments in RE is proven, provided technical problems in service provision are adequately addressed. But the evidence base for the links between RE and poverty remains thin. Improved evaluation tools—of the sort already adopted in some recent projects—are needed to build the case that RE should be a priority for a poverty-oriented lending institution.

### *What has been the growth in coverage of RE in countries receiving Bank support? To what extent has the Bank contributed to these connections? What is the distributional profile of those taking connections? What are the unit costs of connection by type of supply to the user and to the supplier?*

RE has increased substantially in many countries receiving Bank support. Where the Bank has had a series of dedicated projects, it has made a significant contribution to increases in coverage.

Support for electrification has mostly been provided to communities where connection was deemed most cost-effective, leaving remote communities—often among the poorest—the last ones connected. This pattern is at best only partially overcome by the development of off-grid electricity sources, but per unit costs of off-grid sources are significantly higher than the price of electricity on the grid. Once a community is connected, however, electricity from both grid and off-grid sources represents substantial cost savings compared with kerosene. However, the connection charge barrier prevents many of the poorest from connecting once electricity is available, and few Bank projects have introduced mechanisms to help overcome this barrier.

### What are the direct economic benefits from RE? Who gains these benefits? What are the indirect economic benefits (employment generation), and who gains them? How does the distribution of benefits change as coverage of electrification programs expands?

Direct economic benefits from RE occur as electricity supply lowers the cost of energy to the user, resulting in an increase in consumer surplus. Such benefits tend to favor the well-off, because connection charges and tariffs are often prohibitive for the poorest. The pattern of electrification favors the non-poor, but distribution becomes more equitable as electrification coverage expands.

RE does not in general drive industrial development, but it can spur growth of home businesses. Such businesses mostly employ family labor and increase their hours once electricity becomes available. Electrification thus provides a small, but not negligible, boost to the incomes of some households. However, the evidence base on this point remains thin.

### What is the impact of RE on time use, and what are the welfare implications of these changes for health, education, and increased leisure?

Electrification extends waking hours, with a principle impact being more time spent watching television. Time is also saved from chores, but this gain is limited, and the time spent in home businesses increases. Health clinics remain open longer. Again, more evidence is needed to substantiate these findings.

### How does RE affect the quality of health and education services?

RE benefits the quality of health services and lowers costs by extending opening hours and significantly strengthening the cold chain for vaccines—though it does not increase the extent to which such services are offered. Electrification was also found to reduce worker absenteeism in both health clinics and schools by improving living conditions and morale. However, the cases studied are few, so further analysis is required.

### How do the aggregate private benefits and the public good benefits compare with the WTP? What is the distributional profile of these benefits?

The WTP internalizes many of the benefits and exceeds the supply cost. The benefits, like electricity consumption, favor the better-off.

### What are the private and social rates of return from investments in RE?

The private returns to electrification are high—as indicated by the fact that most, if not all, households that can afford electricity take it once it becomes available. Great value is placed on the improved lighting it makes available and the possibility of watching TV. Because these benefits are mostly private, the economic and social returns would be close if electricity prices reflected economic cost. The divergence between the two returns emerges because of the subsidy element and makes a case for reducing the amount of that subsidy, which could be better targeted to getting poorer households connected.

## Lessons Learned

It is difficult to generalize about RE because both costs and benefits are context specific. However, some broad statements can be made.

- RE investments have often generated sufficient benefits for the investment to be warranted from an economic standpoint.
- The value of these benefits to households is above the average supply cost, so cost-recovery tariff levels are achievable, even if

they are politically unpopular in countries with a history of low tariffs.

- Analysis of feasible tariff levels can be informed by good quality economic analysis of the sort pioneered by the Philippines ESMAP study (ESMAP 2003). But the quality of that study is not uniformly replicated, as the quality of project-level analysis is uneven, with apparent weak quality control.
- The evidence base remains weak for many of the claimed benefits of RE. Tailor-made surveys, designed to test these benefits, need to be built into a greater number of Bank projects and designed so they allow rigorous testing of the impact of electrification.
- Countries with low coverage rates, which are now mostly in Africa, still have to make investments in generation, transmission, and distribution, which implies relatively high average supply costs and low coverage, increasing slowly by extensive growth for some years to come. The principal challenge is to balance financial sustainability with growing coverage, requiring efficiency by limiting system losses. Because grid connections will grow slowly, many areas may be eligible for off-grid connections, but the logistics of maintaining technical quality will be challenging.
- Some countries in Asia and Latin America are reaching the limits of grid extension. Further increases in coverage require intensive growth, which requires instruments designed for that purpose, or off-grid schemes, which need design improvements if they are to be financially sustainable.
- There are project design options that have been uncommon but that would enhance project benefits. These include financing schemes for connection charges, consumer education, and support for productive uses.

Turbine on stream near village generating energy as part of hydro scheme.
(Photo from the World Bank Photo Library.)

# Appendixes

# APPENDIX A: RURAL ELECTRIFICATION PORTFOLIO

**Table A.1: Project Portfolio Data**

| Country | Project | Approval date | Planned closure date | Actual closure date | IDA funding amount ($ millions) | IBRD funding amount ($ millions) | GEF funding amount ($ millions) | Prototype carbon fund amount ($ millions) |
|---|---|---|---|---|---|---|---|---|
| **Africa** | | | | | | | | |
| Benin | Energy Services Delivery Project | 2005 | 2009 | | 45.0 | | | |
| Burundi | Energy Sector Rehabilitation Project | 1991 | 1996 | 1999 | 20.4 | | | |
| Cape Verde | Energy and Water Sector Reform and Development Project | 1999 | 2004 | | 17.5 | | 4.7 | |
| Eritrea | Power Distribution and Rural Electrification | 2005 | 2009 | | 50.0 | | | |
| Ethiopia | Energy 2 | 1998 | 2004 | 2006 | 200.0 | | | |
| Ethiopia | Energy Access Project | 2003 | 2009 | | 132.7 | | 4.9 | |
| Ethiopia | Electricity Access (Rural) Expansion | 2006 | 2010 | | 133.4 | | | |
| Ghana | Northern Grid Extension Project | 1987 | 1992 | 1992 | 6.9 | | | |
| Ghana | Sixth Power Project | 1990 | 1996 | 1998 | 9.2 | | | |
| Ghana | National Electrification Project | 1993 | 1998 | 2000 | 80.0 | | | |
| Guinea | Decentralized Rural Electrification Project | 2003 | 2008 | | 5.0 | | 2.0 | |
| Guinea-Bissau | Energy Project | 1991 | 1995 | 1998 | 13.3 | | | |
| Kenya | Geothermal Development and Energy Pre-Investment Project | 1988 | 1994 | 1996 | | 41.3 | | |
| Madagascar | Energy Sector Development Project | 1996 | 2002 | 2006 | 44.2 | | | |
| Malawi | Power V Project | 1992 | 1998 | 2000 | 91.5 | | | |
| Malawi | Infrastructure Services Project | 2006 | 2012 | | 40.0 | | | |
| Mali | Household Energy and Universal Access | 2004 | 2009 | | 35.7 | | 3.5 | |
| Mauritania | Energy, Water, and Sanitation Sector Reform Technical Assistance | 2000 | 2003 | 2005 | 9.9 | | | |
| Mozambique | Energy Reform and Access | 2004 | 2008 | | 40.3 | | 3.1 | |
| Niger | Energy Project | 1988 | 1995 | 1997 | 17.5 | | | |
| Nigeria | Privatization Support Project | 2001 | 2008 | | 114.3 | | | |
| Nigeria | National Energy Development Project | 2006 | 2008 | | 172.0 | | 1.0 | |
| Senegal | Electricity Services for Rural Areas Project | 2005 | 2009 | | 29.9 | | 5.0 | |
| Tanzania | Songo Songo Gas Development and Power Generation | 2002 | 2006 | 2008 | 183.0 | | | |
| Uganda | Energy for Rural Transformation | 2002 | 2009 | | 49.2 | | 12.1 | |
| **East Asia and Pacific** | | | | | | | | |
| Cambodia | Rural Electrification and Transmission | 2004 | 2009 | | 40.0 | | 5.8 | |
| China | Daguangba Multipurpose Project | 1992 | 1998 | 1999 | | 69.3 | | |
| China | Tarim Basin Project | 1992 | 2008 | 2008 | 128.0 | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| China | Second Red Soils Area Development Project | 1993 | 2001 | 2002 | 150.0 | | |
| China | Southwest Poverty Reduction Project | 1995 | 2002 | 2006 | 200.0 | 47.5 | |
| China | Western Poverty Reduction—Gansu and Inner Mongolia | 1999 | 2006 | 2006 | 100.0 | 60.0 | |
| China | Renewable Energy Development | 1999 | 2008 | | 100.0 | 35.0 | |
| China | Hubei Hydropower Development in Poor Areas | 2002 | 2009 | | | 105.0 | |
| China | Renewable Energy Scale-Up Program | 2005 | 2011 | | | 87.0 | 40.2 |
| China | Follow Up to Renewable Energy Scale-Up | 2006 | 2011 | | | 86.3 | |
| Indonesia | Power Sector Efficiency Project | 1989 | 1995 | 1996 | | 309.3 | |
| Indonesia | Rural Electrification Project I | 1990 | 1994 | 1995 | | 261.3 | |
| Indonesia | Second Rural Electrification Project | 1995 | 1999 | 2000 | | 244.7 | |
| Indonesia | Solar Homes System Project | 1997 | 2002 | 2004 | | 0.1 | 4.5 |
| Lao PDR | Southern Provinces Electrification Project | 1987 | 1993 | 1994 | 0.5 | 25.9 | |
| Lao PDR | Provincial Grid Integration Project | 1992 | 1998 | 1999 | 34.9 | | |
| Lao PDR | Southern Provinces Rural Electrification Project | 1998 | 2004 | 2005 | 34.7 | | 0.7 |
| Lao PDR | Rural Electrification Phase 1 | 2006 | 2010 | | 10.0 | | 3.8 |
| Malaysia | Rural Electrification Project | 1982 | 1986 | 1988 | | 36.3 | |
| Malaysia | Eleventh Power Project | 1984 | 1989 | 1990 | | 70.0 | |
| Papua New Guinea | Yonki Hydroelectric Project | 1986 | 1993 | 1993 | | 28.5 | |
| Philippines | Rural Electrification Revitalization Project | 1992 | 1997 | 1998 | | 54.6 | |
| Philippines | Leyte Luzon Geothermal Project | 1994 | 1999 | 2000 | | 177.3 | 31.2 |
| Philippines | Transmission Grid Reinforcement Project | 1996 | 2001 | 2004 | | 203.9 | |
| Philippines | Rural Power Project | 2004 | 2010 | | | 10.0 | 9.0 |
| Philippines | Electric Cooperative System Loss Reduction Project | 2004 | 2011 | | | | 12.0 |
| Thailand | Second Accelerated Rural Electrification Project | 1980 | 1986 | 1987 | | 75.0 | |
| Thailand | Provincial Power Distribution Project | 1983 | 1987 | 1988 | | 30.6 | |
| Thailand | Power Transmission Project | 1988 | 1993 | 1993 | | 110.0 | |
| Thailand | Distribution System Reinforcement Project | 1995 | 1999 | 1999 | | 47.6 | |
| Vietnam | Power Development Project | 1996 | 2000 | 2000 | 179.6 | | |
| Vietnam | Rural Energy | 2000 | 2007 | | 150.0 | | |
| Vietnam | Community-Based Rural Infrastructure | 2001 | 2008 | | 102.8 | | |
| Vietnam | System Efficiency, Equitization, and Renewables | 2002 | 2008 | | 225.0 | | 4.5 |
| Vietnam | Second Rural Energy Project | 2005 | 2012 | | 220.0 | | 5.3 |
| **Europe and Central Asia** | | | | | | | |
| Albania | Power Transmission and Distribution | 1996 | 2001 | 2003 | 17.7 | | |
| Portugal | Tras os Montes Regional Development | 1989 | 1997 | 1997 | | 30.7 | |

(Table continues on next page)

**Table A.1: Project Portfolio Data *(continued)***

| Country | Project | Approval date | Planned closure date | Actual closure date | IDA funding amount ($ millions) | IBRD funding amount ($ millions) | GEF funding amount ($ millions) | Prototype carbon fund amount ($ millions) |
|---|---|---|---|---|---|---|---|---|
| **Latin America and the Caribbean** | | | | | | | | |
| Argentina | Renewable Energy in the Rural Market Project | 1999 | 2009 | | | 30.0 | 7.2 | |
| Bolivia | Decentralized Infrastructure for Rural Transformation | 2003 | 2008 | | 20.0 | | | |
| Brazil | Rural Poverty Alleviation—Sergipe | 2002 | 2006 | | | 20.8 | | |
| Brazil | Sergipe Rural Poverty Alleviation | 1995 | 2001 | 2001 | | 36.0 | | |
| Brazil | Pernambuco Rural Poverty Reduction | 2001 | 2010 | | | 30.1 | | |
| Brazil | Northeast Rural Poverty Alleviation Project—Pernambuco | 1997 | 2001 | 2002 | | 36.0 | | |
| Brazil | Ceara Rural Poverty-Alleviation Project | 1995 | 2001 | 2001 | | 70.0 | | |
| Brazil | Ceara Rural Poverty-Alleviation Project | 2001 | 2009 | | | 37.5 | | |
| Brazil | Itaparica Resettlement and Irrigation Project | 1988 | 1995 | 1998 | | 132.0 | | |
| Brazil | Bahia State Integrated Project: Rural Poverty | 2006 | 2011 | | | 54.4 | | |
| Brazil | Bahia Rural Poverty Reduction | 2001 | 2005 | 2005 | | 54.4 | | |
| Brazil | Irrigation Subsector Project | 1988 | 1994 | 1998 | | 195.0 | | |
| Brazil | Rural Poverty Alleviation—Paraiba | 1998 | 2003 | 2006 | | 60.0 | | |
| Brazil | Northeast Rural Poverty-Alleviation Program—Muranhao | 1998 | 2003 | 2004 | | 80.0 | | |
| Brazil | Rural Poverty Reduction—Minas Gerais | 2006 | 2010 | | | 35.0 | | |
| Brazil | Rural Electrification | 1984 | 1990 | 1990 | | 222.0 | | |
| Brazil | Energy Sector Reform Loan | 2002 | 2003 | 2003 | | 454.6 | | |
| Brazil | Electrobras 1st Distribution | 1982 | 1988 | 1990 | | 172.1 | | |
| Brazil | Electrobras 2nd Distribution | 1984 | 1989 | 1992 | | 237.0 | | |
| Chile | Infrastructure for Territorial Development | 2005 | 2010 | | | 50.3 | | |
| Colombia | Village Electrification Project | 1981 | 1986 | 1988 | | 30.1 | | |
| Colombia | Private Sector Energy Development Project | 1996 | 2003 | 2003 | | 249.3 | | |
| Colombia | Jepirachi Carbon Offset | 2003 | 2020 | | | | | 3.2 |
| Dominican Republic | Power Sector Technical Assistance | 2004 | 2009 | | | 7.3 | | |
| Ecuador | Power and Communications Sectors Modernization and Rural Services | 2001 | 2007 | | | 23.0 | 2.8 | |
| Honduras | Rural Infrastructure Project | 2006 | 2010 | | 47.0 | | 2.3 | |
| Mexico | Decentralization and Regional Development | 1991 | 1996 | 1996 | | 350.0 | | |
| Mexico | Renewable Energy for Agriculture | 2000 | 2004 | 2006 | | 13.7 | 8.9 | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Mexico | Waste Management and Carbon Offset | 2005 | 2015 | | | | | 0.9 |
| Nicaragua | Off-Grid Rural Electrification | 2003 | 2009 | | 12.0 | | 4.0 | |
| Panama | Social Investment Fund | 1997 | 2002 | 2004 | | 21.9 | | |
| Panama | Utilities Restructuring Technical Assistance | 1998 | 2001 | 2004 | 16.0 | 12.7 | | |
| Peru | Social Development and Compensation Fund Project | 1993 | 1997 | 1997 | | 100.0 | | |
| Peru | Second Social Development and Compensation Fund | 1997 | 1999 | 2000 | | 124.4 | | |
| Peru | Rural Electrification Project | 2006 | 2013 | | | 50.0 | 10.0 | |
| **Middle East and North Africa** | | | | | | | | |
| Jordan | Energy Development Project | 1984 | 1988 | 1991 | 29.3 | | | |
| Jordan | 6th Power Project | 1986 | 1991 | 1992 | | 27.5 | | |
| Morocco | Village Electrification Project | 1979 | 1984 | 1986 | | 36.3 | | |
| Morocco | Second Rural Electrification Project | 1991 | 1997 | 1997 | | 36.5 | | |
| Morocco | Irrigation-Based Community Development | 2001 | 2008 | | | 32.6 | | |
| Morocco | Integrated Solar Combined Cycle Power Project | 2007 | 2009 | | | | 43.2 | |
| Tunisia | 4th Power Project | 1984 | 1989 | 1991 | | 21.5 | | |
| **South Asia** | | | | | | | | |
| Bangladesh | Rural Electrification Project | 1981 | 1989 | 1990 | 49.4 | | | |
| Bangladesh | Second Rural Electrification Project | 1985 | 1991 | 1993 | 80.1 | | | |
| Bangladesh | Third Rural Electrification | 1990 | 1998 | 2000 | 110.2 | | | |
| Bangladesh | Rural Electrification and Renewable Energy Development | 2002 | 2008 | | 191.0 | | 8.2 | |
| India | Third Rural Electrification Project | 1982 | 1986 | 1988 | | 295.5 | | |
| India | Maharashtra | 1989 | 1997 | 1999 | | 336.6 | | |
| India | Nathpa Jhakri Power Project | 1989 | 1998 | 2002 | | 427.0 | | |
| India | Renewable Resources Development Project | 1993 | 2000 | 2002 | 110.4 | 75.0 | 26.2 | |
| India | Second Renewable Energy | 2000 | 2008 | | 50.0 | 80.0 | 5.0 | |
| India | The Rajasthan Power Sector Restructuring Project | 2001 | 2005 | 2006 | | 166.2 | | |
| Nepal | Power Sector Efficiency Project I | 1992 | 1998 | 1999 | 56.5 | | | |
| Nepal | Power Development | 2003 | 2009 | | 75.6 | | | |
| Pakistan | Private Tubewell Development Project | 1989 | 1995 | 1995 | 35.3 | | | |
| Pakistan | Rural Electrification I | 1990 | 1996 | 1997 | 37.0 | 123.0 | | |
| Pakistan | Transmission Extension and Reinforcement | 1990 | 1996 | 1997 | | 160.4 | | |
| Sri Lanka | Energy Services Delivery Project | 1997 | 2003 | 2003 | 22.1 | | 5.7 | |
| Sri Lanka | Renewable Energy for Rural Economic Development Project | 2002 | 2008 | | 22.1 | | 5.7 | |

*Note:* IBRD = International Bank for Reconstruction and Development; IDA = International Development Association; GEF = Global Environment Facility.

# APPENDIX B: STATISTICAL OVERVIEW OF PORTFOLIO

**Table B.1: Number and Percentage of Projects by Region and Period**

| | Number of projects | | | Percentage | | |
|---|---|---|---|---|---|---|
| | 1980–95 | 1996–2006 | Total | 1980–95 | 1996–2006 | Total |
| Entire RE portfolio | | | | | | |
| Latin America and Caribbean | 10 | 25 | 35 | 19.2 | 36.8 | 29.2 |
| Middle East and North Africa | 5 | 2 | 7 | 9.6 | 2.9 | 5.8 |
| Sub-Saharan Africa | 8 | 17 | 25 | 15.4 | 25.0 | 20.8 |
| South Asia | 11 | 6 | 17 | 21.2 | 8.8 | 14.2 |
| East Asia and Pacific | 17 | 17 | 34 | 32.7 | 25.0 | 28.3 |
| Europe and Central Asia | 1 | 1 | 2 | 1.9 | 1.5 | 1.7 |
| Total | 52 | 68 | 120 | 100 | 100 | 100 |
| Energy sector only | | | | | | |
| Latin America and Caribbean | 4 | 10 | 14 | 10.0 | 21.7 | 16.3 |
| Middle East and North Africa | 5 | 1 | 6 | 12.5 | 2.2 | 7.0 |
| Sub-Saharan Africa | 8 | 13 | 21 | 20.0 | 28.3 | 24.4 |
| South Asia | 10 | 6 | 16 | 25.0 | 13.0 | 18.6 |
| East Asia and Pacific | 13 | 15 | 28 | 32.5 | 32.6 | 32.6 |
| Europe and Central Asia | 0 | 1 | 1 | 0.0 | 2.2 | 1.2 |
| Total | 40 | 46 | 86 | 100 | 100 | 100 |

**Table B.2: Number and Percentage of Projects by Rating and Period**

| | Number of projects | | | Percentage | | |
|---|---|---|---|---|---|---|
| | 1980–95 | 1996–2006 | Total | 1980–95 | 1996–2006 | Total |
| Entire RE portfolio | | | | | | |
| Highly satisfactory | 4 | 1 | 5 | 7.7 | 1.0 | 7.0 |
| Satisfactory | 27 | 10 | 37 | 51.9 | 52.6 | 52.1 |
| Moderately satisfactory | 7 | 2 | 9 | 13.5 | 10.5 | 12.7 |
| Moderately unsatisfactory | 3 | 1 | 4 | 5.8 | 5.3 | 5.6 |
| Unsatisfactory | 11 | 5 | 16 | 21.2 | 26.3 | 22.5 |
| Total | 52 | 19 | 71 | 100 | 100 | 100 |
| Energy sector only | | | | | | |
| Highly satisfactory | 3 | 1 | 4 | 7.5 | 9.1 | 7.8 |
| Satisfactory | 20 | 5 | 25 | 50.0 | 45.5 | 49.0 |
| Moderately satisfactory | 5 | 1 | 6 | 12.5 | 9.1 | 11.8 |
| Moderately unsatisfactory | 3 | 0 | 3 | 7.5 | 0 | 5.9 |
| Unsatisfactory | 9 | 4 | 13 | 22.5 | 36.4 | 25.5 |
| Total | 40 | 11 | 51 | 100 | 100 | 100 |

*Source:* IEG ratings database.

*Note:* No projects were rated unsatisfactory. Some totals do not equal exactly 100 because of rounding.

**Table B.3: Proportion of Projects by Objective and Period**

| Objective | By sector: Excluding multisector | By sector: Multisector | 1980–95 | 1996–2006 | All projects |
|---|---|---|---|---|---|
| Increase general welfare | 0.19 | 0.26 | 0.15 | 0.25 | 0.21 |
| Increase incomes, economic growth | 0.21 | 0.53 | 0.21 | 0.37 | 0.30 |
| Reduce poverty | 0.07 | 0.59 | 0.13 | 0.28 | 0.22 |
| Improve health | 0.00 | 0.03 | 0.02 | 0.00 | 0.01 |
| Increase agricultural production | 0.03 | 0.18 | 0.13 | 0.03 | 0.08 |
| Increase industrial/SME production | 0.03 | 0.03 | 0.02 | 0.04 | 0.03 |
| Beneficial environmental effects | 0.30 | 0.06 | 0.17 | 0.28 | 0.23 |
| Increase access: general | 0.15 | 0.03 | 0.12 | 0.12 | 0.12 |
| Increase access: rural | 0.37 | 0.06 | 0.27 | 0.29 | 0.28 |
| Support electricity supply—general | 0.31 | 0.03 | 0.33 | 0.16 | 0.23 |
| Support electricity supply—poor/disadvantaged | 0.01 | 0.00 | 0.02 | 0.00 | 0.01 |
| Support electricity supply—rural | 0.19 | 0.00 | 0.15 | 0.12 | 0.13 |
| Improve sector efficiency | 0.36 | 0.12 | 0.31 | 0.28 | 0.29 |
| Develop energy resources | 0.08 | 0.03 | 0.10 | 0.04 | 0.07 |
| Promote RET | 0.28 | 0.06 | 0.06 | 0.34 | 0.22 |
| Institutional development | 0.42 | 0.15 | 0.42 | 0.28 | 0.34 |
| Capacity building of utility | 0.29 | 0.06 | 0.38 | 0.10 | 0.23 |
| Capacity building: pricing | 0.08 | 0.03 | 0.13 | 0.01 | 0.07 |
| Capacity building: private sector | 0.08 | 0.03 | 0.04 | 0.09 | 0.07 |
| Capacity building: RET | 0.06 | 0.00 | 0.04 | 0.04 | 0.04 |
| Capacity building: other | 0.09 | 0.41 | 0.17 | 0.19 | 0.18 |
| Promote private sector involvement | 0.35 | 0.12 | 0.10 | 0.43 | 0.28 |
| Third sector (NGOs/CSOs/ECs) involvement | 0.10 | 0.32 | 0.12 | 0.21 | 0.17 |
| Nonelectrification objective | 0.00 | 0.65 | 0.15 | 0.21 | 0.18 |

*Note:* CSO = civil society organization; EC = electric cooperative; NGO = nongovernmental organization; RET = renewable energy technology; SME = small and medium enterprise.

**Table B.4: Proportion of Projects by Component and Period**

| Component | Proportion of projects 1980–95 | 1996–2006 | Total |
|---|---|---|---|
| Hydro plant | 0.13 | 0.03 | 0.08 |
| Grid expansion | 0.88 | 0.44 | 0.63 |
| Off-grid generation | 0.00 | 0.16 | 0.09 |
| RET—wind, mini hydro, SHS | 0.13 | 0.46 | 0.32 |
| Other (dispatch, substations, etc.) | 0.40 | 0.10 | 0.23 |
| Rehabilitation | 0.29 | 0.18 | 0.23 |
| System loss reduction | 0.02 | 0.01 | 0.02 |
| Facilities n.e.s. | 0.19 | 0.03 | 0.10 |
| Independent grid | 0.00 | 0.04 | 0.03 |
| Study—tariff policy | 0.13 | 0.07 | 0.10 |
| Study—project feasibility | 0.19 | 0.06 | 0.12 |
| Study—other | 0.38 | 0.26 | 0.32 |
| Technical assistance: staff/management/IT | 0.56 | 0.82 | 0.71 |
| Technical assistance: engineering design/increase efficiency | 0.33 | 0.21 | 0.26 |
| Technical assistance: commercialization | 0.06 | 0.29 | 0.19 |
| Reform/Create government agency | 0.04 | 0.09 | 0.07 |
| Policy development—RET | 0.02 | 0.21 | 0.13 |
| Policy development—general | 0.08 | 0.16 | 0.13 |
| Procure equipment, instruments, software | 0.33 | 0.15 | 0.23 |
| Consumer subsidies | 0.00 | 0.01 | 0.01 |
| Credit to private providers | 0.04 | 0.16 | 0.11 |
| Open market to private tenders | 0.02 | 0.03 | 0.03 |
| Finance pilot projects | 0.08 | 0.38 | 0.25 |
| End user training/education | 0.00 | 0.19 | 0.11 |
| Resettlement/compensation | 0.08 | 0.10 | 0.09 |
| Demand-side management | 0.00 | 0.12 | 0.07 |
| Nonelectrification activities | 0.25 | 0.26 | 0.26 |

*Note:* IT = information technology; n.e.s. = not otherwise specified; RET = renewable energy technology; SHS = solar home system.

**Table B.5: Number and Percentage of Projects by Period and Objective Category**

| | Number of projects | | | Percentage | | |
|---|---|---|---|---|---|---|
| | 1980–95 | 1996–2006 | Total | 1980–95 | 1996–2006 | Total |
| Entire RE portfolio | | | | | | |
| Improve welfare | 26 | 46 | 72 | 50.0 | 67.6 | 60.0 |
| Energy supply | 39 | 49 | 88 | 75.0 | 72.1 | 73.3 |
| Institutional development | 39 | 51 | 90 | 75.0 | 75.0 | 75.0 |
| Nonelectrification objective | 8 | 14 | 22 | 15.4 | 20.6 | 18.3 |
| Total | 52 | 68 | 120 | 100 | 100 | 100 |
| Energy sector only | | | | | | |
| Improve welfare | 15 | 30 | 45 | 37.5 | 65.2 | 52.3 |
| Energy supply | 38 | 42 | 80 | 95.0 | 91.3 | 93.0 |
| Institutional development | 33 | 34 | 67 | 82.5 | 73.9 | 77.9 |
| Nonelectrification objective | 0 | 0 | 0 | 0.0 | 0.0 | 0.0 |
| Total | 40 | 46 | 86 | 100 | 100 | 100 |

**Table B.6: Number and Percentage of Projects by Period and Component Category**

| | Number of projects | | | Percentage | | |
|---|---|---|---|---|---|---|
| Component | 1980–95 | 1996–2006 | Total | 1980–95 | 1996–2006 | Total |
| Infrastructure | 49 | 49 | 98 | 94.2 | 72.1 | 81.7 |
| Institutional development | 41 | 61 | 102 | 78.8 | 89.7 | 85.0 |
| Project financing mechanisms | 7 | 34 | 41 | 13.5 | 50.0 | 34.2 |
| Consumer relations | 4 | 26 | 30 | 7.7 | 38.2 | 25.0 |
| Nonelectrification activities | 13 | 18 | 31 | 25.0 | 26.5 | 25.8 |
| Total number of projects | 52 | 68 | 120 | 100 | 100 | 100 |

**Table B.7: Proportion of Projects by Region and Component Category**

| Region | Infrastructure | Institutional development | Other electrification components | Other electrification components | Non-electrification activities |
|---|---|---|---|---|---|
| Latin America and Caribbean | 0.57 | 0.74 | 0.54 | 0.23 | 0.43 |
| Middle East and North Africa | 1.00 | 0.86 | 0.00 | 0.00 | 0.29 |
| Sub-Saharan Africa | 0.84 | 1.00 | 0.24 | 0.32 | 0.32 |
| South Asia | 1.00 | 0.76 | 0.41 | 0.29 | 0.06 |
| East Asia and Pacific | 0.91 | 0.88 | 0.24 | 0.26 | 0.12 |
| Europe and Central Asia | 1.00 | 1.00 | 0.50 | 0.00 | 0.50 |
| Total | 0.82 | 0.85 | 0.34 | 0.25 | 0.26 |

*Note:* Figures are proportions expressed as between 0 and 1 rather than 0 and 100.

**Table B.8: Number and Percentage of Projects by Planned Use and Period**

| | Number of projects | | | Percentage | | |
|---|---|---|---|---|---|---|
| **Planned use** | **1980–95** | **1996–2006** | **Total** | **1980–95** | **1996–2006** | **Total** |
| Residential | 31 | 40 | 71 | 93.9 | 97.6 | 95.9 |
| Agricultural | 24 | 15 | 39 | 72.7 | 36.6 | 52.7 |
| Commercial | 12 | 7 | 19 | 36.4 | 17.1 | 25.7 |
| SME | 17 | 27 | 44 | 51.5 | 65.9 | 59.5 |
| Public | 5 | 22 | 27 | 15.2 | 53.7 | 36.5 |
| Total number of projects | 33 | 41 | 74 | 100 | 100 | 100 |

*Note:* SME = small and medium-size enterprises.

**Table B.9: Number of Projects by Planned Use and Region**

| | Planned use | | | | | |
|---|---|---|---|---|---|---|
| **Region** | **Residential** | **Agricultural** | **Commercial** | **SME** | **Public** | **Total** |
| Latin America and Caribbean | 20 | 14 | 1 | 14 | 12 | 35 |
| Middle East and North Africa | 4 | 2 | 0 | 2 | 2 | 7 |
| Sub-Saharan Africa | 13 | 3 | 2 | 9 | 8 | 25 |
| South Asia | 15 | 11 | 10 | 10 | 4 | 17 |
| East Asia and Pacific | 18 | 8 | 6 | 9 | 1 | 34 |
| Europe and Central Asia | 1 | 1 | 0 | 0 | 0 | 2 |
| Total | 71 | 39 | 19 | 44 | 27 | 120 |

*Note:* SME = small and medium-size enterprises. Totals may not sum across because each project can have more than one planned use.

**Table B.10: Number of Projects On and Off Grid**

| | Number of projects | | | Percentage | | |
|---|---|---|---|---|---|---|
| | **No off grid** | **Off grid** | **Total** | **No off grid** | **Off grid** | **Total** |
| No grid | 5 | 6 | 11 | 7.6 | 18.2 | 11.1 |
| Grid | 61 | 27 | 88 | 92.4 | 81.8 | 88.9 |
| Total | 66 | 33 | 99 | 100.0 | 100.0 | 100.0 |

*Note:* No grid = grid extension was not in project design.

**Table B.11: Projects with an Off-Grid Component by Period**

| | Number of projects | | | Percentage | | |
|---|---|---|---|---|---|---|
| | **1980–95** | **1996–2006** | **Total** | **1980–95** | **1996–2006** | **Total** |
| No off-grid component | 45 | 21 | 66 | 95.7 | 40.4 | 66.7 |
| Off-grid component | 2 | 31 | 33 | 4.3 | 59.6 | 33.3 |
| Total | 47 | 52 | 99 | 100 | 100 | 100 |

*Note:* No off grid = off-grid generation was not in project design.

**Table B.12: Number and Percentage of Projects by Promotional Activities and Approval Period**

| Type of promotional activity | Number of projects 1980–95 | Number of projects 1996–2006 | Number of projects Total | Percentage 1980–95 | Percentage 1996–2006 | Percentage Total |
|---|---|---|---|---|---|---|
| Primary | | | | | | |
| Workshops to educate consumers | 0 | 8 | 8 | 0.0 | 11.8 | 6.7 |
| Newspaper/radio/TV broadcast to educate consumers | 0 | 6 | 6 | 0.0 | 8.8 | 5.0 |
| Demonstrations/village visits | 0 | 1 | 1 | 0.0 | 1.5 | 0.8 |
| Total | 0 | 15 | 15 | 0.0 | 22.1 | 12.5 |
| Secondary | | | | | | |
| Workshops to educate consumers | 0 | 1 | 1 | 0.0 | 1.5 | 0.8 |
| Newspaper/radio/TV broadcast to educate consumers | 4 | 7 | 11 | 7.7 | 10.3 | 9.2 |
| Demonstrations/village visits | 0 | 1 | 1 | 0.0 | 1.5 | 0.8 |
| Total | 4 | 9 | 13 | 7.7 | 13.2 | 10.8 |
| Tertiary | | | | | | |
| Demonstrations/village visits | 0 | 4 | 4 | 0.0 | 5.9 | 3.3 |
| Total | 0 | 4 | 4 | 0.0 | 5.9 | 3.3 |

**Table B.13: Number and Percentage of Projects by Region and Scope**

| Region | Number of projects: Dedicated to RE | Number of projects: Larger energy project w/ RE component | Number of projects: Multisectoral project | Number of projects: Total | Percentage: Dedicated to RE | Percentage: Larger energy project w/ RE component | Percentage: Multisectoral project | Percentage: Total |
|---|---|---|---|---|---|---|---|---|
| Latin America and Caribbean | 8 | 6 | 21 | 35 | 22.9 | 17.1 | 60.0 | 100.0 |
| Middle East and North Africa | 2 | 4 | 1 | 7 | 28.6 | 57.1 | 14.3 | 100.0 |
| Sub-Saharan Africa | 6 | 15 | 4 | 25 | 24.0 | 60.0 | 16.0 | 100.0 |
| South Asia | 8 | 8 | 1 | 17 | 47.1 | 47.1 | 5.9 | 100.0 |
| East Asia and Pacific | 18 | 10 | 6 | 34 | 52.9 | 29.4 | 17.6 | 100.0 |
| Europe and Central Asia | 0 | 1 | 1 | 2 | 0.0 | 50.0 | 50.0 | 100.0 |
| Total | 42 | 44 | 34 | 120 | 35.0 | 36.7 | 28.3 | 100.0 |

*Note:* RE = rural electrification.

**Table B.14: Number and Percentage of Projects by Period and Scope**

| | Number of projects | | | Percentage | | |
|---|---|---|---|---|---|---|
| **Project scope** | **1980–95** | **1996–2006** | **Total** | **1980–95** | **1996–2006** | **Total** |
| Dedicated to RE | 17 | 25 | 42 | 32.7 | 36.8 | 35.0 |
| Larger energy project w/RE component | 23 | 21 | 44 | 44.2 | 30.9 | 36.7 |
| Multisectoral project | 12 | 22 | 34 | 23.1 | 32.4 | 28.3 |
| Total | 52 | 68 | 120 | 100.0 | 100.0 | 100.0 |

*Note:* RE = rural electrification.

**Table B.15: Number of Beneficiaries**

| | Number of beneficiaries | Number of projects for which data available |
|---|---|---|
| Villages | 137,173 | 15 |
| New customers | 35,000 | 1 |
| Rural customers | 383,179 | 6 |
| Off-grid customers | 22,685 | 1 |
| Off-grid villages | 46 | 1 |
| RET-supplied customers | 11,230 | 2 |
| Newly electrified town | 150 | 1 |
| People | 18,600,000 | 13 |
| Households | 17,200,000 | 38 |

*Note:* RET = renewable energy technology.

**Table B.16: Lines and Substations Built**

| | Built | Number of projects for which data available |
|---|---|---|
| Kilometers of lines | 607,069 | 55 |
| Number of substations | 526 | 20 |

**Table B.17: Projects by Objective Category and Scope**

| | Number of projects | | | | Column percentage | | | |
|---|---|---|---|---|---|---|---|---|
| Objective | Dedicated to RE | Larger energy project w/RE component | Multisectoral project | Total | Dedicated to RE | Larger energy project w/RE component | Multisectoral project | Total |
| Improve welfare | 27 | 18 | 27 | 72 | 64.3 | 40.9 | 79.4 | 60.0 |
| Energy supply | 38 | 42 | 8 | 88 | 90.5 | 95.5 | 23.5 | 73.3 |
| Institutional development | 30 | 37 | 23 | 90 | 71.4 | 84.1 | 67.6 | 75.0 |
| Nonelectrification objective | 0 | 0 | 22 | 22 | 0.0 | 0.0 | 64.7 | 18.3 |
| Total number projects | 42 | 44 | 34 | 120 | 100.0 | 100.0 | 100.0 | 100.0 |

*Note:* RE = rural electrification.

**Table B.18: Projects with Poverty-Reduction Objective by Scope**

| | Number of projects w/poverty-reduction objective | Total | Percentage of projects w/poverty-reduction objective |
|---|---|---|---|
| Dedicated to RE | 3 | 42 | 7.1 |
| Larger energy project w/RE Component | 3 | 44 | 6.8 |
| Multisectoral project | 20 | 34 | 58.8 |
| Total | 26 | 120 | 21.7 |

*Note:* RE = rural electrification.

**Table B.19: Number of Projects by Scope and Rating**

| Rating | Dedicated to RE | Large energy project w/RE component | Multisectoral project | Total |
|---|---|---|---|---|
| Highly satisfactory | 1 | 3 | 1 | 5 |
| Satisfactory | 13 | 12 | 12 | 37 |
| Moderately satisfactory | 0 | 6 | 3 | 9 |
| Moderately unsatisfactory | 1 | 2 | 1 | 4 |
| Unsatisfactory | 5 | 8 | 3 | 16 |
| Total | 20 | 31 | 20 | 71 |

*Note:* RE = rural electrification.

**Table B.20: Economic Rate of Return for Grid and Off-Grid Components**

| Country | Project | Grid | Minigrid | Off-grid |
|---|---|---|---|---|
| Cambodia | Rural Electrification and Transmission | 19.8 | 22.3 | 11 |
| Honduras | Rural Infrastructure Project | 33 | 20 | 30 |
| India | Renewable Resources Development | 14 | n.a. | 41 |
| Lao PDR | Rural Electrification Phase 1 | 687[a] | n.a. | 36 |
| Lao PDR | Southern Provinces Rural Electrification | 60.5 | n.a. | 26 |
| Mozambique | Energy Reform and Access | 22.7 | n.a. | 14.5 |
| Nicaragua | Off-Grid Rural Electrification | 40 | 23 | 27 |
| Peru | Rural Electrification Project | 22.6 | n.a. | 23.8 |
| Philippines | Rural Power Project | 26.4 | 21.5 | 48 |
| Sri Lanka | Renewable Energy for Rural Energy | 15.2 | n.a. | 10.9 |
| Sri Lanka | Energy Services Delivery Project | 23.5 | n.a. | 8.5 |

*Source:* Project documents.

a. See project PAD, p. 12.

**Table B.21: Connections by Type**

| | | Connection | | | | |
|---|---|---|---|---|---|---|
| **Country** | **Project** | **Domestic** | **Public institutions** | **Agricultural** | **Industrial/ commercial** | **Percent residential** |
| Tunisia | Fourth Power Project | 35,000 | 0 | 1500 | 50 | 95.8 |
| Thailand | Second Accelerated Rural Electrification | 534,496 | 0 | 463 | 26,809 | 95.1 |
| Pakistan | Rural Electrification | 153,000 | 0 | 127 | 299 | 99.7 |
| Mali | Household Energy and Universal Access | 40,000 | 1,199 | 0 | 0 | 97.1 |

**Table B.22: Utility Cost Recovery by Income Level and Region**

| Electricity utilities | Percentage of utilities whose average tariffs appear to be… Too low to cover basic O&M costs | Enough to cover most O&M | Enough to cover O&M and partial capital |
|---|---|---|---|
| Global | 15 | 44 | 41 |
| By income | | | |
| High | 0 | 17 | 83 |
| Upper-middle | 0 | 71 | 29 |
| Lower-middle | 27 | 50 | 23 |
| Low | 31 | 44 | 25 |
| By Region | | | |
| OECD | 0 | 17 | 83 |
| Latin America and the Caribbean | 0 | 47 | 53 |
| Eastern and Central Asia | 31 | 38 | 31 |
| East Asia and Pacific | 29 | 65 | 6 |
| Sub-Saharan Africa | 29 | 71 | 0 |
| South Asia | 33 | 67 | 0 |

*Source:* Komives and others 2005, p. 26.
*Note:* O&M = operation and management.

**Table B.23: Number and Percentage of Projects with RET by Period and Region**

| | Number of projects | | | Percentage | | |
|---|---|---|---|---|---|---|
| Region | 1980–95 | 1996–2006 | Total | 1980–95 | 1996–2006 | Total |
| Latin America and Caribbean | 0 | 11 | 11 | 0.0 | 26.2 | 18.3 |
| Middle East and North Africa | 1 | 1 | 2 | 5.6 | 2.4 | 3.3 |
| Sub-Saharan Africa | 5 | 13 | 18 | 27.8 | 31.0 | 30.0 |
| South Asia | 4 | 6 | 10 | 22.2 | 14.3 | 16.7 |
| East Asia and Pacific | 8 | 11 | 19 | 44.4 | 26.2 | 31.7 |
| Total | 18 | 42 | 60 | 100.0 | 100.0 | 100.0 |

*Note:* RET = renewable energy technology.

**Table B.24: Number and Percentage of Projects with RET by Period and Scope**

| | Number of projects | | | Percentage | | |
|---|---|---|---|---|---|---|
| Region | 1980–95 | 1996–2006 | Total | 1980–95 | 1996–2006 | Total |
| Dedicated to RE | 4 | 21 | 25 | 22.2 | 50.0 | 41.7 |
| Larger energy project w/RE component | 12 | 14 | 26 | 66.7 | 33.3 | 43.3 |
| Multisectoral project | 2 | 7 | 9 | 11.1 | 16.7 | 15.0 |
| Total | 18 | 42 | 60 | 100.0 | 100.0 | 100.0 |

*Note:* RE = rural electrification; RET = renewable energy technology.

**Table B.25: Number and Percentage of Projects with RET by Period and Scope**

| Region | Number of projects | | | | Percentage | | | |
|---|---|---|---|---|---|---|---|---|
| | Dedicated to RE | Larger energy project w/RE component | Multi-sectoral project | Total | Dedicated to RE | Larger energy project w/RE component | Multi-sectoral project | Total |
| Latin America and the Caribbean | 6 | 1 | 4 | 11 | 54.5 | 9.1 | 36.4 | 100.0 |
| Middle East and North Africa | 0 | 2 | 0 | 2 | 0.0 | 100.0 | 0.0 | 100.0 |
| Sub-Saharan Africa | 5 | 11 | 2 | 18 | 27.8 | 61.1 | 11.1 | 100.0 |
| South Asia | 3 | 7 | 0 | 10 | 30.0 | 70.0 | 0.0 | 100.0 |
| East Asia and Pacific | 11 | 5 | 3 | 19 | 57.9 | 26.3 | 15.8 | 100.0 |
| Total | 25 | 26 | 9 | 60 | 41.7 | 43.3 | 15.0 | 100.0 |

*Note:* RE = rural electrification; RET = renewable energy technology.

**Table B.26: Projects with Off-Grid Components and Type of Energy Source**

| Country | | MH | PV | W | Bio | D | D/RET | Infrastructural outputs |
|---|---|---|---|---|---|---|---|---|
| Argentina | Renewable Energy in the Rural Market Project | | ✓ | ✓ | | | ✓ | 65,500 SHS, 2 wind home systems |
| Bangladesh | Rural Electrification and Renewable Energy Development | | ✓ | | | | | 64,000 SHS |
| Bolivia | Decentralized Infrastructure for Rural Transformation | | ✓ | | | | | 15,000 SHS |
| Brazil | Bahia Rural Poverty Reduction | | ✓ | | | | | 16,000 SHS |
| Cambodia | Rural Electrification and Transmission | ✓ | ✓ | | | | | 12,000 SHS<br>0.85 MW micro hydro |
| Cape Verde | Energy and Water Sector Reform and Development Project | | ✓ | ✓ | | | | 7.8 MW wind energy |
| Chile | Infrastructure for Territorial Development | ✓ | ✓ | ✓ | ✓ | | ✓ | |
| Ecuador | Power and Communications Sectors Modernization and Rural Services | ✓ | ✓ | ✓ | | | | |
| Honduras | Rural Infrastructure Project | ✓ | ✓ | | | | | 5,000 SHS<br>2 micro hydro systems |
| India | Renewable Resources Development Project | ✓ | ✓ | ✓ | ✓ | | | 2.145 MW<br>87.2 MW wind energy |
| Indonesia | Solar Homes System Project | | ✓ | | | | | 8,054 SHS |
| Lao PDR | Southern Provinces Rural Electrification Project | ✓ | ✓ | | | ✓ | | |
| Lao PDR | Rural Electrification Phase 1 | | ✓ | | | | | 9,000 SHS |

*(Table continues on next page)*

**Table B.26: Projects with Off-Grid Components and Type of Energy Source** ***(continued)***

| Country | | MH | PV | W | Bio | D | D/RET | Infrastructural outputs |
|---|---|---|---|---|---|---|---|---|
| Madagascar | Energy Sector Development Project | | | | ✓ | ✓ | | 82 diesel units |
| Malaysia | Rural Electrification Project | ✓ | | | | | | |
| Mali | Household Energy and Universal Access | | ✓ | ✓ | ✓ | | | 10,150 SHS |
| Mexico | Renewable Energy for Agriculture | | ✓ | ✓ | | | | 1,545 SHS<br>92 wind systems<br>150 MW from solar/diesel hybrid |
| Mexico | Waste Management and Carbon Offset | | | | | | ✓ | |
| Mozambique | Energy Reform and Access | | ✓ | | | | | 2,800 SHS |
| Nepal | Power Development | ✓ | | | | | | 0.2 MW solar/diesel hybrid<br>125 micro hydro systems |
| Nicaragua | Off-grid Rural Electrification | ✓ | ✓ | | | | | 6 solar charging stations<br>7 micro hydro systems |
| Nigeria | National Energy Development Project | | ✓ | | | | | 1 SHS |
| Peru | Rural Electrification Project | ✓ | | | | | | 15 MW micro hydro |
| Philippines | Rural Power Project | ✓ | ✓ | ✓ | | | | |
| Senegal | Electricity Services for Rural Areas Project | | ✓ | | | | | |
| Sri Lanka | Energy Services Delivery Project | ✓ | ✓ | ✓ | | | | 20,953 SHS<br>0.35 MW micro hydro |
| Sri Lanka | Renewable Energy for Rural Economic Development Project | ✓ | ✓ | ✓ | | | | 85,000 SHS<br>21 MW wind energy |
| Tanzania | Songo Songo Gas Development and Power Generation | | ✓ | | | | | 1,600 SHS |
| Uganda | Energy for Rural Transformation | | ✓ | | | | | 7,496 SHS |
| Vietnam | Community Based Rural Infrastructure | ✓ | | | | | | 1 SHS |
| Vietnam | System Efficiency, Equitization, and Renewables | | | | | | ✓ | |
| Vietnam | Rural Energy | ✓ | | | | | ✓ | |
| Number of projects | | 15 | 24 | 10 | 4 | 2 | 5 | |
| As a percentage of RET projects | | 46.9 | 75.0 | 31.3 | 12.5 | 6.3 | 15.6 | |

*Note:* Bio = biomass; D = diesel; D/RET = diesel/renewable hybrid; MH = micro hydro; MW = megawatts; PV = photovoltaic; RET = renewable energy technology; SHS = solar home system; W = wind.

**Table B.27: Gender as a Design Feature in Projects**

| | 1980–96 | | | 1996 onward | | |
|---|---|---|---|---|---|---|
| | RE projects | Other energy | Multisector | RE projects | Other energy | Multisector |
| No mention of gender | 15 | 18 | 4 | 12 | 12 | 7 |
| Gender mentioned, but did not influence design | 2 | 2 | 1 | 7 | 6 | 2 |
| Gender influenced design | 0 | 3 | 7 | 6 | 3 | 13 |
| Total | 17 | 23 | 12 | 25 | 21 | 22 |

*Note:* RE = rural electrification.

**Table B.28: Number and Percentage of Projects by Rating and Objective Category**

| Rating | Increase welfare | Energy supply | Institutional development | Other (non RE) | Total |
|---|---|---|---|---|---|
| Number of projects | | | | | |
| Highly satisfactory | 3 | 3 | 5 | 1 | 12 |
| Satisfactory | 19 | 25 | 29 | 8 | 81 |
| Moderately satisfactory | 5 | 8 | 7 | 1 | 21 |
| Moderately unsatisfactory | 1 | 3 | 4 | 1 | 9 |
| Unsatisfactory | 8 | 13 | 10 | 2 | 33 |
| Total | 36 | 52 | 55 | 13 | 156 |
| Percentage (by objective) | | | | | |
| Highly satisfactory | 8.3 | 5.8 | 9.1 | 7.7 | 7.7 |
| Satisfactory | 52.8 | 48.1 | 52.7 | 61.5 | 51.9 |
| Moderately satisfactory | 13.9 | 15.4 | 12.7 | 7.7 | 13.5 |
| Moderately unsatisfactory | 2.8 | 5.8 | 7.3 | 7.7 | 5.8 |
| Unsatisfactory | 22.2 | 25 | 18.2 | 15.4 | 21.2 |
| Total | 100 | 100 | 100 | 100 | 100 |

*Note:* RE = rural electrification. Totals may not sum 100 exactly because of rounding.

**Table B.29: Comparisons for PV System Retail Prices**

| Watt peak | China | Philippines | Indonesia | Sri Lanka | India | Kenya | Zambia |
|---|---|---|---|---|---|---|---|
| 10 | 85 | | | | | | |
| 15 | 120 | | | | | | |
| 20 | 150 | 300 | | 302 | | | 300 |
| 30 | 203 | | | | | | |
| 40 | | 520 | 303 | 419 | 307 | | |
| 50 | | 660 | 300–408 | 480 | 360 | 822 | |
| 75–80 | 640 | 750–1000 | | 686 | | | |

*Source:* World Bank 2002.

**Table B.30: Connection Costs and Charges in Project Countries**

| Country | Year | Connection cost | Connection charge |
|---|---|---|---|
| Morocco | 1979 | 350 | 300 |
| Thailand | 1980 | 98 | 98 |
| Thailand | 1982 | 348 | |
| Tunisia | 1984 | 82 urban/164 rural | |
| Pakistan | 1989 | 45 | |
| Thailand | 1989 | | 22 |
| Burundi | 1991 | | 500–750 |
| Malaysia | 1992 | 1,284 | |
| Malawi | 1992 | | 19 |
| Brazil | 1993 | 393 | |
| Jordan | 1994 | | 135 |
| Morocco | 1998 | —monthly charge of $4.20 over 7 years— | |
| Bangladesh | 2001 | 417 | |
| Pakistan | 2001 | 1,729 | |
| Lao PDR | 2002 | 746 urban/1,047 rural | ~100 |
| Cambodia | 2003 | 214 | |
| Bolivia | 2003 | 150 | |
| Eritrea | 2004 | | 68 |
| Lao PDR | 2005 | | 75–122 |
| Honduras | 2005 | 300–400 urban/768 rural | |
| Ethiopia | 2006 | —500 (50–100 in electrified village)— | |
| Peru | 2006 | 940 | |

**Table B.31: Subsidy Types for Off-Grid Project Components**

| Country | Project | Subsidy type |
|---|---|---|
| Argentina | Renewable Energy in the Rural Market Project | Declining capital cost subsidy—OBA approach |
| Bangladesh | Rural Electrification and Renewable Energy Development | Declining capital cost subsidy |
| Bolivia | Decentralized Infrastructure for Rural Transformation | Capital cost subsidy |
| Brazil | Bahia Rural Poverty Reduction | No mention |
| Cambodia | Rural Electrification and Transmission | Capital cost subsidy |
| Cape Verde | Energy and Water Sector Reform and Development Project | Declining capital cost subsidy |
| Chile | Infrastructure for Territorial Development | Capital cost subsidy |
| China | Renewable Energy Development | Subsidized loans for technology development |
| Ecuador | Power and Communications Sectors Modernization and Rural Services | Capital cost subsidy for demonstration projects |
| Honduras | Rural Infrastructure Project | Capital cost subsidy—OBA approach, micro credit to providers |
| India | Renewable Resources Development Project | Capital cost subsidy 50% and subsidized credit scheme |
| Indonesia | Solar Homes System Project | Credit at market rates |
| Lao PDR | Southern Provinces Rural Electrification Project | No mention |
| Lao PDR | Rural Electrification Phase 1 | Capital cost subsidy 100% |
| Madagascar | Energy Sector Development Project | No mention |
| Malaysia | Rural Electrification Project | No mention |
| Mali | Household Energy and Universal Access | Capital cost subsidy—OBA approach |
| Mexico | Renewable Energy for Agriculture | Matching grants for capital investments |
| Mexico | Waste Management and Carbon Offset | No subsidy |
| Mozambique | Energy Reform and Access | Capital cost subsidy 50%—OBA approach |
| Nepal | Power Development | No mention |
| Nicaragua | Off-Grid Rural Electrification | Capital cost subsidy for part, down payment by consumer 5–10%, micro credit to spread rest out over 3 years |
| Nigeria | National Energy Development Project | Some subsidy |
| Peru | Rural Electrification Project | Capital cost subsidy—average $457 |
| Philippines | Rural Power Project | Some targeted subsidies |
| Senegal | Electricity Services for Rural Areas Project | Capital cost subsidy—OBA approach |
| Sri Lanka | Energy Services Delivery Project | No subsidy |
| Sri Lanka | Renewable Energy for Rural Economic Development Project | Declining scale capital cost subsidy—OBA approach; micro credit to providers |
| Tanzania | Songo Songo Gas Development and Power Generation | No mention |
| Uganda | Energy for Rural Transformation | Capital cost subsidy and credit support facility |
| Vietnam | Community Based Rural Infrastructure | No mention |
| Vietnam | Rural Energy | No mention |
| Vietnam | System Efficiency, Equitization, and Renewables | Capital cost subsidy |

*Note:* OBA = output-based aid.

## Intensive versus Extensive Growth in Electrification Coverage

The rural electrification (RE) rate may be broken down as follows:

$$\frac{P_e}{P} = \frac{P_e}{P^{ec}} \frac{P^{ec}}{P}, \tag{C.1}$$

where $P_e$ are households with electricity, $P^{ec}$ the population of communities with electricity, and $P$ the total population. The first term on the right-hand side of the equation is the electrification rate in electrified communities and the second term is the share of the population of electrified communities in the total population (that is, the population-weighted proportion of electrified communities).

Figure C.1 shows these three terms for four countries at two times using Demographic and Health Survey (DHS) data. The final bar in each set shows coverage of rural communities: the Philippines had achieved a high level of coverage (more than 80 percent of the population lived in communities that had electricity) in the first year shown (1993), and Bangladesh achieved a substantial increase in the proportion of the population living in electrified villages, from 52 to 90 percent, between 1992 and 2004.

A closer examination of the change in the electrification rate can be made through a decomposition analysis. From equation C.1, the percentage change in the electrification rate can be decomposed as follows:

$$\frac{\hat{P}_e}{P} = \frac{\hat{P}_e}{P^{ec}} + \frac{\hat{P}^{ec}}{P}, \tag{C.2}$$

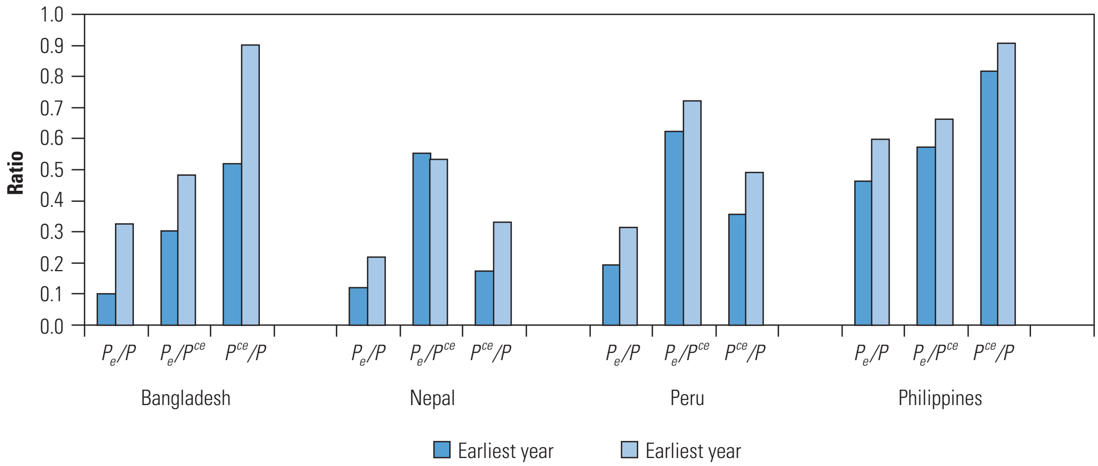
where the ˆ denotes the percentage change in the ratio. For large changes there will also be a residual. These two terms may be interpreted as intensification and extension, respectively. That is, coverage may expand either by households in connected villages taking connections or by extending connections to new villages.

Table C.1 summarizes the analysis of this decomposition. As might be expected, when the coverage rate is low, then the bulk of the increase comes from extension, meaning that there remains a sizeable number of unconnected households in communities with electricity. This was evident in figure C.1, looking at the ratio $P_e/P^{ce}$, where in Bangladesh and Nepal only about half of households in electrified communities have electricity. Only in the Philippines, where more than half the population lives in connected communities, does the majority of the increase in coverage come from intensification.

## Lorenz Curves

Which households are connecting to the grid can be further analyzed using Lorenz curves. In the first set of curves presented here, households are ranked according to a wealth index, starting with the poorest. The curve plots the cumulative share of electrified households against the cumulative share of households (ranked by wealth). If this line lies below the 45° line, then poorer households are less likely to have electricity. DHS data are used to show these curves for five countries (figure C.2), drawn for rural areas only. All graphs show the same two points: (1) access to the grid is bias toward the non-poor, and (2) the bias reduces over time (as the electrification rate increases) (Nepal is an exception). This reduction in bias is most marked in Ghana, where the government embarked on a program to bring

**Figure C.1: Rural Electrification Rate Ratios**




*Note:* $P$ = total population, $P^{ce}$ = population of communities with electricity; $P_e$ = households with electricity.

**Table C.1: Decomposition of Changes in Rural Electrification Rate**

| Country | Period | Electrification rate: Earliest year (%) | Electrification rate: Latest year (%) | Percent increase in rate | Change in rate attributable to: Intensification | Extension | Residual |
|---|---|---|---|---|---|---|---|
| Bangladesh | 1992–2004 | 10 | 30 | 207 | 28 | 46 | 26 |
| Nepal | 1996–2001 | 12 | 17 | 45 | –10 | 116 | –5 |
| Peru | 1992–2004 | 19 | 35 | 84 | 20 | 68 | 12 |
| Philippines | 1993–2003 | 46 | 60 | 29 | 56 | 37 | 6 |

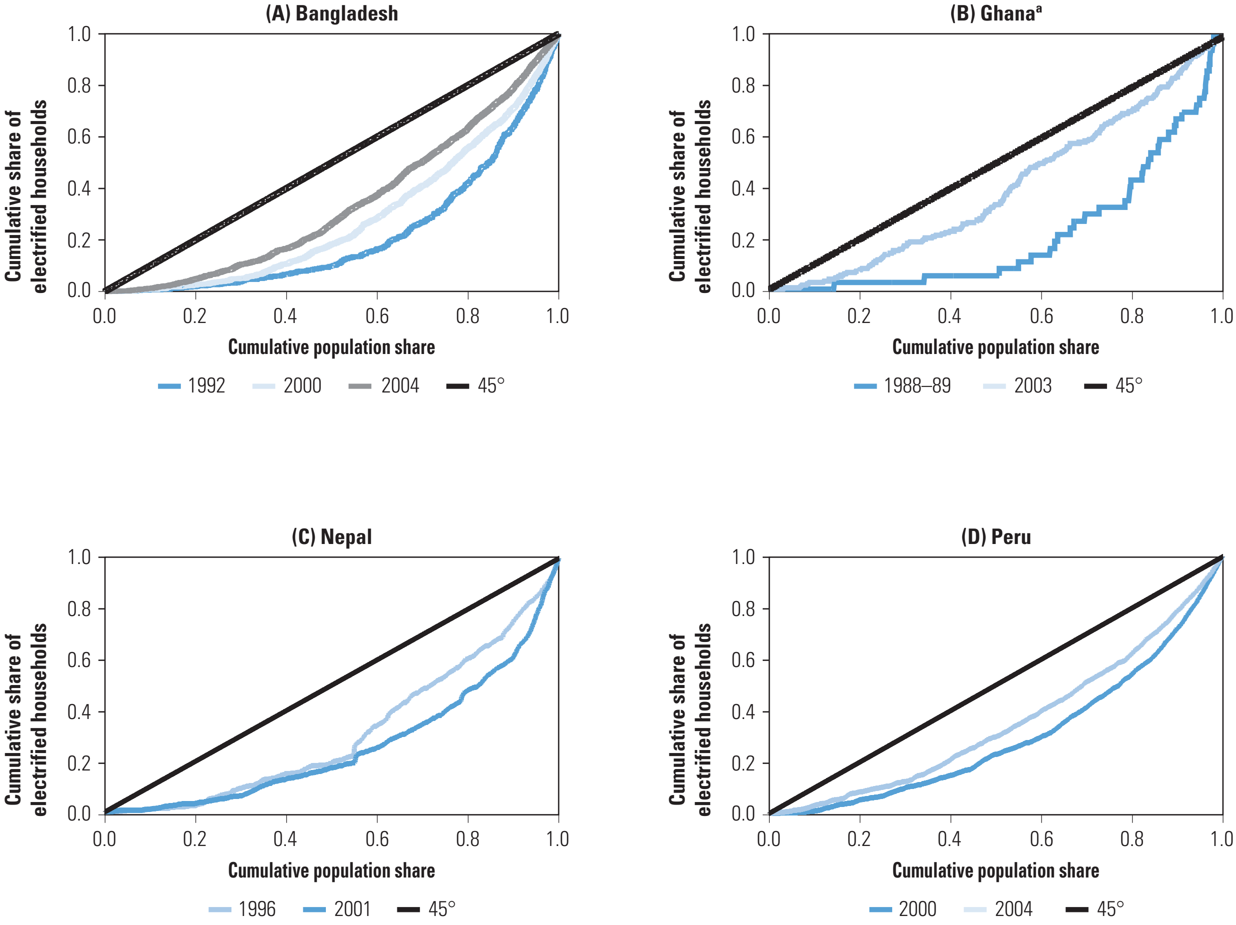
*Source:* DHS data.

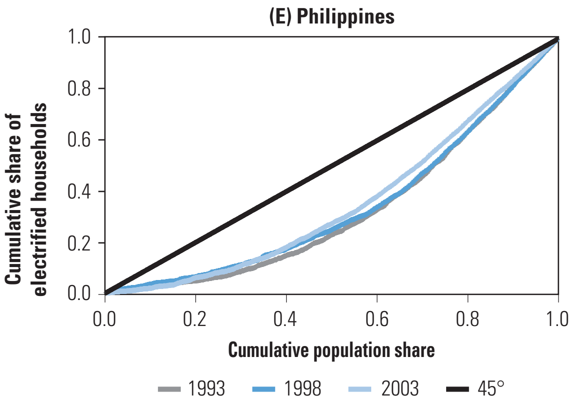
electricity to all districts. This pattern is also shown in table C.2, which reports the Gini coefficient (an inequality measure between 0 and 1, which would be 0 if grid access were equitably distributed).

For the countries for which an energy survey is available, the Lorenz curve may also be calculated for electricity consumption. Because the better-off consume greater amounts of electricity, the distribution of consumption is more unequal than is shown by the dichotomous variable of connected or not (see figure 3.2 in the main report for the cases of Lao PDR and the Philippines).

In one case (Sri Lanka) there are sufficient observations to draw separate curves for grid and off-grid connections (see figure C.3). The sample for this survey is not representative—connected households are oversampled—and survey weights are not available, so the general shape of the line is misleading (the true share of unconnected is understated, making the distribution look more

**Figure C.2: Electrification Lorenz Curves**




Access to electricity is biased toward the better off. But that bias reduces as electrification rates increase.

*Source:* DHS data.

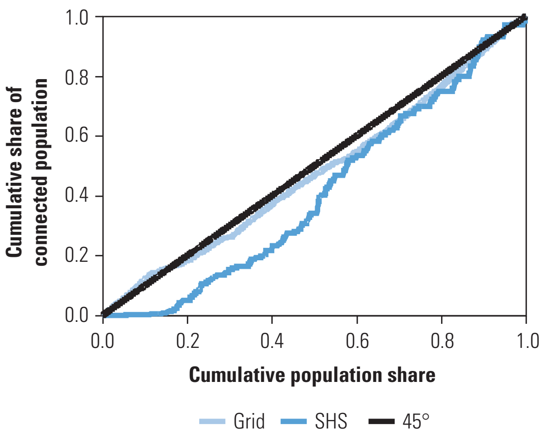
a. Sources for this section are Ghana Livings Standards Survey and IEG 2004.

**Table C.2: Gini Coefficients for Access to Electricity**

| Country | Year | National | Rural |
|---|---|---|---|
| Bangladesh | 2000 | 0.40 | 0.44 |
| | 2004 | | 0.32 |
| Ghana | 1999 | 0.37 | 0.40 |
| | 2003 | 0.22 | 0.20 |
| Ghana[a] | 1989 | n.a. | 0.58 |
| | 2003 | n.a. | 0.20 |
| Morocco | 2004 | 0.17 | 0.21 |
| Nepal | 1996 | 0.48 | 0.38 |
| | 2001 | 0.52 | 0.49 |
| Nicaragua | 2001 | 0.32 | 0.44 |
| Peru | 2000 | 0.31 | 0.40 |
| | 2004 | 0.23 | 0.29 |
| Philippines | 1998 | 0.24 | 0.33 |
| | 2003 | 0.20 | 0.29 |
| Senegal | 2005 | 0.45 | 0.57 |
| Nepal | 1996 | 0.48 | 0.38 |

*Source:* DHS data.
a. Source for this category is Ghana Living Standards Survey.

**Figure C.3: Lorenz Curve for Grid and Off-Grid Connections, Sri Lanka**




*Source:* IEG calculation from Sri Lanka household survey data.
*Note:* SHS = solar home system.

equal than it is), but the curves for grid and off-grid can be compared. These curves show that off-grid connections are less equitably distributed than are grid connections.

## Electricity Pricing and Subsidy Distribution

Economists generally argue that efficiency is obtained through marginal cost pricing. However, for industries with large fixed costs, there may be increasing returns to scale, so that average costs fall as supply expands. Under these circumstances marginal cost pricing implies running at a loss, and in public economics this has long been taken as a case for state subsidy. Governments have also been keen to subsidize to ensure public utilities achieve good coverage; once established, subsidies become entrenched and politically difficult to remove. Fiscal pressures in developing countries have pushed some governments to seek greater levels of cost recovery, but electricity supply is still subsidized in virtually every country in the world.

Foster and Yepes (2006) analyze cost structures to derive the following basic categorization: (1) tariffs below $0.04 per kilowatt hour (kWh) are insufficient to cover basic operations and management (O&M) costs for either residential or industrial customers; (2) tariffs above $0.05/kWh are sufficient to cover O&M and make a significant contribution toward capital costs for industrial users; and (3) tariffs above $0.08/kWh are sufficient to cover O&M and make a significant contribution toward capital costs for residential users. This categorization applies to most, though not all, grid-based distribution systems.

Using these figures a regional classification can be produced, as shown in table C.3. There is a clear pattern showing that countries in poorer Regions are less likely to achieve cost recovery, with nearly a third of countries in East Asia and Pacific, Sub-Saharan Africa, and South Asia charging insufficient fees to cover O&M and virtually all the remainder unable to make a contribution toward capital costs.

Who benefits from this subsidy clearly depends both on who uses electricity and how much they use and on the nature of the subsidy scheme. Subsidies may be either to the cost of connection or on the tariff. A linear tariff (that is, a fixed amount per kilowatt hour) will give the subsidy propor-

**Table C.3: Percentage of Countries Covering O&M and Capital Costs through Electricity Charges**

| | Too low to cover basic O&M | Enough to cover most O&M | Enough to cover O&M and partial capital |
|---|---|---|---|
| OECD (n = 23) | 0 | 17 | 83 |
| Latin America and Caribbean (n = 19) | 0 | 47 | 53 |
| Europe and Central Asia (n = 18) | 31 | 38 | 31 |
| East Asia and Pacific (n = 13) | 29 | 65 | 6 |
| Sub-Saharan Africa (n = 8) | 29 | 71 | 0 |
| South Asia (n = 3) | 33 | 67 | 0 |
| Global (n = 84) | 15 | 44 | 41 |

*Source:* Komives and others 2005, table 2.5.

tional to consumption, or more than proportional if the tariff is a monthly fixed charge plus a linear tariff (because then the average charge per kilowatt hour falls as consumption rises). But the majority of electricity companies use differentiated tariffs.

These tariffs take two basic forms. Most common is the increasing block tariff, whereby consumers pay more for units of consumption above a certain threshold. The alternative is a volume-differentiated tariff, where those who consume above the threshold pay a higher rate on all consumption, not just that above the threshold.

Komives and others (2005) present a comprehensive analysis of who benefits from electricity tariffs. The general finding is that these subsidies are poorly targeted, being less pro-poor than a simple random allocation of money among the population. The targeting measure used is ø, which is the ratio of the share of the subsidy going to the poor to their share in the population. Hence if ø = 1, the subsidy goes to the poor exactly in proportion to their population share (which is what a random allocation would achieve). In contrast, ø < 1 means the poor get a lower share of the subsidy than their population shares; that is, it disproportionately benefits the non-poor. Quantity-based tariff subsidies have an average ø of just 0.62, though this performance can be improved (to ø > 1) if combined with geographic targeting or means testing.

The reason for this finding is clear. The poor are less likely to be connected (as shown in the analysis above) and so are excluded from the subsidy altogether. And the better-off consume more, so even if the tariff rises, as long as it is still subsidized, the non-poor may obtain a greater absolute benefit.

Connection subsidies appear to be a different story, although few studies have been done. Because connection rates among the poor are low, even untargeted subsidies have ø > 1, with still higher values if combined with geographic targeting.

## Fuelwood Collection and Cooking

Table D.1 shows that the time spent collecting wood each day varies quite considerably. But the average time is more than 2.5 hours, and it can be eight times that. The largest share of the burden is carried by women.

If electrification means that less firewood is collected, then there are time savings to the households. However, the main use for firewood is for cooking, and, as table D.2 shows, in most countries less than 1 percent of the rural population (and usually not a much larger share of those with electricity) uses it for cooking. Therefore, these benefits will not be realized in the short to medium term.

East Asian countries may be something of an exception, because rice cookers are a common purchase in electrified households: in Lao People's Democratic Republic just over a quarter (27 percent) of electrified households have a rice cooker, so electrified households do use significantly less fuelwood in these countries.

## Ownership of Electric Goods

Figure D.1 uses DHS data for 53 countries, several with data from more than one survey, giving a sample of up to 113 observations. The graphs plot the percentage of people in rural areas owning the specified good against the RE rate. The 45° line and fitted line are also shown.

**Table D.1: Time Spent Collecting Wood (hours/day)**

| Country | Boys | Girls | Men | Women | Total |
|---|---|---|---|---|---|
| Benin | n.a. | n.a. | 0.47 | 1.60 | 2.07 |
| Benin | n.a. | n.a. | 0.50 | 2.90 | 3.40 |
| Ghana (rural)[a] | n.a. | n.a. | 3.23 | 4.60 | 7.83 |
| Guinea (rural) | 2.50 | 1.50 | 1.60 | 2.40 | 8.00 |
| Madagascar | n.a. | n.a. | 1.35 | 0.82 | 2.17 |
| South Africa | n.a. | n.a. | 0.35 | 0.70 | 1.05 |
| Indonesia | n.a. | n.a. | 0.21 | 0.09 | 0.30 |
| Burkina Faso | n.a. | n.a. | 0.03 | 0.10 | 0.13 |
| India | n.a. | n.a. | 0.65 | 0.65 | 1.30 |
| Nepal | n.a. | n.a. | 0.83 | 2.37 | 3.20 |
| Himachal Pradesh[b] | n.a. | n.a. | n.a. | n.a. | 1.30 |
| Tamil Nadu[c] | n.a. | n.a. | n.a. | n.a. | 0.65 |
| Rajastan[c] | n.a. | n.a. | n.a. | n.a. | 1.64 |

*Sources:* Bardasi and Wodon 2006; Charmes 2006; Dutta 2005; GSS 2000; Nathan and Kelkar 1997; Laxmi and others 2003; Parikh 2005; Parikh and Laxmi 2000; Blackden and Wodon 2006.

*Note:* n.a. = not available.

a. Average for forest and savannah.

b. Average across Regions. Gender division of labor varies by Region. Daily average over a month.

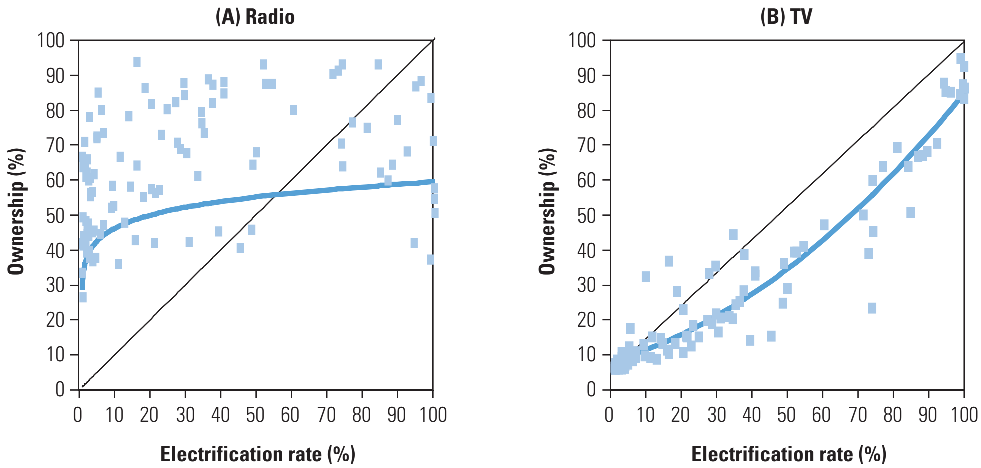
c. Average across Regions. Daily average over a month.

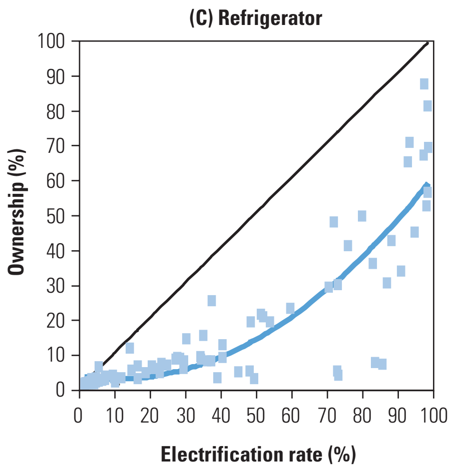
**Table D.2: Use of Electricity for Cooking**

| | | Percent of rural population | | Percent of total population | | Percent of those with electricity using electricity for cooking | |
|---|---|---|---|---|---|---|---|
| Country | Year | Electricity | Use electricity for cooking | Electricity | Use electricity for cooking | Rural | Total |
| Armenia | 2000 | 98.6 | 20.4 | 98.9 | 37.4 | 20.7 | 37.8 |
| Bangladesh | 2004 | 30.4 | 0.0 | 40.6 | 0.1 | 0.0 | 0.2 |
| Bolivia | 1998 | 29.0 | 0.0 | 71.2 | 0.9 | 0.0 | 1.3 |
| Bolivia | 2003 | 35.7 | 0.0 | 72.3 | 0.5 | 0.0 | 0.7 |
| Burkina Faso | 2003 | 0.8 | 0.0 | 11.4 | 0.0 | 0.0 | 0.0 |
| Cambodia | 2000 | 9.0 | 0.1 | 16.6 | 0.1 | 1.1 | 0.6 |
| Colombia | 2000 | 83.8 | 5.0 | 95.2 | 13.8 | 6.0 | 14.5 |
| Colombia | 2005 | 89.2 | 4.1 | 96.8 | 7.2 | 4.6 | 7.4 |
| Dominican Republic | 2002 | 80.6 | 0.1 | 92.3 | 0.1 | 0.1 | 0.1 |
| Egypt, Arab Rep. of | 2000 | 95.9 | 0.3 | 97.7 | 0.4 | 0.3 | 0.4 |
| Eritrea | 2002 | 3.0 | 0.0 | 32.2 | 0.6 | 0.0 | 1.9 |
| Ethiopia | 2000 | 0.4 | 0.0 | 12.7 | 0.1 | 0.0 | 0.8 |
| Ghana | 2003 | 24.1 | 0.1 | 48.3 | 0.3 | 0.4 | 0.6 |
| Haiti | 2000 | 5.2 | 0.0 | 33.7 | 0 | 0.0 | 0.0 |
| India | 1998 | 48.1 | 0.2 | 60.1 | 0.4 | 0.4 | 0.7 |
| Indonesia | 2002 | 84.5 | 0.2 | 90.7 | 0.4 | 0.2 | 0.4 |
| Jordan | 2002 | 98.7 | 0.0 | 99.5 | 0.1 | 0.0 | 0.1 |
| Kenya | 2003 | 4.6 | 0.1 | 16 | 0.3 | 2.2 | 1.9 |
| Madagascar | 2003 | 10.8 | 0.1 | 20.3 | 0.3 | 0.9 | 1.5 |
| Malawi | 2000 | 1.0 | 0.2 | 4.8 | 2.1 | 20.0 | 43.8 |
| Mali | 2001 | 2.2 | 0.0 | 10.8 | 0 | 0.0 | 0.0 |
| Morocco | 2003 | 51.3 | . . | 78.2 | 7.8 | . . | 10.0 |
| Mozambique | 2003 | 1.1 | 0.2 | 8.1 | 0.8 | 18.2 | 9.9 |
| Namibia | 2000 | 13.2 | 5.5 | 36.5 | 26.4 | 41.7 | 72.3 |
| Nepal | 2001 | 17.4 | 0.0 | 24.6 | 0.1 | 0.0 | 0.4 |
| Nicaragua | 2001 | 40.1 | 0.1 | 72.6 | 0.9 | 0.2 | 1.2 |
| Nigeria | 2003 | 33.8 | 0.1 | 52.2 | 0.3 | 0.3 | 0.6 |
| Peru | 2000 | 28.9 | 0.0 | 69.3 | 1.1 | 0.0 | 1.6 |
| Rwanda | 2000 | 0.9 | 0.0 | 6.2 | 0.2 | 0.0 | 3.2 |
| Tanzania | 2004 | 1.6 | 0.0 | 11.4 | 0.3 | 0.0 | 2.6 |
| Turkmenistan | 2000 | 99.6 | 0.4 | 99.6 | 0.5 | 0.4 | 0.5 |
| Uganda | 2000 | 2.4 | 0.1 | 8.6 | 0.8 | 4.2 | 9.3 |
| Zambia | 2001 | 2.9 | 1.9 | 17.4 | 14.1 | 65.5 | 81.0 |
| Zimbabwe | 1999 | 8.3 | 1.9 | 38.4 | 27.4 | 22.9 | 71.4 |

*Source:* DHS data: ORC Macro, 2006. MEASURE DHS STATcompiler. http://www.measuredhs.com, October 28, 2006.
*Note:* . . = excluded because of discrepancy between published data and IEG calculations.

**Figure D.1: Electrification and Consumer Goods Ownership in Rural Areas**




The graphs plot the percentage of people in rural areas owning the specified good against the RE rate. The 45º line and fitted line are also shown. As expected, electrification is close to a necessary condition for TV and refrigerator ownership (no points above the 45º line) but not for radio, for which there is a very weak association between ownership and electrification.

*Source:* DHS data (MEASURE DHS STATcompiler, http://www.measuredhs.com, March 8 2007).

As expected, electrification is close to a necessary condition for TV and refrigerator ownership (no points above the 45º line). But it is not a sufficient condition, because many data points lie below the 45º line. This is especially so for refrigerator ownership, which only rises above low levels for countries with very high electrification rates—reflecting, of course, the income effect. The two relatively poor countries (Indonesia and Vietnam) with high electrification rates have low fridge ownership.

In contrast, TV ownership rises quite quickly with electrification; the data support the argument that the majority of electrified households acquire a TV in most countries (again Indonesia and Vietnam are outliers, but not as extreme as in the case of fridge ownership). By contrast, there is a very weak association between radio ownership and electrification. Many observations lie above the 45° line, because radio ownership is not dependent on a grid connection.

Because the surveys are relatively close together, many variables can be controlled for by modeling the changes in the variables between survey rounds (changes in other determinants will generally be small compared with the intracountry variation). The results from regressing the change in ownership of

**Table D.3: Change in Electric Goods Ownership as a Function of Change in Electrification Rate**

| | Radio | TV | Refrigerator |
|---|---|---|---|
| Intercept | –0.03 | 3.42* | 3.01* |
| | (–0.56) | (2.66) | (4.24) |
| Coefficient | 6.15* | 0.47** | 0.93* |
| | (1.24) | (2.48) | (4.99) |
| R2 | 0.00 | 0.18 | 0.47 |
| N | 59 | 59 | 59 |

*Note:* Ordinary least squares with robust standard errors. Figures in parentheses are t-statistics.
*Significant at 1 percent.
**Significant at 5 percent.

each of the three changes in electrification are shown in table D.3. Consistent with the above analysis, there is a significant impact on TV and refrigerator ownership but not for radio.

TV watching is unsurprisingly associated with TV ownership. Table D.4 reports DHS data (women's survey) for nine countries, showing this association, which is summarized in figure D.2. On average, 60 percent of women in households with TV watch almost every day, whereas less than 10 percent of women in households without TV watch that frequently. These data thus support the argument that "communal viewing," while not unknown, is not the norm.

## Health Facilities

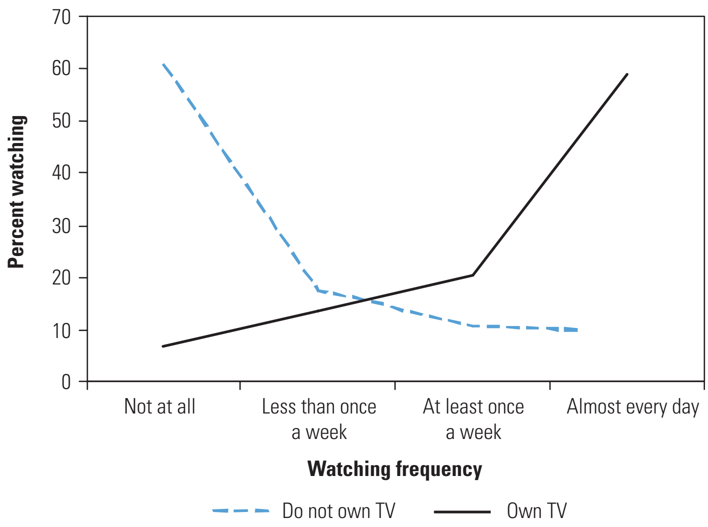
RE is argued to facilitate the cold chain and so improve health status. Analysis of health facility data from six countries shows that the cold chain is significantly more present in electrified rural facilities than in those without electricity (see table D.5)—this difference is significant in all six

**Table D.4: TV Watching by TV Ownership (Women)**

| | | Frequency of watching | | | | |
|---|---|---|---|---|---|---|
| Country | Television ownership | Not at all | Less than once a week | At least once a week | Almost every day | Number |
| Bangladesh | Do not own TV | 64.2 | 10.6 | 19.9 | 5.2 | 6,193 |
| | Own TV | 9.7 | 5.7 | 19.0 | 65.4 | 1,343 |
| Ghana | Do not own TV | 70.4 | 15.4 | 10.1 | 4.0 | 2,985 |
| | Own TV | 13.7 | 14.9 | 24.3 | 47.1 | 329 |
| Indonesia | Do not own TV | 30.3 | 32.1 | 18.4 | 18.8 | 9,279 |
| | Own TV | 2.0 | 7.4 | 6.4 | 83.8 | 7,886 |
| Morocco | Do not own TV | 49.3 | 6.5 | 11.5 | 32.7 | 4,715 |
| | Own TV | 5.4 | 3.5 | 9.9 | 81.2 | 3,085 |
| Nepal | Do not own TV | 90.4 | 0.0 | 9.6 | 0.0 | 6,943 |
| | Own TV | 12.4 | 0.0 | 87.6 | 0.0 | 629 |
| Nicaragua | Do not own TV | 84.6 | 3.2 | 4.2 | 7.9 | 4,111 |
| | Own TV | 5.1 | 2.0 | 9.1 | 83.7 | 1,662 |
| Peru | Do not own TV | 50.2 | 43.9 | 1.3 | 4.5 | 9,751 |
| | Own TV | 3.3 | 33.1 | 1.8 | 61.7 | 5,735 |
| Philippines | Do not own TV | 52.3 | 31.3 | 9.5 | 6.4 | 7,843 |
| | Own TV | 3.9 | 47.9 | 7.8 | 40.0 | 5,601 |
| Senegal | Do not own TV | 58.0 | 18.2 | 13.9 | 9.8 | 6,071 |
| | Own TV | 5.6 | 9.3 | 17.4 | 67.7 | 2,218 |
| Unweighted average | Do not own TV | 61.1 | 17.9 | 11.0 | 9.9 | |
| | Own TV | 6.8 | 13.8 | 20.4 | 59.0 | |

*Source:* IEG analysis of DHS data.

**Figure D.2: TV Watching Is Far Greater in TV-Owning Households**




*Source:* IEG analysis of DHS data.

**Table D.5: Electrification of Rural Health Clinics and the Cold Chain by Country**

| | Ghana (2003) | | Egypt (2002) | | Kenya (2004) | |
|---|---|---|---|---|---|---|
| | Electricity | No electricity | Electricity | No electricity | Electricity | No electricity |
| Electricity | 72.8 | 27.2 | 98.6 | 1.4 | 77.5 | 22.5 |
| Refrigerator | 64.2 | 40.7*** | 51.3 | 0.0*** | 71.9 | 67.3 |
| Ice | 2.6 | 6.2* | 0.6 | 0.0 | 0.6 | 0.0 |
| No storage | 21.9 | 37.2** | 11.6 | 0.0*** | 3.3 | 7.1*** |
| Immunization | 88.7 | 84.1 | 63.4 | 0.0*** | 75.7 | 74.5 |

| | Electrified (%) | Not electrified (%) |
|---|---|---|
| Bangladesh (2000) | | |
| Cold chain equipment available and operational | 55.9 | 10.0*** |
| Nicaragua (2001) | | |
| Electric refrigerator | 65.5 | 10.2*** |
| Solar refrigerator | 15.2 | 20.7* |
| Any refrigerator | 80.7 | 31.0*** |
| Cold box | 29.2 | 14.1* |
| Termo | 92.6 | 65.9*** |
| Rwanda (2001) | | |
| Refrigerator | 80.8 | 96.6*** |
| Immunization | 80.8 | 98.8*** |

*Source:* DHS data except Nicaragua, from Measure Evaluation Health Facility Survey.
*Significant difference at 10 percent.
**Significant difference at 5 percent.
***Significant difference at 1 percent.

**Table D.6: Average Number of Hours Rural Clinics Are Open**

| | Electricity | No electricity |
|---|---|---|
| Bangladesh | 7.1 | 6.1[a] |
| Kenya | 15.1 | 11.0[a] |

*Source:* DHS facility surveys.
a. Significant difference at 1 percent.

countries. However, the difference in the proportion of clinics providing immunization services does *not* vary according to electrification status—meaning that clinics are used for immunization days and so forth. The impact of RE on immunization rates is thus not likely to be strong, but it can help build the immunization into routine service delivery at the clinic level and thus reduce the cost of delivering immunization services. Data are not available to explore this issue further.

It is also argued that electrification allows longer opening hours for community facilities. Data for health facilities were only available for two countries, but in both cases electrified clinics had significantly longer opening hours (table D.6).

Finally, access to electricity may improve the water supply (see table D.7). Data from health facilities from three countries show a significant difference in source of water. The electrified facilities were more likely to have access to piped water (index = 1 for piped water; two-thirds for protected well/borehole; one-third for unprotected well) compared with the nonelectrified facilities. Availability of water within 500 meters of the facility was significantly higher for electrified facilities in two of the four countries. However, availability of water year 'round was better for electrified facilities only in one of four countries. Causality is not established here, as both electricity and better water supply may reflect some third factor.

## Access to Water

Water supply frequently needs pumping, which can be done using either diesel or electric pumps. Figure D.3 shows a positive association between rural access to water and RE in cross-country data. It might be thought that this is a spurious correlation, explained by income per capita, which is an explanatory factor for both these variables. However, electrification remains a significant determinant of water supply once income is allowed for (table D.8). The relationship between water supply and electrification deserves further study but is not pursued in this report.

**Table D.7: Electrification of Rural Health Centers and Water Availability**

| | Water available on site | | Water available all year round | | Source of water index | |
|---|---|---|---|---|---|---|
| Country and year | Electricity | No electricity | Electricity | No electricity | Electricity | No electricity |
| Ghana 2003 | 77.4 | 47.5[a] | 37.7 | 24.6[a] | | |
| Bangladesh 2000 | | | | | 0.54 | 0.38[a] |
| Egypt 2002 | 96.3 | 33.3[a] | 4.2 | 0.0 | 0.97 | 0.44[a] |
| Kenya 2004 | 64.3 | 69.4 | 71.1 | 68.4 | 0.86 | 0.58[a] |
| Rwanda 2001 | 16.4 | 13.8 | 58.6 | 52.1 | | |

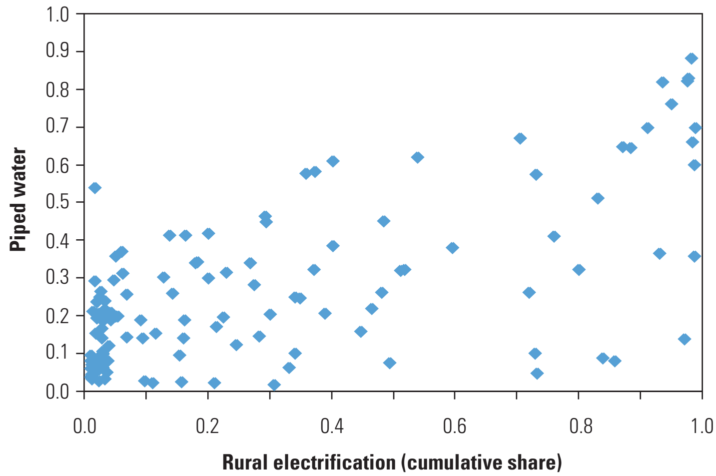
*Source:* DHS facility surveys.
a. Significant difference at 1 percent.

**Table D.8: Regression of Rural Water Supply Using Cross-Country Data**

| | Coefficient | t-stat |
|---|---|---|
| Electrification rate | 0.192 | 2.04[a] |
| Floor material | –0.026 | –0.34 |
| Nonelectric assets | –0.025 | –0.10 |
| GDP per capita | 0.000 | 2.60[a] |

*Note:* GDP = gross domestic product.
a. Significant difference at 5 percent.

**Figure D.3: Rural Electrification and Access to Piped Water**




*Source:* DHS data.

# APPENDIX E: LITERATURE SURVEY

**Latin America and Caribbean**

| Topic | Mexico | Peru | Colombia | El Salvador | Guatemala | Costa Rica |
|---|---|---|---|---|---|---|
| Poverty targeting, pro-poor government policy, and end-user knowledge | Government, via the Federal Power Commission, subsidized capital costs and tariffs in rural areas. (Barnes 2007, p. 156). | Large subsidy for poor through "social tariffs" on electricity use of up to 30 kWh/month. Cost with social tariff is more than 20 times less than real cost, but lack of information on the amount of electricity that can be used within the minimum tariff, so does not have intended effect. Sixty-eight percent pay the minimum tariff (Valencia and others 1990). | | USAID CARES project introduced the DAM, which allowed communities to be ranked on the benefit cost ratio, thus prioritizing those communities in which benefits will be greatest (Shonder and Wilbanks 1996). | USAID CARES project introduced the DAM, which allowed communities to be ranked on the benefit cost ratio, thus prioritizing those communities in which benefits will be greatest (Shonder and Wilbanks 1996). | Rural cooperatives give concessionary connection fees to those below the poverty line (Barnes 2007, p. 38). |
| Usage patterns | In rural areas: household use, especially lighting, and pumping for irrigation (Barnes 2007, p. 146). | Electricity was mainly used for lighting, leading to more leisure for men and children but also longer workdays, especially for women. Local economy is based on agriculture, but there is a missing link between electrification and agriculture.<br><br>Ninety percent of electricity consumed by households, 5 percent commercial, and 3 percent industrial. For commercial use, there has been no change in use of electricity, but mainly in productivity (Valencia and others 1990). | Increased use of appliances increases productive hours (Barnes 1988), through the use of hot plates, irons, and sewing machines. Results in staying up later at night (20 minutes more than non-electrified households) (Barnes 1988). | | | Rural families: lighting, television, ironing, refrigeration, household appliances, and cooking only when fuelwood is unavailable (wood preferred). Larger farms: irrigation, milling refrigeration, sawing, welding, and so on. Dairy farms: milking machines, refrigerators, boiling water, fences. Communities benefited from public lighting, educational institutions, and night classes (Barnes 2007, pp. 25, 34). |

| | | | | | | |
|---|---|---|---|---|---|---|
| Time savings from not collecting biomass | | | Although there was use of hot plates by some richer households, most households still used traditional means for cooking (Barnes 1988). | | | |
| Promotional activities | Solar program includes promotional information—how photovoltaic systems work, their benefits, and how they differ from grid systems (Barnes 2007). | | | | | Each rural cooperative has an education committee to inform members of technical information/new ways of using electricity for residential, farm, and commercial use (Barnes 2007, p. 27). |
| Household income effect | Higher agricultural productivity brought about by electrification raised rural income (Barnes 2007). | | Very little impact on agricultural development (Barnes 1988) | | | |
| Productive uses: agricultural targeting | | | Absolute business activity was positively correlated with year of electrification; percent of households with business higher in electrified than in unelectrified villages; most business started after electrification. About two-thirds of surveyed businessmen indicated that they would face difficulty without electricity supply (Barnes 1988). | | | Small farms did not have a marked increase in productivity once electrified (Barnes 2007, pp. 32, 34). |
| Productive uses: business targeting (industry and/or SME) | | | | | FUNDAP carried out promotion activities on benefits of electrification and uses of electrical machin- | |

*(Table continues on next page)*

**Latin America and Caribbean** ***(continued)***

| Topic | Mexico | Peru | Colombia | El Salvador | Guatemala | Costa Rica |
|---|---|---|---|---|---|---|
| | | | | | ery and gave loans to small businesses supported by technical assistance, targeting those that would not otherwise have access to credit (creating a likely downward bias compared to control). The results suggest higher electricity usage among loan beneficiaries and a consequent positive impact on income (Shonder and Wilbanks 1996). | |
| Health benefits | More refrigeration for food and medicines and reduction in kerosene use lead to better health (Barnes 2007). | Lighting and vaccine cold storage for small hospitals; fuelwood is still the main source for cooking, so there is no effect on indoor air quality; street lighting led to fewer attacks at night (Valencia and others 1990). | | | | Increase in the number of health centers (Barnes 2007, pp. 32, 34). |
| Alternative energy | Since 1990, the Federal Power Commission has been incorporating renewables in electrification planning for rural areas (Barnes 2007, p. 150). | | | | | Consortium of cooperatives building a hydroplant to connect to grid for lower-cost energy. Some users are also connecting SHS and wind to grid (Barnes 2007, pp. 34, 40). |

## South Asia Region

| Topic | India | Bangladesh | Sri Lanka |
|---|---|---|---|
| Poverty targeting, pro-poor government policy and end-user knowledge | | | |
| Usage patterns | Increased working hours, because cooking is delayed to evening; increased productivity of women making handicrafts using night light; increased reading time for children and adults; increased fan use (Barnes 1988). | | |
| Time savings from not collecting biomass | Electricity did not replace firewood and kerosene as the energy source for cooking (Barnes 1988). | | |
| Promotional activities | RE resulted in positive agricultural productivity because it was complemented as part of development programs (for example, hybrid seeds/fertilizer in the Green Revolution) and government policies (credit for electric pumps and subsidized tariffs, resulting in an increase in the number of electrified fields/pump sets in India from 500,000 in 1966 to 10 million in 1992) (Barnes 1988). India Grameen Shakti, an outgrowth of the Grameen microfinance group, offers improved credit terms for SHS, with concessional loan from GEF/IFC. The program includes intensive outreach and a training program through 52 branch offices. A variety of artisan, rural industry, and agricultural uses are reported. Industrial charges are triple that of agricultural, but much lower compared to the alternative energy source, diesel (Barnes 1988). | Potential new consumers are informed about how to obtain service. Meetings are held with community leaders and rural industries, farming groups, and commercial leaders to disseminate key information and ensure that their interests are considered. Rural Electrification Board personnel organize membership committees to encourage community participation. Awareness of key issues is also promoted through distribution of information bulletins and through consumer meetings and village electrification committees (Barnes 2007). | |
| Household income effect | Impact on household income is indirect, through changes in irrigation patterns (that is, active promotion of electric pumps since 1966) and agricultural in- | | |

*(Table continues on next page)*

**South Asia Region** *(continued)*

| Topic | India | Bangladesh | Sri Lanka |
|---|---|---|---|
| | novations (increased access through improved distribution of fertilizer and hybrid seeds—Green Revolution). RE without pumping for irrigation means that new agricultural technology is less likely to improve agricultural productivity. Growth of agricultural pump sets was slow, a gradual, cumulative process (Barnes 1988). Traditional methods of irrigation were replaced by electrical pump sets in electrified villages, resulting in increased agricultural productivity. | | |
| Productive uses: agricultural targeting | Government policy was that electricity should be used for agricultural and rural productivity, specifically. RE found to have direct impact on investment in pumps and then, indirectly, on well irrigation. Study suggests that electricity had an impact on multiple cropping although findings are not robust. Same for impact on level of agricultural innovations, which seem to reach high levels a number of years after electrification (Barnes and Binswanger 1986). RE was found to be positively associated with business development, resulting in an increase in both new businesses and businesses using electricity. Electrified businesses have twice the capital, more employees, lower fuel costs, and higher productivity. The cottage industry also benefited from extended hours and improved income. In the short run, the cottage industry does not seem to be affected by the increase in rural industry due to electrification (Barnes 1988). | Promotion of productive uses has become priority for the Rural Electrification Board. This is reflected in the requirement that all rural communities meet certain revenue requirements. Emphasis has been on the promotion of irrigation and rice milling (Barnes 2007). | |
| Productive uses: business targeting (industry and/or SME) | RE and education programs had mutually reinforcing consequences, through lighting for reading and the village environment (Barnes 1988). RE appeared to lead to the setting up of a larger number of shops in the village and engendered a structural shift in employment to the tertiary sector. In individual service | In addition to the above, electricity cooperatives provide technical assistance to potential small industrial and commercial clients, for example, assistance in purchasing of electric motors and machinery (Barnes 2007). | Mini-grid was used for grinding mills, radio repair shops, and carpenters, but its potential was not realized. Reasons for this include that the suppliers were not oriented to promoting productive uses, and locations using minihydro were remote so there was limited market |

| | | | |
|---|---|---|---|
| | establishments, RE seems to lead to larger firm size, more items sold, longer working hours, higher income, and higher incomes per employee (Barnes and Binswanger 1986). | | access. For off-grid, there were few productive uses because of low voltage of supply. |
| Social service staffing (education and health staff) | Some substitution of electricity for kerosene in lighting (Barnes 1988). | The proportion of households in the community with electricity has a strong positive impact on the likelihood of living in the community, which in turn reduces absenteeism (Chaudhury and Hammer 2003). | |

**Asia**

| Topic | Indonesia | Thailand | China |
|---|---|---|---|
| Poverty targeting, pro-poor government policy, and end-user knowledge | Government policy was to target the early stages of RE toward villages that were already "relatively well developed"—villages in study were all within 10 km of the district capital and 20 percent below the poverty line as opposed to 45 percent, the rate in rural Java overall (Meier 2001). RE progress initially (the 1980s) was in areas that had potential—first, ones near the grid, second, ones with non-oil energy potential, and third, others using diesel power (Barnes 1988). | Government plan was to electrify whole of Thailand by the end of the 20th century. However, within villages, no major pro-poor policy was in effect, and as a result a quarter of the households remain unconnected even when the village has had electricity for 20+ years. This was largely because of high up-front costs and monthly bills and inappropriate dwellings (Piampiti and others 1982). The government provided solar battery charging stations to indigenous peoples in Thailand (these are village-level systems, from which households take electricity rather than household level SHS) (Green 2005). | |
| Usage patterns | High use of appliances such as TV, fridge, sewing machine, and water pumps (Barnes 1988) | Increased use of appliances (for example, rice cookers) and productive hours (Cecelski 1992). Electrified villages are generally better equipped than nonelectrified: 37:26 piped water; 65:29 concrete roads; 40:14 health centers; 8:0 secondary schools. Econometric modeling indicates that the availability of electricity had a positive impact on migration, though not on the crude birth rate at village level, couples' income, female labor force participation, fertility, mortality, and migration at the household level (Pi- | Stage 1: (1949–57): Lighting and food processing. Stage 2: (1958–78) also: Flood prevention, irrigation, productive uses (see below) (Barnes 2007). |

(Table continues on next page)

**Asia** ***(continued)***

| Topic | Indonesia | Thailand | China |
| --- | --- | --- | --- |
| | | ampiti and others 1982). There was no observable effect on child literacy rates, and there are a lot of problems with low educational achievement in this Region—having electricity is a low priority for helping education (Green 2005). | |
| Time savings from not collecting biomass | | Households rarely use electricity for cooking; they typically use charcoal or firewood instead (Piampiti and others 1982). | |
| Promotional activities | Indonesia subsidizes diesel and has high tariff and installation charges for electricity, which makes electric power an unattractive option (Barnes 1988). | | Stage 2: As part of strategy to promote productive uses of RE, the government organized workshops to disseminate successful experiences in the development of small hydropower. Also developed a quota scheme for raw materials, giving priority to the rural industrial sector. Financial and technical support for local manufacturers producing goods needed for development of RE. Stage 3: Starting in 1950 the government used professional personnel to disseminate technologies through national and provincial meetings, training courses, and workshops (Barnes 2007). |
| Household income effect | Very little impact on agricultural development (Barnes 1988) | Irrigation is insufficient in villages in northeast Thailand (electrified and nonelectrified) (Piampiti and others 1982). There was no income-generation effect, as people did not have access to appliances, and the power supply from SCBS was too low for many appliances anyway. It was also risky because supply was not reliable (Green 2005). | Stage 2: RE to support irrigation and agricultural mechanization and water conservation. General: Subsidies for sectors that consider energy critical including agricultural product processing (Barnes  2007). |
| Productive uses: agricultural targeting | Electrification resulted in extension of work hours, but not employment. Electric tools not used, except for lighting (Barnes 1988). Business development hin- | Noted increase in household industry (Cecelski 1992). About a third of the industries electrified in the electrified villages. | Stage 2: RE as support for development of rural small industry and steel making (Barnes 2007) |

| | | | |
|---|---|---|---|
| | dered by subsidization of diesel, capital scarcity, poor product marketing channels, and inadequate information (Barnes 1988). | | |
| Productive uses: business targeting (industry and/or SME) | Kiosk owners reported sales increases, as they could extend their product ranges to include wiring material, lightbulbs, and kerosene cookers (some electricity consumers have substituted firewood for kerosene previously used for lighting). The most prevalent productive use of electricity was ice production in freezers used for ice lollies and ice cubes (Meier 2001). Productive uses of electricity were found within various sectors, with the largest percentage in the services sector. At the household level 26 percent of households with home enterprise increased income following electrification, as opposed to 4 percent without electrification (Brodman 1982). Obstacles in optimizing productive uses included difficulty obtaining credit, need for marketing assistance, lack of information on, for example, electricity use, amount of power available, comparative costs, maintenance requirements for electric equipment. | Staffing of doctors and nurses was better at the electrified health stations than unelectrified (12:0.1) (Piampiti and others1982). | |
| Alternative energy | Mini-hydro (Meier 2001) | Solar (Green 2005) | Small hydro power (Barnes 2007) |

**Sub-Saharan Africa**

| Topic | Tunisia | Kenya | Botswana | Ethiopia | Zambia | Nambia |
|---|---|---|---|---|---|---|
| Poverty targeting, pro-poor government policy, and end-user knowledge | Lifeline tariff for rural low-voltage grid consumers using less than 50 kWh/month. Tariffs have increased less and more slowly for these consumers than for other groups. Also, more than | Tariffs are based on successive consumption bands where decreases occur as consumption increases—favoring large consumers. Consumers are organized in five different tariff categories | Coverage existed to rural areas where economic and industrial activities were easy to stimulate (Ramasedi 1992). | Government wants RE but has left subsidization to the utilities, resulting in long waiting lines and reduced hours of operation. Energy is supplied (through diesel in Bonga) | Financing RE is a major problem for ZESCO, so the normal criterion used in the selection of projects for implementation is economic viability. The only users that are better | Grid users enjoy free connections. Solar users have a down payment of 20 percent of the system cost. Households must have a minimum income of $2,500. |

(Table continues on next page)

**Sub-Saharan Africa *(continued)***

| Topic | Tunisia | Kenya | Botswana | Ethiopia | Zambia | Nambia |
|---|---|---|---|---|---|---|
| | 90 percent of PV systems for remote rural areas are heavily subsidized (Barnes 2007). | (< 7 M kWh/month; 7–100, >100, off-peak interruptible service, street lighting), with tariff uniform within each category. As it is cheaper to supply services to urban areas, rural consumers are effectively subsidized. However, tariffs are high and increasing (Walubengo and Onyango 1992). | | for 6 hours per day to metered consumers (Mariam 1992). | off are those connected to the grid. Some economically impractical projects were included by government on social or political grounds but were then subsidized under special funding (Foley 1993). | |
| Usage patterns | | Stem migration, water heating (accounted for 20 percent of all consumption in 1986), provision of clean water through electric pumping, lighting, refrigeration, communication, cinema, employment, and convenience (Walubengo and Onyango 1992) | Electricity has meant decreased water supply interruptions. The average income of a household of five has increased from $15 per month to $30 per month. (Ramasedi 1992). | The limited supply in rural areas has supported the municipal water supply, central clinics, street lighting, adult education, and other civic systems. Drop-out rate has improved over the years (Mariam 1992). | | Electricity mainly used for lighting. Just under 10 percent of grid-electrified households use electricity for cooking, and none of solar powered households do, as voltage is insufficient. Solar also is not used for radio, as it provides 12 volts and radio requires 9 volts. |
| Time savings from not collecting biomass | | Majority of population still uses wood for cooking (Walubengo and Onyango 1992). | | | | |
| Household income effect | | Price of paraffin (kerosene) has been kept low, and any attempt to remove the subsidy on it would be politically difficult. Liquefied petroleum gas is not subsidized, | Instead of load-promoting connection policy, the Business Partnership Center has a load-deterring connection policy of making the subscriber pay for the | | Some projects were initiated on a cost-sharing basis with private sector industries or agricultural enterprises (Foley 1993). | |

| | | | | | |
|---|---|---|---|---|---|
| | | however. The electrification program has been to electrify all 42 district headquarters, then rural industries formerly dependent on diesel, then small market centers. Domestic consumers are expected to be targeted only in the 21st century. The government currently pays a higher subsidy/grant to those whose demand is higher (Walubengo and Onyango 1992). | long-term costs, distribution transformer, and service connection. A consumer has to make an initial payment of $800 for single-phase connection and incur a cost of US$5591 for a 30 KVA pump station. The corresponding supply costs are half these amounts—implying 100 percent profit margin (Ramasedi 1992). | | |
| Productive uses: agricultural targeting | Since the early days of RE, tariff policies have encouraged agricultural activities such as irrigation, oil pressing, and milling/grinding as part of a broader program to stimulate rural development (Barnes 2007). | | There has been significant growth in small-scale activities such as dairy farming, horticulture, and pig raising over 10 years (Ramasedi 1992). | | Some evidence of the use of electricity for productive purposes on commercial farms close to urban areas, but overall electricity has had no discernible development impact in most areas (Foley 1993). |
| Productive uses: business targeting (industry and/or SME) | | In most areas with electrification, diesel motors have been replaced by electric ones, which are cheaper and more efficient (Walubengo and Onyango 1992). | New activities attracted because of electrification, such as a defense air base, a police college, and a Rural Industries Office (using PC) (Ramasedi 1992). | The range of electrically operated coffee processing equipment has increased Bebeka Coffee Plantation's production by 35–40 percent over 10 years. However, in most places the main use is for lighting, cutting out all productive uses (Mariam 1992). | |

*(Table continues on next page)*

**Sub-Saharan Africa** *(continued)*

| Topic | Tunisia | Kenya | Botswana | Ethiopia | Zambia | Nambia |
|---|---|---|---|---|---|---|
| Social service staffing (education and health staff) | | There are new and improved health and education centers operated on cheaper and more efficient electricity, rather than diesel (Walubengo and Onyango 1992). | There are new education centers and schools and suitable accommodation for staff who teach agricultural skills, hygiene by medical staff, and other education staff (Ramasedi 1992). | Lighting at educational officer's residence resulted in having an in-house educational officer (Mariam 1992). | The main beneficiaries of RE were public service workers or employees of private companies (Foley 1993). | There was no evidence of impact: no new businesses started after electrification (and home business were even more among the non-electrified). |
| Health benefits | | | There has been a decline in the crude death rate over past 10 years (Ramasedi 1994). | | | |
| Alternative energy | Photovoltaic systems (Barnes 2007) | | | Analysis reveals that, where possible, hydro is the best, least-cost option for Ethiopia, followed by grid and then diesel (Mariam 1992). | | As electricity little used for cooking, these benefits are limited. |

*Note:* DAM = Demand Assessment Model; FUNDAP = Fundacao de Desenvolvimento Administrativo do Estado de Sao Paulo; GEF = Global Environment Facility; IFC = International Finance Corporation; km = kilometer; PV = photovoltaic; RE = rural electrification; SBCS = solar battery charging station; SHS = solar home system; SME = small and medium-size enterprises.

# APPENDIX F: IMPACT OF RURAL ELECTRIFICATION ON MICROENTERPRISE

While stimulation of productive enterprise is claimed to be among the benefits of electrification, few studies have tried to quantify these benefits using an impact evaluation methodology. For example, the USAID evaluation of RE in Bangladesh (Barkat and others 2002) identifies those enterprise activities that use electricity and attribute the total income from these to electrification, thus ignoring the possibility of substitution of either one activity for another or energy sources—and so overestimating the benefit. An exception is the ESMAP study of the Philippines, the data from which are reanalyzed in this appendix.

The Independent Evaluation Group (IEG) analyzed three different effects considered important to achieving higher economic benefits: (i) complementary infrastructure—such as roads, transport, markets, bank, and adult literacy; (ii) stock of equipment and tools of microenterprises; and (iii) hours of operation. The empirical evidence relating to each of these points is discussed in the following sections.

## Data Sources

The Living Standard Measurement Survey (LSMS) for Peru in 1994 covered 112 conglomerates, with the sample drawn from all three rural regions—mountain, coast, and forest—of the country. The 1991 LSMS for Peru covered 43 conglomerates restricted to the rural mountain regions of the country. The 1994 LSMS sample, however, covered all 43 conglomerates and all dwellings within these conglomerates that were interviewed in the 1991 LSMS, thus giving panel data for the rural mountain regions of the country.

It is these data that are used here to analyze the short-term growth and development impacts of RE on microenterprises. A difference-in-difference approach (the change over time in the difference between electrified and nonelectrified communities) was used to analyze the impact of electrification, because only two conglomerates were newly electrified during the three years 1991–94. The 1994 nationally representative LSMS was analyzed by examining the links in the casual chain.

The Ghana education impact evaluation (IEG 2004) covered the same communities (though not the same households) that were covered by the LSMS for Ghana in 1988. This community-level panel was used to analyze the long-term impacts of RE on growth and development of microenterprises. The 1998 nationally representative LSMS for Ghana was analyzed using the casual chain. In each case, only those communities classified as rural were used. Table F.1 presents the breakdown of communities by electrification status for each year for the two countries. Also analyzed were the Lao PDR and the Philippines RE-specific data sets.

**Are complementary infrastructure—such as roads, transport, markets, bank—and adult literacy more likely in electrified communities?**

Complementary infrastructure such as roads, transport, markets, buildings, equipment, and training and information—often not provided in tandem with electricity—are important to achieve economic benefits from electrification (Cecelski 2004). There are two issues here. First, is general infrastructure, such as roads for access to markets, available in electrified communities? Second, are business-specific services more available? The first question is clearly a matter of correlation

**Table F.1: Breakdown of Communities by Electrification Status (Number of Communities)**

| | Peru | | | Ghana | | |
|---|---|---|---|---|---|---|
| Community status | 1991 | 1994 (1991 sample) | 1994 | 1998 | 1988 (2003 sample) | 2003 |
| Electrified | 22 | 24 | 42 | 64 | 4 | 21 |
| Nonelectrified | 17 | 15 | 69 | 126 | 32 | 16 |
| Total | 39 | 39 | 111 | 190 | 36 | 37 |

**Table F.2: Complementary Infrastructure**

| | Peru | | Ghana | |
|---|---|---|---|---|
| Facility | Electrified | Nonelectrified | Electrified | Nonelectrified |
| Post office | 0.071 | 0.140 | 0.368 | 0.056** |
| Restaurants | 0.262 | 0.246 | 0.887 | 0.403** |
| Bank | 0.000 | 0.000 | | |
| Market | 0.047 | 0.058 | 0.351 | 0.103** |
| Road | 0.809 | 0.695* | 0.958 | 0.818** |
| Transport | | | 0.895 | 0.605** |
| Water | | | 0.509 | 0.024** |
| Primary school | 0.905 | 0.927 | 0.949 | 0.878* |
| Secondary school | 0.714 | 0.464** | 0.775 | 0.488** |
| Health staff | | | 0.657 | 0.410** |
| Health facility | | | 0.635 | 0.440** |
| Adult literacy | 0.619 | 0.580 | 0.737 | 0.831 |
| Wage | 3.002 | 2.553** | | |
| Microenterprises | 0.435 | 0.375 | 0.580 | 0.359* |
| Number of communities | 42 | 69 | 57 | 124 |

*Significant differences at 1 percent.
**Significant differences at 5 percent.

rather than causation—the point of the analysis being to see whether conditions for successful utilization of electricity for business purposes are in place.

The data used are from LSMS community questionnaires for Peru 1994 and Ghana 1998. In Ghana in 1998, electrified communities had a significantly higher number of facilities—post office, restaurant, market, roads, transport, water, school, and health—than the nonelectrified communities and a significantly higher percentage of households operating a microenterprise as their primary or secondary occupation.

In Peru in 1994, electrified communities had similar complementary infrastructure, compared with the nonelectrified communities, except for roads and secondary schools. Electrified communities have significantly better roads and higher probability of having a secondary school (table F.2). Although electrified communities had a significantly higher reservation wage, there was no significant difference between electrified and nonelectrified

**Table F.3: Ghana Community Panel Analysis by Electrification Status (Considering only Nonelectrified Communities in 1988)**

| | Nonelectrified in 2003 | Electrified in 2003, not in 1988 | Electrified in 1988 | Difference-in-difference t-statistics | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (1) & (2) | (1) & (3) |
| Enterprises in 1988 | 9.7 | 5.8 | 9.2 | | |
| Enterprises in 2003 | 9.1 | 12.6 | 10.2 | –2.76[b] | –0.33 |
| Hours worked/day in 1988[a] | 4.1 | 4.9 | 5.0 | | |
| Hours worked/day in 2003[a] | 4.6 | 4.8 | 5.3 | 0.80 | 0.21 |
| Number of communities | 15 | 17 | 4 | 32 | 19 |

a. Number of hours reported by self-employed members who are working in manufacturing, service, or retail industry.
b. Significant difference at 1 percent.

communities in percentage of households operating a microenterprise as their primary or secondary occupation.

Significant differences in access to road, transport, and even market between electrified and nonelectrified communities are not surprising. The economics of extending the grid to rural areas is least prohibitive for communities closer to a road. Thus, communities closer to a road are likely to be electrified first, and other facilities and infrastructure usually expand over time.

The second question relates to business support services such as microfinance—a common finding in the literature is that these services are necessary to ensure that RE has the desired impact on microenterprise development. Few Bank RE projects have contained explicit components on either nurturing enterprise development or providing training in using electricity for productive purposes, though of course another scheme may provide microfinance, for example, the Grameen Bank in Bangladesh.

Credit and concessional loans allowed local entrepreneurs to explore possibilities for electrification in India Grameen Shaki and the Sri Lanka SEEDS/ESD Project; knowledge and training on how to use newfound electrical and motive power increased profitability for households under the Nepal Home Employment and Lighting Package. In Morocco, a United Nations Development Programme program sponsored workshops for the youth promoters on starting up and managing a microenterprise and establishing network of collaborators.

**Does electricity increase productivity/profitability through increased hours of operation and use of equipment and tools?**

The Ghana panel (1988–2003) has 48 communities, of which 32 were not electrified in 1988 (see table F.3). Of these 32 communities, 17 were electrified as of 2003. The number of people reporting self-employment in areas of manufacturing, service, or retail businesses has increased significantly in the electrified communities, compared with the nonelectrified communities, but the hours worked per day are not significantly different between the two.

The Peru panel has 224 rural households that were interviewed in 1991 and again in 1994. Of these, 113 (50 percent) did not operate a microenterprise in 1991 or in 1994. In 1994, 35 households reported a microenterprise but did not report having one in 1991; and 26 households reported a microenterprise in 1991 but not in 1994. Although the turnover was higher in electrified communities, the absolute increase in number of microenterprises was higher in the nonelectrified communities.

The balanced panel results in the 50 households with a microenterprise in both periods. However, the industry code used to classify industry activities changed between 1991 and 1994, so analysis based on microenterprise-level data (change in profits, equipment, and so forth) is difficult. The number of hours worked by these households before and after (irrespective of industry codes) was found to be independent of electrification status. In a further analysis carried out for all common households between 1991 and 1994, for change in self-employed hours reported by household (irrespective of industry code), differences between the electrified and nonelectrified households were also found to be insignificant.

Because of limited observations in Ghana and mismatched data in Peru, the panel data do not shed light on the impact of electrification on productivity/profitability of microenterprises. The causal chain for the impact using cross-sectional data was thus analyzed—for Peru 1994, Ghana 1998, Philippines 2002, ESMAP data and Lao PDR 2002—as follows: (1) access to electricity increases hours household members put into the business; (2) access to electricity increases use of equipment and tools, thereby increasing productivity; (3) access to electricity improves community infrastructure required to reap economic benefits; and (4) improved community environment, increased productivity, and hours of operation result in increased profits.

The variable used to measure hours put in by household members in the microenterprise comes from data on the economic activity module, which records average hours worked per week by each member of the household, by industry code. These were matched to industry codes specified in the business module and summed over households. The variable used to measure value of equipment and tools owned by the business came directly from the business module. The data in LSMS are deflated to correct for inflation during the survey period.

The explanatory variables are (1) household characteristics (housing index, education of household head, dependent-adult ratio, and household electricity status),[1] (2) entrepreneur characteristics (age, marital status, and education), and (3) community characteristics (regional dummies; reservation wage in the case of Peru [proxy for opportunity cost of doing business]; price of alternate fuels and some infrastructure variables, for example, distance to road; community electrification status). These variables are selected as being exogenous with respect to electrification. In a theoretical household model, income would enter the model but be endogenous; here the income term is instrumented by the education of the household head and a housing index (rather than a more extended wealth index, which is arguably endogenous).

In the revenue/profit equation, electricity appears as a variable both in its own right and through the channels affecting hours worked (Peru, Ghana, and Philippines), equipment (Peru and Ghana), and distance to road as a proxy for community development. The channels are tested by running the regression with and without hours of operation and value of equipment owned. If the electricity channel is measured only through hours of operation and value of equipment owned, then the household electricity variable will be significant when these variables are dropped but insignificant when they are included.

The two-step Heckman model is used to correct for sample selection bias, estimating the equation for those rural households with a microenterprise. Tables F.4–F.7 present the results for Peru, Ghana, the Philippines, and Lao PDR, respectively, for two or three variables: total hours worked by household members on the business, value of equipment and tools owned by the business, and business returns.

The housing index does not capture much except in Lao PDR. Households with more dependents are more likely to operate a microenterprise in Ghana and the Philippines and less likely to operate a business in Lao PDR. Education of the household head has a positive influence on the propensity to operate a microenterprise in all countries but Peru. The probability of a household running a business was found to be positively related to electrification status in the Philippines and to community electrification status in Ghana. The price of alternative fuel was a deterrent for oper-

**Table F.4: Peru: Impact on Microenterprises**

| | Propensity to operate ME | Hours worked | Value of worth | Revenue | Revenue + |
|---|---|---|---|---|---|
| House quality index | 0.7 | | | | |
| Household has electricity | | 0.59 | 0.41 | –0.23 | –0.08 |
| Education of household head = 1 | –0.11 | | | | |
| Education of household head = 2 | 0.05 | | | | |
| Entrepreneur education level = 1 | | 0.22 | 0.68 | 0.63[a] | 0.33 |
| Entrepreneur education level = 2 | | –0.16 | 0.82[c] | 0.45 | 0.19 |
| Entrepreneur head of household | | 1.65[a] | –0.16 | –0.58[a] | –0.41 |
| Age of head of household | –0.28 | | | | |
| Age of entrepreneur | | | 1.69[b] | 0.74[a] | –0.03 |
| Dependency ratio [0 – 14/15+] | 0.09 | | | | |
| Male entrepreneur | | 0.3 | 0.87[c] | 0.64[b] | 0.12 |
| Business is the main occupation of entrepreneur | | 2.61[b] | 0.72[c] | 0.35[a] | 0.11 |
| Years of operation (business) | | 0.19 | 0 | 0 | –0.04 |
| Business outside home (fixed) | | 2.05[a] | 0.17 | 0.57[a] | 0.24 |
| Mobile business | | –0.54 | –0.83 | 0.24 | 0.48[a] |
| Retail business | | 1.95[a] | 0.76[c] | 0.79[b] | 0.53[a] |
| Service business | | 1.09 | 0.25 | –0.2 | –0.34 |
| Household hours in business | | | | | 0.06[a] |
| Value of business | | | | | 0.48[b] |
| Road index | –0.73[a] | | | | –0.27 |
| Price of candle | –1.68 | | | | |
| Price of kerosene | 0.27 | | | | |
| Reservation wage (community average) | 0.08 | | | | |
| Community electrified | 0.24 | | | | |
| 3 regional dummies suppressed | | | | | |
| Constant | 0.73 | 2.49 | –0.29 | 4.14[b] | 2.01 |
| Observations | 1338 | 524 | 524 | 524 | 524 |
| F-stat | 1.63 | 5.22 | 6.23 | 8.12 | 22.44 |

*Note:* ME = microenterprise.
a. Significant at 5 percent.
b. Significant at 1 percent.
c. Significant at 10 percent.

ating a microenterprise in all countries, but significant only in Ghana.

Entrepreneurs who are heads of households were more likely to put more hours into the enterprise than others in both Peru and Ghana, where information was available on the person responsible for the microenterprises; however, the result was significant only in Peru. In the Philippines, older or educated entrepreneurs were more likely to put in fewer hours. Households operating retail enterprises are more likely to put extra hours in Peru and the Philippines.[2] Lao PDR data do not have information on total hours worked by the household in running a microenterprise.

In Ghana, the stock of equipment a microenterprise owned was likely to be greater for older

**Table F.5: Ghana: Impact on Microenterprises**

| | Propensity to operate ME | Equipment purchased | Hours worked | Revenue | Revenue + |
|---|---|---|---|---|---|
| House quality index | 0.17 | | | | |
| Household has electricity | | 0.12[c] | 0.32 | 0.08[b] | 0.07 |
| Education of household head | –0.13 | | | | |
| Education of household head | –0.25 | | | | |
| Education of household head | 0.01 | | | | |
| Education of household head | 0.89[a] | | | | |
| Entrepreneur uneducated | | –0.09[b] | 0.26 | –0.01 | –0.01 |
| Female head of household | –0.1 | | | | |
| Entrepreneur head of household | | 0.03 | 0.36 | 0.03 | 0.02 |
| Male entrepreneur | | 0.24[a] | –0.55 | 0.11c | 0.10[c] |
| Dependency ratio (0–14s/15+) | 0.08[b] | | | | |
| Age of head of household | –0.62[a] | | | | |
| Age of entrepreneur | | 0.11[b] | | –0.09[b] | –0.08 |
| Years of operation (business) | | 0.02[b] | 0.18[b] | 0.04[a] | 0.04[a] |
| Manufacturing business | | 0.19[c] | –0.06 | –0.16[a] | –0.18[a] |
| Service business | | 0.28[a] | 0.35 | –0.26[a] | –0.30[a] |
| Value of equipment | | | | | 0.10[b] |
| Household hours in business | | | | | 0.01[b] |
| Distance to road | –0.03 | | | | 0.01 |
| Price of kerosene | –0.20[b] | | | | |
| Community electrified | 0.35[a] | | | | |
| 10 regional dummies suppressed | | | | | |
| Constant | 2.17[a] | –0.31 | 4.83[a] | 0.44[a] | 0.38[c] |
| Observations | 3,938 | 1,742 | 1,742 | 1,742 | 1,675 |
| F-stat | 5.39 | 6.81 | 3.62 | 28.57 | 8.1 |

*Note:* ME = microenterprise.
a. Significant at 1 percent.
b. Significant at 10 percent.
c. Significant at 5 percent.

enterprises and enterprises that were operating a manufacturing or service unit. Male entrepreneurs were likely to invest more in equipment, as were entrepreneurs who were educated. In Peru, because of lack of data on equipment, the net worth of the microenterprise was regressed instead. The worth of the enterprise was likely to be higher for older and educated entrepreneurs. Mobile businesses, not surprisingly, were likely to be of low worth. Philippines ESMAP data and the Lao PDR data set do not have information on equipment owned by the microenterprise.

The revenue of the enterprise was higher for fixed and retail businesses in Peru, lower for manufacturing and service units in Ghana, and higher for retail businesses in Lao PDR. Older enterprises were likely to have higher earnings, as were enterprises operated by men in Ghana. Household hours put into the business were positively related to revenue/profit earnings of the microenterprise for Peru, Ghana, and the Philippines. Stock of equipment and worth of the microenterprise were positively related to revenue/profit earnings of the microenterprise in both Peru and Ghana.

**Table F.6: The Philippines: Impact on Microenterprises**

| | Propensity to operate ME | Hours worked | Income | Income + |
|---|---|---|---|---|
| House quality index | 0.18 | | | |
| Household has electricity | 0.59[a] | | | |
| Male household head | –0.08 | –0.99 | 0.64 | 0.76 |
| Age of head of household | 0.41[b] | –2.83[a] | 2.19 | 2.2 |
| Household education (in years) | 0.04[b] | –0.15[c] | 0.34[a] | 0.34[a] |
| Dependency ratio [0–14/15+] | 0.07[c] | | | |
| Cultivators | –0.13 | | | |
| Commercial farming | 0.19 | | | |
| Livestock rearing | 0.18[c] | | | |
| Finland fishing | –0.54 | | | |
| Sari-sari store | | 3.11[a] | 1.86[b] | 1.60[c] |
| Business is the main occupation of entrepreneur | | 0.77 | 0.4 | 0.05 |
| Business uses electricity | | 1.47[b] | 1.74[b] | 1.64[b] |
| Business uses kerosene | | –0.21 | 1.02 | |
| Business uses biomass | | –0.43 | 0.53 | |
| Business uses liquefied petroleum gas | | –2.09[b] | 1.02 | |
| Hours worked in business | | | | 0.14[c] |
| Price of dry-cell batteries | –0.03 | | | |
| Time taken to collect water | 0.01[b] | | | |
| 3 regional dummies suppressed | | | | |
| Constant | –3.29[a] | 15.11[a] | –10.44 | –10.53 |
| Observations | 1,979 | 250 | 250 | 250 |
| F-stat | 8.29 | 6.75 | 11.2 | 10.23 |

*Note:* ME = microenterprise.
a. Significant at 1 percent.
b. Significant at 5 percent.
c. Significant at 10 percent.

Electrification status of the household was significantly and positively related to equipment and earnings in Ghana, but not hours worked; it was positively related to hours worked and revenue earnings in the Philippines and to revenue earnings in Lao PDR. All three equations were found to be independent of the electrification status in Peru. The channel of electrification is clear in Ghana, where the variable capturing electrification status of the household becomes insignificant once the hours and value of equipment are added as regressors in the revenue equation. In the Philippines, the variable capturing use of electricity in home business is significant even when hours worked is added as a regressor. One possible explanation, stemming from the Ghana analysis, may be that electricity is capturing electrical tools used in businesses.

Electrification has a small but significant impact on the revenue earnings of the microenterprise. The possible channels are increase in number of hours worked per day by the household members and use of electrical equipment.

**Table F.7: Lao PDR: Impact on Microenterprises**

| | Propensity to operate microenterprise | Business income |
|---|---|---|
| House quality index | 0.41[a] | |
| Household has grid | | 0.53[b] |
| Household has electricity | | 0.17 |
| Household education (in years) | 0.07[b] | |
| Dependency ratio (0–14/15+) | –0.10[c] | |
| Number of businesses | | –0.11 |
| Business is the main occupation of entrepreneur | | 1.45[b] |
| Home-based business | | –0.19 |
| Retail business | | 1.39[b] |
| Pieces of farmland owned | 0.00 | |
| Distance to road | –0.01 | |
| Price of electricity | 0.13 | |
| Price of diesel | –0.03 | |
| Community electrified | –0.13 | |
| 15 regional dummies suppressed | | |
| Constant | –2.26[b] | 14.02[b] |
| Observations | 5,446 | 529 |

a. Significant at 5 percent.
b. Significant at 1 percent.
c. Significant at 10 percent.

DHS data were analyzed for 11 countries (table G.1). DHS survey instruments are reasonably standardized across countries, allowing the same model specification to be used for different countries, albeit with some variations in variable definition. In each case only those households classified as rural were used. The sample size varied from 2,801 (child nutrition in Peru) to 17,165 (women in Indonesia).

Three different effects were examined using these data: first, how access to information from TV and radio influences health knowledge and so health behavior and health outcomes; second, how the availability of refrigerated storage improves nutrition; and third, how electricity affects schooling.

The causal chain for the first possible impact is as follows: (1) access to electricity increases time spent watching TV and listening to the radio; (2) increased access to media increases awareness of health issues; (3) this increased awareness results in changed health behavior; and (4) changed behavior improves health outcomes and reduces fertility. The empirical evidence relating to each of these points is discussed in turn.

## Knowledge-Media Link

Two variables are used to measure health knowledge. The first is the response to the DHS question regarding knowledge of modern contraceptives. Women are asked to name modern contraceptive methods they know; the questionnaire records those they name against a list in the survey. The number of possible methods ranges from 0 to 12 (Ghana). The variable is simply the number of methods named. The coefficients are thus not comparable between the regressions.

The second knowledge variable is a simple average of four separate questions from the survey: (1) the contraceptive knowledge variable already mentioned, but scaled to be between 0 and 1; (2) knowledge of the timing of ovulation (0 = incorrect answer "do not know, any time, or middle of the periods," 0.5 = "after period ends or before period starts," and 1 = correct answer "middle of cycle") (this question was not asked in Bangladesh, where instead a question was asked on knowledge of signs of a risky pregnancy); (3) knowledge of the symptoms of AIDS, scaled between 0 and 1; and (4) knowledge of oral rehydration salts.

The explanatory variables are the same in each case covering (1) household characteristics (housing index, education of household head, and whether the household has electricity); (2) individual characteristics (age, marital status, literacy, agency, and whether the women listen to the radio at least once a week and watch TV at least once a week); and (3) community characteristics (regional dummies and the share of women who have heard of family planning by family planning worker by cluster). The share of women visited by a family planning worker is a proxy for active health or family programs in the area. Most of these variables are self-explanatory, but some require a little discussion. A more general wealth index is not used, to avoid problems of endogeneity, and the housing index, together with education of the household head, may be regarded as an instrument for income.

Electricity appears as a variable in its own right, through the channels of affecting women's access to TV directly and indirectly through someone else owning a TV (proxied by household electrification rate in the community). This channel is tested by

**Table G.1: DHS Sample Sizes**

| Country | Survey year | Eligible women | Children under 5 |
|---|---|---|---|
| Bangladesh | 2004 | 7,536 | 4,835 |
| Ghana | 2003 | 3,317 | 2,801 |
| Indonesia | 2002–03 | 17,165 | 9,636 |
| Morocco | 2003–04 | 7,801 | 3,496 |
| Nepal | 2001 | 7,572 | 6,294 |
| Nicaragua | 2001 | 5,775 | 3,973 |
| Peru | 2000 | 10,749 | 7,467 |
| Peru | 2004 | 4,737 | 2,717 |
| Philippines | 1998 | 7,253 | 5,004 |
| Philippines | 2003 | 6,197 | 3,854 |
| Senegal | 2005 | 8,290 | 7,364 |

*Source:* DHS data.

running the regression with and without the variables capturing women's access to TV (direct and indirect). If a TV channel is the only one through which electricity affects knowledge, then the household electricity variable will be significant when the access to TV variables are dropped but significant when they are included.

The estimation method used is as follows: The contraceptive knowledge equations are estimated using an ordered probit, an extension of the binary probit model that is used in cases with multiple and ranked discrete dependent variables. The ordered probit model is of the form:

$$p_1 = \phi(\alpha_1 + \beta' x)$$
$$p_{i>1} = \phi(\alpha_i + \beta' x) - \phi(\alpha_{i-1} + \beta' x)$$
$$\ldots\ldots$$
$$p_k = 1 - \phi(\alpha_{k-1} + \beta' x),$$

where $\phi$ denotes the cumulative standard normal distribution function and $p_i$ is the probability of the event i occurring; in this case it would denote that probability that women know i contraceptive methods. The health knowledge equations are estimated using ordinary least square.

The estimates for Peru and the Philippines are calculated from two rounds of the DHS, and data are pooled across surveys, so estimates become more precise as they are based on a larger sample. This results in a nine-country analysis for each variable.

Most of the conditioning variables have the expected sign (tables G.2 and G.3). The better off and literate women have more health knowledge, as do those with higher mobility, control over decisions affecting their lives (agency),[1] and some urban living. For both contraceptive knowledge and health knowledge variables, TV is significant for all nine countries. The electricity status, in its own right, significantly increases both contraceptive and health knowledge in the Philippines and Indonesia and health knowledge in Bangladesh as well. When the regressions are run dropping the variable capturing access to TV as the source of information, then the household electricity coefficient is positive and significant for most of the knowledge equations.

Taken as a whole, the regressions provide sufficient evidence that access to TV increases health and family planning knowledge and that it is this that is the channel through which electrification affects health knowledge.

The next step is to examine the extent to which knowledge affects practice. Two health practice variables are examined: (1) use of modern

## Table G.2: Health Knowledge [Range 0–1]

| | Bangladesh | Ghana | Indonesia | Morocco | Nepal | Nicaragua | Peru | Philippines | Senegal |
|---|---|---|---|---|---|---|---|---|---|
| House quality index | 0.01[a] | 0.00 | 0.03[b] | 0.07[b] | –0.01 | 0.02[a] | 0.08[b] | 0.02[b] | 0.03[b] |
| Education of the head (0–1.7) | 0.03[b] | 0.05[b] | 0.09[b] | 0.03[b] | 0.03[b] | 0.05[b] | 0.07[b] | 0.05[b] | 0.06[b] |
| Household has electricity | 0.01[c] | 0.02 | 0.02[b] | 0.00 | 0.00 | 0.01 | 0.01 | 0.02[b] | 0.00 |
| Woman can read and write | 0.04[b] | 0.07[b] | 0.09[b] | 0.06[b] | 0.07[b] | 0.05[b] | 0.12[b] | 0.07[b] | 0.07[b] |
| Woman’s current age | 0.09[b] | 0.24[b] | 0.11[b] | 0.16[b] | 0.10[b] | 0.10[b] | 0.31[b] | 0.21[b] | 0.34[b] |
| Woman’s age square | –1.39[b] | –3.32[b] | –1.76[b] | –2.20[b] | –1.54[b] | –1.25[b] | –4.39[b] | –2.97[b] | –4.73[b] |
| Woman is head of household | 0.00 | 0.03[c] | 0.01 | 0.00 | 0.01 | 0.01[a] | 0.00 | -0.02 | 0.02[a] |
| Woman is divorced/widowed/not living together | –0.03[b] | –0.01 | –0.01 | –0.02[c] | –0.03[b] | –0.02[b] | –0.01 | 0.00 | –0.04[b] |
| Woman never married | | –0.05[b] | | 0.07[b] | | –0.06[b] | –0.02[b] | –0.07[b] | –0.07[b] |
| Some urban living | 0.04[b] | 0.01 | | 0.03[b] | 0.02[c] | 0.01 | 0.04[b] | 0.01[c] | 0.04[b] |
| Getting medical help is small problem | 0.02[b] | 0.01[c] | 0.01[b] | 0.01[b] | | 0.00[c] | 0.01[b] | | 0.01[c] |
| Woman alone has the final say | 0.00[c] | 0.00 | 0.00 | 0.00 | 0.01[b] | 0.00 | 0.01[b] | | 0.01[a] |
| Reads paper at least once a week | 0.04[b] | 0.01 | 0.08[b] | 0.04[b] | 0.04[b] | 0.05[b] | 0.04[b] | 0.04[b] | 0.03[a] |
| Listens to radio at least once a week | 0.02[b] | 0.08[b] | 0.03[b] | 0.02[b] | 0.04[b] | 0.03[b] | 0.03[b] | 0.01[a] | 0.05[b] |
| Watches TV at least once a week | 0.04[b] | 0.04[b] | 0.04[b] | 0.02[c] | 0.03[b] | 0.02[b] | 0.05[b] | 0.02[b] | 0.03[b] |
| Share of women visited by family planning worker by cluster | 0.01 | -0.01 | 0.02 | –0.13[b] | 0.06 | 0.12[b] | 0.00 | 0.09[b] | 0.06 |
| Cluster probably has electricity | 0.01[c] | 0.01 | 0.02 | 0.00 | 0.00 | 0.01 | 0.01 | 0.00 | –0.01 |
| Survey | | | | | | | 0.09[b] | –0.10[b] | |
| Constant | 0.19[b] | –0.02 | –0.02 | 0.18[b] | 0.33[b] | 0.19[b] | –0.40[b] | 0.02 | –0.32[b] |
| Observations | 7,535 | 3,312 | 17,073 | 7,778 | 7,550 | 5,762 | 15,470 | 13,413 | 8,262 |
| R-squared | 0.23 | 0.27 | 0.28 | 0.16 | 0.20 | 0.25 | 0.31 | 0.19 | 0.27 |
| F-stat | 80.30 | 34.15 | 83.52 | 25.99 | 38.06 | 49.34 | 162.64 | 85.06 | 110.40 |

*Sources:* DHS data; IEG calculations.
*Note:* Regional dummies suppressed.
a. Significant at 10 percent.
b. Significant at 1 percent.
c. Significant at 5 percent.

**Table G.3: Knowledge of Modern Contraceptives [Range 0–12]**

| | Bangladesh | Ghana | Indonesia | Morocco | Nepal | Nicaragua | Peru | Philippines | Senegal |
|---|---|---|---|---|---|---|---|---|---|
| House quality index | –0.04 | 0.12 | 0.11 | 0.35[a] | –0.02 | 0.28[a] | 0.42[a] | 0.11[a] | 0.16[a] |
| Education of the head | 0.23[a] | 0.21[a] | 0.60[a] | 0.03 | 0.32[a] | 0.37[a] | 0.30[a] | 0.32[a] | 0.21[a] |
| Household has electricity | –0.11[b] | 0.00 | 0.11[a] | –0.09 | 0.09 | 0.04 | –0.03 | 0.09[a] | 0.04 |
| Woman can read and write | 0.10[c] | 0.17[a] | 0.43[a] | 0.42[a] | 0.65[a] | 0.35[a] | 0.58[a] | 0.42[a] | 0.32[a] |
| Woman's current age | 1.80[a] | 1.05[a] | 0.91[a] | 1.06[a] | 0.77[a] | 0.93[a] | 1.47[a] | 1.18[a] | 1.62[a] |
| Woman's age square | –25.87[a] | –14.44[a] | –13.04[a] | –13.96[a] | –12.35[a] | –12.31[a] | –22.68[a] | –15.70[a] | –23.01[a] |
| Woman is head of household | 0.00 | 0.09 | 0.14 | 0.01 | 0.08 | 0.06 | 0.05 | –0.06 | 0.08 |
| Woman divorced/widowed/not living together | –0.36[a] | 0.01 | –0.14[b] | –0.19[a] | –0.23[a] | –0.05 | –0.05 | –0.09 | –0.18[a] |
| Woman never married | | –0.34[a] | | –0.42[a] | | –0.53[a] | –0.25[a] | –0.25[a] | –0.41[a] |
| Some urban living | 0.07 | 0.09[c] | | 0.12[b] | 0.37[a] | 0.09[c] | 0.22[a] | 0.11[a] | 0.31[a] |
| Getting medical help is small problem | 0.25[a] | 0.04[b] | 0.09[a] | 0.07[a] | | 0.03[b] | 0.07[a] | | 0.05[a] |
| Woman alone has the final say | 0.04[a] | 0.03[b] | 0.01 | 0.02 | 0.07[a] | 0.03 | 0.05[a] | | 0.00 |
| Reads paper at least once a week | 0.13[c] | 0.19[c] | 0.52[a] | 0.34[a] | 0.53[a] | 0.34[a] | 0.20[a] | 0.29[a] | 0.18[c] |
| Listens to radio at least once a week | 0.17[a] | 0.41[a] | 0.18[a] | 0.12[a] | 0.55[a] | 0.27[a] | 0.18[a] | 0.16[a] | 0.29[a] |
| Watches TV at least once a week | 0.14[a] | 0.33[a] | 0.38[a] | 0.20[a] | 0.21[a] | 0.18[a] | 0.28[a] | 0.19[a] | 0.20[a] |
| Percent women visited by family planning worker by cluster | 0.21 | 0.32[c] | 0.01 | –0.53[a] | 0.16 | 0.72[b] | –0.01 | 0.65[a] | 1.18[a] |
| Cluster probably has electricity | 0.16[a] | –0.03 | 0.09 | 0.01 | 0.05 | 0.12[c] | 0.09 | 0.07 | –0.17[b] |
| Survey | | | | | | | 2.01[a] | 1.32[a] | |
| Observations | 7,535 | 3,312 | 17,073 | 7,778 | 7,550 | 5,762 | 15,470 | 13,413 | 8,262 |
| F-stat | 40.81 | 33.85 | 71.62 | 41.2 | 50.82 | 45.92 | 199.63 | 199.68 | 77.01 |

*Source:* DHS data; IEG calculations.
*Note:* Regional dummies suppressed.
a. Significant at 1 percent.
b. Significant at 5 percent.
c. Significant at 10 percent.

contraceptives by women who have had at least one intercourse and (2) child immunization for children older than 18 months. Contraceptive practice is a dichotomous variable of whether a woman has ever used modern contraception. Immunization is similarly defined, corresponding to the child's status for BCG (for tuberculosis), DPT (for diphtheria, pertussis, and tetanus), measles, and polio vaccinations, and two variables corresponding to having all vaccines or no vaccines at all, respectively. Hence, for immunization, six separate regressions were estimated for each of the nine countries for which data were available, making 54 equations in all.

The right-hand side variables for contraceptive practice are similar to those used for the knowledge regressions, plus the knowledge variable, information capturing children, and partner's education (see table G.4). The general determinants are as expected and are similar to those for knowledge. Of interest here is the knowledge variable, which is significantly positive in all equations (table G.4). For immunization status, the knowledge variable was positive and significant in 44 of the 45 "have vaccination" regressions. For "no vaccination," knowledge was, as expected, significantly negative in all but one case (table G.6). The link between knowledge and practice is thus firmly established (see table G.5).

Some surveys interviewed men, and for four of the nine countries, men's knowledge variable was also included as a regressor in the contraceptive practice equation.[2] In three of the four cases, the knowledge variable is significantly positive.

Fertility outcomes are measured as total children ever born as a ratio to the total fertility rate for that age group of women, using 5-year age ranges starting at age 20. In five of the nine cases, the health knowledge variable has a significant negative impact on fertility. The household electricity variable is also significant and negative in eight of the nine cases (table G.7). What are the possible reasons for this latter finding?

A possible explanation is that electricity reduces coital frequency by increasing waking hours, both because there is more light and because TV and radio provide an "alternative to sex" for recreation. However, the data do not support this point of view. TV watching only significantly affects sexual activity in one of the eight cases, and household electricity is not significant. On the contrary, electrification indirectly increases sexual activity, as coital frequency is higher for those women with higher contraceptive knowledge.

These results can be used to estimate the impact electrification has on fertility (table G.8). The total effect is the combination of the direct impact from the fertility equation and the indirect impact via higher knowledge (which is the knowledge coefficient from the fertility equation multiplied by how electricity affects knowledge, taken as the coefficient on the household electricity variable in the absence of the TV variables). These calculations show an impact on fertility reduction from a low of 0.04 in Nicaragua to about 2.00 in Senegal as result of electrification.

The health outcomes used are nutrition and under-five mortality. Electricity may positively affect nutrition directly by allowing refrigerated food storage and indirectly through knowledge. Two nutrition measures are used: the height for age z score (HAZ) and the weight for age z score (WAZ). The z-score is a standardized measure; being more than two z scores below the reference value constitutes being undernourished and more than three, severely undernourished. HAZ is taken as a measure of long-run nutritional status; WAZ indicates short-run status.

The explanatory variables are similar for the two equations, which in turn are similar to those used throughout this analysis but with more demographic variables because there is possible competition for resources between siblings. In each case the variables cover (1) household characteristics (housing index, education in years of household head, number of young children, and whether the household has electricity and a refrigerator); (2) mother's characteristics (age, height, marital status, literacy and knowledge, mother is head of household, mobility, and agency); (3) child's characteristics (gender, birth order, gap between own

**Table G.4: Practice of Modern Contraceptives**

| | Bangladesh | Ghana | Indonesia | Morocco | Nepal | Nicaragua | Peru | Philippines | Senegal |
|---|---|---|---|---|---|---|---|---|---|
| House quality index | 0.17 | 0.07 | 0.14 | 0.26 | 0.16 | 0.07 | 0.42[a] | 0.05 | 0.17[a] |
| Education of the head | 0.08 | 0.16[b] | 0.18[a] | 0.21[c] | 0.25[a] | 0.19 | 0.05 | 0.21[a] | 0.33[a] |
| Household has electricity | 0.15[a] | –0.04 | 0.11[b] | –0.20[b] | 0.08 | 0.09 | –0.04 | 0.11[a] | 0.20[a] |
| Women's health knowledge | 2.30[a] | 1.35[a] | 0.69[a] | 1.36[a] | 1.69[a] | 2.04[a] | 0.85[a] | 1.10[a] | 1.34[a] |
| Woman can read and write | –0.20[b] | 0.09 | 0.20[a] | –0.06 | 0.22[a] | 0.13[b] | 0.06 | 0.07 | 0.19[a] |
| Couple is uneducated | –0.15[a] | –0.32[a] | –0.02 | –0.17[b] | –0.11[b] | –0.15[b] | –0.17 | –0.62[a] | –0.36[a] |
| Woman's current age | 2.31[a] | 0.43[c] | 2.05[a] | 2.29[a] | 2.62[a] | 1.52[a] | 1.32[a] | 1.91[a] | 0.97[a] |
| Woman's age square | –35.92[a] | –7.37[c] | –29.75[a] | –31.15[a] | –35.16[a] | –25.17[a] | –23.05[a] | –27.48[a] | –13.21[a] |
| Woman divorced/widowed/not living together | –0.69[a] | –0.02 | –0.33 | –1.69[a] | –0.86[a] | –0.54[a] | –0.55[a] | –0.54[a] | –0.13 |
| Woman never married | | –0.03 | | | | –1.42[a] | –1.17[a] | –1.69[a] | 0.21 |
| Woman is head of household | –0.30[a] | –0.07 | –0.16 | –0.09 | –0.16[c] | 0.01 | 0.05 | –0.05 | –0.05 |
| Woman alone has the final say | 0.03[c] | 0.00 | 0.04[b] | 0.05[c] | 0.05[a] | 0.02 | 0.07[a] | | 0.05[b] |
| Getting medical help is small problem | 0.20[a] | 0.03[c] | 0.01 | 0.02 | 0.02[c] | 0.02 | 0.01 | | 0.01 |
| Some urban living | 0.03 | 0.20[a] | | –0.15 | 0.19[b] | –0.03 | 0.11[a] | 0.07[c] | 0.19[a] |
| Woman has only living girls | –0.12 | –0.05 | 0.11 | –0.02 | –0.38[a] | –0.17 | –0.24[a] | –0.37[a] | –0.14 |
| Number of children born—only girls | –0.03 | –0.01 | 0.03 | 0.09 | –0.10[a] | 0.11[b] | 0.06[c] | 0.13[a] | 0.01 |
| Muslim | 0.02 | –0.14 | 0.22[a] | | –0.81[a] | | | –1.08[a] | –0.04 |
| Source of FP method by cluster | 0.99[a] | 0.91[a] | 1.33[a] | –0.04 | 0.72[a] | 0.41[b] | 0.65[a] | 0.47[a] | 0.15 |
| Share of women accessing health care by cluster | 0.34 | 0.25[c] | 0.18 | 0.23 | 0.50[b] | 0.37[b] | 0.89[a] | 0.12 | 0.74[a] |
| Cluster probably has electricity | –0.02 | –0.13 | –0.07 | 0.12 | 0.12 | 0.05 | –0.09 | 0.11[c] | –0.19[b] |
| Survey | | | | | | | –0.10[b] | –0.07 | |
| Constant | –4.56[a] | –2.43[a] | –4.89[a] | –3.58[a] | –6.40[a] | –3.07[a] | –2.81[a] | –4.14[a] | –3.89[a] |
| Observations | 7,098 | 2,963 | 16,287 | 4,533 | 7,549 | 4,641 | 12,789 | 9,843 | 6,717 |
| F-stat | 36.94 | 14.71 | 25.86 | 18.16 | 39.84 | 22.17 | 56.38 | 42.22 | 28.03 |

*Source:* DHS data; IEG calculations.
*Note:* Regional dummies suppressed.
a. Significant at 1 percent.
b. Significant at 5 percent.
c. Significant at 10 percent.

## Table G.5: Immunization: Child Received All Vaccinations

| | Bangladesh | Ghana | Indonesia | Morocco | Nepal | Nicaragua | Peru | Philippines | Senegal |
|---|---|---|---|---|---|---|---|---|---|
| House quality index | –0.08 | –0.02 | –0.06 | 0.04 | –0.04 | 0.01 | 0.02 | 0.10 | 0.05 |
| Education of the head | 0.19[a] | 0.11 | 0.18[b] | 0.07 | 0.14[c] | –0.10 | 0.10[c] | 0.20[a] | 0.04 |
| Household has electricity | 0.05 | 0.12 | 0.00 | 0.07 | 0.05 | 0.01 | 0.02 | 0.11[b] | 0.11 |
| Women's health knowledge | 1.02[a] | 1.00[a] | 1.24[a] | 0.78[a] | 1.21[a] | 0.77[a] | 0.32[a] | 0.82[a] | 0.61[a] |
| Woman can read and write | –0.04 | 0.12 | 0.26[b] | –0.02 | 0.32[a] | 0.00 | 0.03 | 0.19[a] | 0.15[b] |
| Woman's current age | 0.80[a] | –0.24 | 0.70[b] | 0.66[b] | 0.89[a] | 0.38 | 0.26 | 0.94[a] | 0.22 |
| Woman's age square | –11.78[b] | 6.09 | –11.11[b] | –8.80[c] | –13.44[a] | –3.93 | –1.66 | –13.34[a] | –2.57 |
| Woman has married more than once | –0.26[b] | –0.18[b] | –0.28[b] | 0.07 | –0.13[c] | 0.04 | 0.09 | –0.20[b] | –0.05 |
| Woman is head of household | –0.06 | 0.10 | –0.23 | –0.16 | 0.05 | –0.11 | 0.04 | 0.19 | –0.07 |
| Woman alone has the final say | 0.03 | –0.02 | –0.03 | 0.08[b] | 0.04[c] | 0.00 | 0.01 | | –0.04[c] |
| Getting medical help is small problem | 0.06 | 0.02 | 0.07[a] | 0.04[b] | 0.05[b] | 0.04[b] | 0.02 | | –0.02 |
| Some urban living | –0.02 | –0.14[c] | | –0.09 | 0.01 | –0.05 | –0.07[c] | –0.04 | –0.02 |
| Muslim | 0.42[c] | 0.25[c] | 0.03 | | –0.36 | | | –0.59[a] | –0.23[b] |
| Hindu | 0.66[a] | | | | –0.05 | | | | |
| Christian | | 0.28[b] | 0.09 | | | | | –0.06 | |
| Share of women accessing health care by cluster | 0.58[c] | 0.63[a] | 0.62[a] | 0.37[a] | 0.39 | 0.36[b] | 0.23[c] | 0.31[a] | 0.32[c] |
| Percent women visited by family planning worker by cluster | 0.52[b] | 0.17 | 0.80[b] | 0.31 | 1.10[a] | –0.29 | –0.11 | 0.27[c] | 0.30 |
| Cluster probably has electricity | 0.01 | 0.02 | –0.03 | 0.08 | –0.05 | –0.10 | –0.03 | 0.09 | 0.00 |
| Survey | | | | | | | –0.06 | –0.12[a] | |
| Constant | –2.16[a] | –0.95 | –2.91[a] | –1.44[a] | –2.30[a] | –1.07[a] | –1.03[a] | –2.21[a] | –0.77[b] |
| Observations | 3,475 | 2,032 | 6,924 | 2,408 | 4,454 | 2,817 | 7,001 | 6,333 | 5,428 |
| F-stat | 4.53 | 4.93 | 9.95 | 2.99 | 8.08 | 5.79 | 4.5 | 20.4 | 4.71 |

*Source:* DHS data; IEG calculations.
*Note:* Regional dummies suppressed.
a. Significant at 1 percent.
b. Significant at 5 percent.
c. Significant at 10 percent.

**Table G.6: Immunization: Child Received No Vaccinations**

| | Bangladesh | Ghana | Indonesia | Morocco | Nepal | Nicaragua | Peru | Philippines | Senegal |
|---|---|---|---|---|---|---|---|---|---|
| House quality index | 0.04 | 0.16 | 0.07 | –0.19 | 0.28 | 0.08 | –0.05 | –0.09 | –0.22[c] |
| Education of the head | –0.26[a] | –0.30[a] | –0.28[a] | –0.61[b] | –0.17 | –0.08 | 0.05 | –0.19[a] | 0.06 |
| Household has electricity | 0.05 | -0.09 | 0.01 | –0.16 | 0.48[c] | 0.34[a] | –0.41[a] | –0.26[c] | –0.18 |
| Women's health knowledge | –1.01[b] | –0.79[c] | –1.06[c] | –1.05[a] | –1.41[c] | –0.47 | –1.27[c] | –1.13[c] | –1.04[c] |
| Woman can read and write | 0.31[a] | –0.08 | –0.17 | –0.47[b] | –0.21[a] | –0.07 | –0.11 | –0.22[c] | –0.41[c] |
| Woman's current age | –0.73 | 0.58 | –0.34 | –0.69 | –0.39 | –0.77 | 0.14 | –0.65[a] | 0.27 |
| Woman's age square | 12.57 | –8.80 | 5.51 | 10.39 | 4.08 | 12.58 | –3.45 | 11.01[a] | –5.07 |
| Woman has married more than once | 0.20 | 0.05 | 0.10 | 0.19 | 0.01 | –0.10 | 0.17 | 0.17[b] | 0.02 |
| Woman is head of household | 0.11 | 0.04 | 0.45 | 0.11 | –0.28 | –0.25 | –0.19 | 0.04 | 0.05 |
| Woman alone has the final say | 0.00 | 0.00 | –0.02 | –0.15 | –0.04 | –0.07 | 0.01 | | 0.02 |
| Getting medical help is small problem | –0.15 | –0.08[a] | –0.05[b] | –0.05 | –0.04 | –0.03 | –0.03 | | –0.05[a] |
| Some urban living | 0.17 | 0.01 | | 0.11 | –0.34 | 0.02 | 0.12 | –0.10 | –0.01 |
| Muslim | 4.17[c] | –0.35[b] | –0.27 | | 0.18 | | | 0.58[c] | |
| Hindu | 4.01[c] | | | | –0.10 | | | | |
| Christian | | –0.30[a] | –0.17 | | | | | -0.09 | |
| Share of women accessing health care by cluster | –1.24[c] | –1.01[c] | -0.75[c] | –0.44 | –0.72 | –1.36[c] | –1.07[c] | –0.97[c] | –0.26 |
| Percent women visited by family planning worker by cluster | –1.12[b] | 0.03 | –1.20[c] | –0.07 | –0.23 | –0.12 | –0.82[b] | –0.69[c] | 0.11 |
| Community has electricity | –0.08 | 0.19 | 0.09 | –0.25 | –0.30[b] | –0.01 | –0.03 | –0.12 | –0.17 |
| Survey | | | | | | | –0.22[a] | 0.03 | |
| Constant | –4.20 | –1.30 | 0.95 | 0.21 | 0.28 | 0.14 | –0.96 | 1.29[c] | –0.99[b] |
| Observations | 3,475 | 2,032 | 6,924 | 2,408 | 4,454 | 2,817 | 7,001 | 6,333 | 5,428 |
| F-stat | 184.15 | 2.49 | 3.68 | 2.12 | 4.75 | 6.06 | 7.37 | 18.34 | 6.96 |

*Source:* DHS data; IEG calculations.
*Note:* Regional dummies suppressed.
a. Significant at 5 percent.
b. Significant at 10 percent.
c. Significant at 1 percent.

## Table G.7: Fertility Rate

| | Bangladesh | Ghana | Indonesia | Morocco | Nepal | Nicaragua | Peru | Philippines | Senegal |
|---|---|---|---|---|---|---|---|---|---|
| House quality index | –0.24[a] | –0.12 | –0.10[c] | –0.63[a] | –0.11[b] | –0.38[a] | –0.35[a] | –0.22[a] | –0.11[a] |
| Education of the head | –0.11[a] | –0.13[c] | –0.07[a] | 0.17 | –0.02 | –0.22[a] | –0.03 | –0.33[a] | –0.03 |
| Household has electricity | –0.07[b] | –0.16[c] | –0.11[a] | –0.19[b] | –0.15[a] | –0.07 | –0.08[b] | –0.31[a] | –0.27[a] |
| Women's health knowledge | –0.34[b] | –0.19 | –0.23[a] | –0.36 | 0.17[b] | –0.26[c] | –0.46[a] | –0.42[a] | 0.04 |
| Couple is uneducated | 0.02 | –0.1 | 0.02 | –0.42[a] | 0.05[b] | 0.04 | –0.09[c] | –0.25 | –0.03 |
| Woman divorced/widowed/not living together | –0.24[a] | 0.07 | –0.1 | –1.03[a] | | –0.04 | –0.09[b] | –0.38[a] | –0.31[a] |
| Woman has married more than once | –0.16[a] | –0.01 | –0.07[c] | –0.48[a] | –0.12[a] | –0.01 | –0.02 | –0.15[a] | –0.18[a] |
| Woman is head of household | –0.05 | –0.18[b] | –0.17[a] | –0.03 | –0.03 | | –0.15[a] | –0.04 | –0.09[b] |
| Getting medical help is small problem | | –0.03[c] | –0.03[a] | –0.05[a] | | –0.01 | | | 0.01 |
| Woman alone has the final say | 0.03[a] | 0.00 | 0.01 | –0.07[a] | –0.01 | –0.03 | –0.02[b] | | 0.00 |
| Woman is working | –0.05[b] | –0.19 | –0.13[a] | 0.09 | –0.05 | | –0.15[a] | –0.32[a] | –0.06[c] |
| Some urban living | | –0.02 | | –0.13 | –0.03 | 0.01 | –0.09[a] | –0.08 | –0.04 |
| Christian | | 0.00 | 0.08 | | | | | -0.01 | |
| Hindu | 0.04 | | | | –0.01 | | | | |
| Muslim | 0.20[a] | –0.06 | 0.18[a] | | 0.08 | | | 0.01 | 0.23[a] |
| Source of family planning method by cluster | –0.23 | 0.07 | –0.12[c] | 0.49[c] | –0.13 | –0.23[b] | –0.01 | 0.13 | 0.03 |
| Child mortality rate by cluster | 0.69[b] | 0.5 | 0.26 | 1.3 | 0.39[c] | 0.43 | 0.07 | 0.79[c] | 1.32[a] |
| Survey | | | | | | | 0.01 | –0.07 | |
| Constant | 1.23[a] | 1.71[a] | 1.51[a] | 2.65[a] | 1.15[a] | 1.77[a] | 1.52[a] | 2.32[a] | 1.07[a] |
| Observations | 7,098 | 2,963 | 16,287 | 4,533 | 7,549 | 4,641 | 12,789 | 9843 | 6717 |
| F-stat | 19.23 | 1.99 | 16.38 | 15.66 | 8.1 | 9.61 | 26.67 | 21.46 | 10.27 |

*Source:* DHS Data; IEG calculations.
*Note:* Regional dummies suppressed.
a. Significant at 1 percent.
b. Significant at 5 percent.
c. Significant at 10 percent.

**Table G.8: Impact of Electrification on Fertility Rate**

| | Bangladesh | Ghana | Indonesia | Morocco | Nepal | Nicaragua | Peru | Philippines | Senegal |
|---|---|---|---|---|---|---|---|---|---|
| TFR at age 50 | 5.83 | 6.35 | 4.63 | 6.32 | 5.98 | 7.25 | 6.57 | 5.54 | 7.42 |
| Knowledge equation | | | | | | | | | |
| Electrification status | 0.02 | 0.04 | 0.03 | 0.00 | 0.01 | 0.02 | 0.03 | 0.02 | 0.01 |
| Child ever born: TFR equation | | | | | | | | | |
| Electrification status | –0.07 | –0.16 | –0.11 | –0.19 | –0.15 | –0.07 | –0.08 | –0.31 | –0.27 |
| Health knowledge | –0.34 | –0.19 | –0.23 | –0.36 | 0.17 | –0.26 | –0.46 | –0.42 | 0.04 |
| Reduction | –0.45 | –1.06 | –0.54 | –1.20 | –0.89 | –0.55 | –0.62 | –1.76 | –2.00 |
| Reduction (only significant variables) | –0.45 | –1.06 | –0.54 | –1.20 | –0.89 | –0.04 | –0.62 | –1.76 | –2.00 |

*Note:* TFR = total fertility rate.

birth and birth of previous sibling); and (4) community characteristics (regional dummies, share of households with electricity).

Most of the child conditioning variables have the expected sign. The relationship between birth order and nutrition is as expected, decreasing with increase in birth order, reflecting food availability for older children. Similarly, children born at short intervals show a smaller HAZ. Taller women have taller children and so do women who are literate and with higher agency. The contraceptive knowledge variable affects HAZ in four of the six countries for which data are available, and WAZ in two of the six. Data on the household owning a fridge were available for four countries; the coefficient was significantly positive on HAZ and WAZ in three of the four countries. The household electricity variable is also significant and positive in four of the six cases.

In two countries, a possible reason can be refrigerator ownership. However, what are other possible channels for this finding in two countries with significant household electricity impact and the presence of a refrigerator? There is evidence that electrification improves child nutritional status, but the channels are not fully explained in all countries (table G.9).

Separate equations are estimated for neonatal mortality (death in first month), infant mortality (death in first year), and child mortality (death between first and fifth birthdays), so there are 27 mortality regressions. Although DHS includes questions on self-reported sickness, there are well-known biases in such variables, so they are not used in this analysis. The explanatory variables for the three mortality equations are similar to those used in the nutrition equations.

Most of the child-conditioning variables have the expected sign. A female child is more likely to survive in infancy than at an older age. For biological reasons, males have a higher natural risk of death at all ages. However, preference for boys over girls, especially in Asia, overrides biological factors at later stages in infancy. The relationship between birth order and mortality risk is convex (U-shaped) as expected, reflecting mother's age, social preferences, and food availability for older children.

Similarly, children born at short intervals and twins/triplets show a higher risk of mortality. Women's factors send a mixed message with the mortality regressions. Although cluster averages show expected signs, the household variables do not behave as expected. The results in general are not that good. Immunization and knowledge are both significant in some cases but are not overwhelming, as earlier links in the chain were.

## Electricity and Education

A Cox hazards model (where the hazard for a child between the ages of 6 and 15 is dropping out of school) was estimated to see the impact of electrification, if any, on the propensity of a child to stay in school. Although the model takes care of the censoring problem, the DHS data do not provide much information on education-specific information for children.

Nevertheless, a simple model was estimated with largely time-invariant variables as the independent variables. The estimated model indicates that RE indirectly improves the propensity of child to stay in school via increase in the mother's knowledge and education. Moreover, electricity itself is significant in seven of the nine regressions (table G.10). This might be capturing an increase in reading/studying hours due to illumination after dawn. However, because of lack of time-use data, it is not possible to confirm the impact through this channel.

### Time use

Electrification was found to increase the reading time of both adults and children in the household once the adult and/or child decides to read. Multivariate regressions of the effect of electrification on adult reading and children's studying—controlling for factors such as housing index, education, and age of the head of household—showed that the availability of electricity in the household had no significant effect on adults' and children's propensity to read and study, respectively. However, once individuals choose to read or study, electricity was also found to increase the time the children spend studying by 77 minutes

**Table G.9: HAZ**

| | Bangladesh | Ghana | Morocco | Nepal | Nicaragua | Peru |
|---|---|---|---|---|---|---|
| House quality index | 0.52[a] | –0.09 | 0.73[a] | 0.07 | 0.33[a] | 0.32[a] |
| Education of the head | 0.13[a] | 0.03 | 0.05 | 0.07 | 0.10 | 0.14[a] |
| Household has electricity | 0.20[a] | 0.27[c] | 0.08 | 0.20[a] | 0.04 | 0.10[c] |
| Household owns refrigerator | | 0.24 | 0.35[a] | | 0.38[a] | 0.38[a] |
| Number of household members age 0 – < 5 | –0.10[a] | –0.02 | –0.05 | –0.03 | –0.02 | –0.10[a] |
| Contraceptive knowledge | 0.02 | 0.03[a] | 0.04[b] | 0.03[c] | 0.03[c] | 0.00 |
| Woman can read and write | 0.18[a] | 0.06 | 0.00 | 0.19[a] | 0.04 | 0.08[c] |
| Woman divorced/widowed/not living together | 0.04 | –0.18 | 0.01 | –0.16 | –0.05 | –0.04 |
| Woman's current age | 0.02 | –0.10 | 0.00 | –0.05 | 0.06 | 0.11[a] |
| Woman is head of household | 0.16[b] | –0.17[b] | –0.29[b] | 0.01 | –0.05 | 0.04 |
| Woman alone has the final say | –0.01 | 0.04[c] | 0.08[c] | 0.00 | –0.03 | –0.01 |
| Getting medical help is small problem | 0.01 | 0.01 | –0.02 | 0.00 | 0.00 | 0.00 |
| Log of woman's height (cm) | 6.25[a] | 4.10[a] | 5.96[a] | 5.51[a] | 7.15[a] | 7.14[a] |
| Female child | 0.06[b] | 0.22[a] | 0.22[a] | 0.02 | 0.08[b] | 0.09[a] |
| Order of birth | –0.07[b] | 0.00 | –0.06 | –0.06[c] | –0.09[a] | –0.16[a] |
| Birth order | 0.01 | 0.00 | 0.00 | 0.01[c] | 0.00[c] | 0.01[a] |
| = 1 if < 24 months gap with preceding sibling | –0.14[a] | –0.11 | –0.10 | –0.14[a] | –0.08[b] | –0.12[a] |
| Cluster probably has electricity | –0.13[a] | –0.21[c] | –0.12 | 0.02 | 0.01 | 0.01 |
| Constant | –33.23[a] | –22.30[a] | –31.61[a] | –29.63[a] | –37.58[a] | –37.32[a] |
| Observations | 4,002 | 2,302 | 3,000 | 5,196 | 3,453 | 8,794 |
| F-stat | 22.08 | 5.25 | 8.38 | 18.08 | 16.07 | 33.1 |

*Source:* DHS data; IEG calculations.
*Note:* Regional dummies suppressed.
a. Significant at 1 percent.
b. Significant at 10 percent.
c. Significant at 5 percent.

(1.28 × 60) and the time adults spent reading by 27 minutes per electrified household per day, compared with nonelectrified households (table G.11).

The ESMAP report (2000) conducted a Heckman procedure using child-level information to study the effect of electrification on children's reading and studying—controlling for factors such as income, parents' education, type of dwelling, and price of fuel. The analysis concluded that the availability of electricity in the household had a negative effect on children's propensity to read or study—which in turn is presumed to be caused by more time spent watching TV and other forms of entertainment. Nevertheless, once a child made the choice to study, electricity was found to increase the time he or she spent reading or studying by 48 minutes per day, compared with nonelectrified households. For adults, the study found an increase in time spent reading of close to 15 minutes per day.

The study and reading time was found to be significantly higher for the children and adults of electrified households in electrified villages than for both children and adults in the nonelectrified households in nonelectrified villages and nonelectrified households in electrified villages using the nearest neighbor matching technique (see table G.12). The nearest match was based on education (in years) of the head of the household.

## Table G.10: Education

| | Bangladesh | Ghana | Indonesia | Morocco | Nepal | Nicaragua | Peru | Philippines | Senegal |
|---|---|---|---|---|---|---|---|---|---|
| House quality index | –0.95[a] | –0.23[c] | –0.55[a] | –0.70[a] | –1.14[a] | –0.60[a] | 0.26 | –0.60[a] | –0.07[a] |
| Education of the head | –0.89[a] | –0.34[a] | –0.58[a] | –0.20 | –0.72[a] | –0.64[a] | –1.17[a] | –1.25[a] | –0.37[a] |
| Household has electricity | –0.55[a] | –0.18 | –0.15[c] | –0.30[a] | –0.33[a] | –0.37[a] | –0.30 | –0.49[a] | –0.10[c] |
| Household size | 0.02[b] | 0.01[b] | 0.03[c] | 0.01 | 0.01 | 0.03[a] | 0.03 | 0.09[a] | 0.00 |
| Women's health knowledge | –1.26[a] | –0.32[a] | –1.11[a] | –0.58[a] | –0.97[a] | –0.87[a] | –1.16[a] | –0.71[c] | –0.18[a] |
| Woman's age (in log) | 0.36[c] | –0.29[c] | –1.09[a] | 0.01 | 0.33[a] | –0.53[a] | –0.91[c] | –0.56[c] | 0.04 |
| Some urban living | –0.24 | –0.10[b] | | –0.42[a] | –0.23 | –0.14[b] | 0.11 | –0.12 | –0.08[b] |
| Couple is uneducated | 0.41[a] | –0.06 | 0.19[b] | 0.22[a] | 0.25[a] | 0.28[a] | 0.12 | –0.04 | 0.27[a] |
| Female child | –0.46[a] | –0.02 | –0.06 | 0.26[a] | 0.25[a] | –0.14[a] | –0.11 | –0.28[a] | 0.02 |
| Muslim | 0.41[c] | –0.10 | –0.12 | | 0.21[c] | | | 0.31[b] | 0.57 |
| Hindu | 0.36[b] | | | | 0.00 | | | | |
| Christian | –1.10 | –0.17[a] | –0.21[b] | | | | | –0.16 | 0.01 |
| Distance to school | –0.03 | | | | | | | | |
| Cluster probably has electricity | 0.08 | 0.13 | 0.03 | 0.17[c] | 0.04 | 0.12[b] | –0.69[a] | 0.00 | 0.08[c] |
| Share of women accessing HC by cluster | 0.00 | –0.05 | –0.26[c] | –0.46[a] | –0.63[a] | –0.16 | 0.47 | –0.05 | –0.07 |
| Share of children in school by cluster | –2.50[a] | –2.91[a] | –2.76[a] | –2.67[a] | –2.62[a] | –2.29[a] | –3.49[a] | –3.15[a] | –2.06[a] |
| Observations | 7,334 | 3,053 | 15,805 | 6,096 | 8,722 | 6,925 | 5,126 | 6,481 | 7,119 |
| Wald Chi | 1,193.06 | 1,188.31 | 1,578.32 | 1,178.15 | 2,623.88 | 1,667.93 | 473.73 | 1,328.13 | 1,463.64 |

*Source*: DHS data; IEG calculations.
*Note:* Regional dummies suppressed.
a. Significant at 1 percent.
b. Significant at 10 percent.
c. Significant at 5 percent.

**Table G.11: Reading and Studying Time**

| | Children | | Adult | |
|---|---|---|---|---|
| | Study time | Propensity to study | Read time | Propensity to read |
| Housing index | 0.37 | –0.03 | 0.41 | 0.15 |
| Education (no. of years) of head of household | 0.12[a] | 0.01 | 0.07[a] | 0.07[a] |
| Age of the head (log) of household | | 0.03 | | 0.10 |
| Occupation of head of household | | | | |
| Farmer | 0.30 | 0.01 | –0.36[b] | 0.00 |
| Home business | 0.33 | 0.11 | 0.01 | 0.18[c] |
| Children in the household | | | | |
| Number | 0.66[a] | | –0.16[a] | |
| Child of more than 10 years age (0/1) | 2.56[a] | | | |
| Children in school (0/1) | | 0.97[a] | | |
| Household size | | | | 0.04[a] |
| Source of light: | | | | |
| Grid | 1.28[a] | 0.11 | 0.45[b] | 0.06 |
| Kerosene | –0.37 | | –0.30 | |
| Candle | –0.34 | | –0.17 | |
| Others | 0.02 | | 0.26 | |
| Regional dummies suppressed | | | | |
| Share of households with electricity (cluster average) | | 0.14 | | 0.26 |
| Constant | –4.18[a] | –0.80[b] | 2.14[a] | –1.27[b] |
| Observations | 1,152 | 1,992 | 1,204 | 1,992 |
| Wald Chi | | 10.50 | | 4.76 |

*Sources:* ESMAP 2000, 2003.

*Note:* Ideally this equation should be estimated at the child level. Given data limitation (missing household roster and time-use section), the model uses household-level information and total study time per household. The analysis is based on data collected from 2,000 households in four regions of the island of Luzon.

a. Significant at 1 percent.

b. Significant at 5 percent.

c. Significant at 10 percent.

**Table G.12: Reading and Studying Time (Propensity Score Matching)**

| | Electrified household in electrified villages | Nonelectrified household in electrified villages | Regression coefficient | Nonelectrified household in nonelectrified villages | ATT |
|---|---|---|---|---|---|
| Study time | 1,366 | 260 | 1.405[a] | 346 | 1.374[a] |
| Reading time | 1,366 | 224 | 0.950[a] | 298 | 0.960[a] |

a. Significant at 1 percent.

## The Theory

The theory of calculating the benefits of RE as the increase in consumer surplus is relatively straightforward. The difficulties come in applying that theory.

Electricity supply lowers the cost of energy to the user, resulting in an increase in consumer surplus, which is the difference between what the consumer is willing to pay and what they actually do pay. Assume that before electricity, energy is supplied from a single source, kerosene, at price $P_k$ with consumption $Q_k$ (figure H.1). Once electricity is available at lower price $P_e$, consumption rises to $Q_e$. Using these two points, the demand curve may be interpolated; exactly how this is done is one of the important issues considered below.

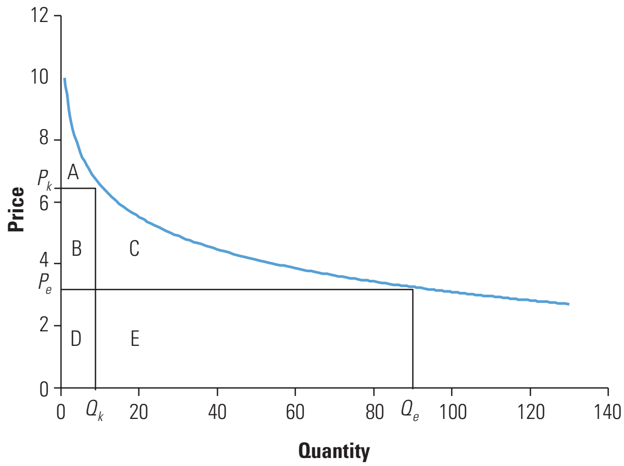
The amount the consumer is willing to pay for a quantity $Q$ is the area under the demand curve from 0 to $Q$. Hence the consumer is willing to pay A + B + D for consumption of $Q_k$ but actually pays B + D (= $P_k Q_k$), leaving a consumer surplus of A. Once electricity becomes available, the consumer surplus is A + B + C, so the increase in consumer surplus as a result of electrification is B + C. This consumer surplus has two parts: that arising from the reduction in the price of the $Q_k$ units already being consumed and that associated with the new consumption, $Q_e - Q_k$.

The benefit to the consumer is B + C. It is common in project analysis to also include areas D + E, sometimes referring to the whole area B + C + D + E as the willingness to pay (WTP), which is not quite correct because WTP includes area A also. It is perfectly acceptable to include areas D + E. This is the amount paid by the consumer, which is simply a transfer payment to the utility and so a neutral flow for economic analysis.[1] The cost side of the analysis will capture the cost of consumption. Assuming that the average cost of supply ($C_e$) is less than the tariff rate, there will be a positive producer surplus, which is being captured in this calculation (figure H.2). The alternative is to deduct the payments (D + E) from consumers but then add them to producers, so when summing across all flows, these payments/receipts cancel out.

A complication in the above is that, in drawing the demand curve between the two observed points, it is assumed that other characteristics that affect demand are the same for those households for which ($P_k$,$Q_k$) is observed and those for which ($P_e$,$Q_e$) is observed. This is almost certainly not the case. Electrified households have higher incomes than nonelectrified, and the average income in electrified communities is higher than that in nonelectrified ones. Energy is a normal good, demand for which rises with income, so ($P_e$,$Q_e$) in fact lies on a higher demand curve than does ($P_k$,$Q_k$).

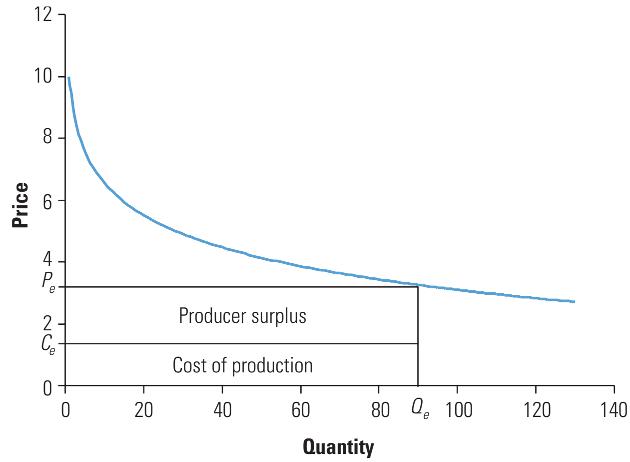
The consumer surplus for customers who are already connected is thus underestimated by this approach. But the consumer surplus for those who will become connected (if they do despite their lower income) is overestimated. In addition, when benefits are projected into the future, real income growth will shift the demand curve to the right over time so that consumer surplus is increasing. The value of this additional consumer surplus can be calculated if the income elasticity of demand for energy is known. If this elasticity is known, along with the average income of currently connected and unconnected households, then different demand curves can

**Figure H.1: Consumer Surplus**




*Note:* $P_e$ = price of electricity from the grid; $P_k$ = price of kerosene; $Q_e$ = quality of electricity used from the grid; $Q_k$ = quantity of kerosene consumed.

**Figure H.2: Producer Surplus**




*Note:* $C_e$ = average cost of supply; $P_e$ = price of electricity from the grid; $Q_e$ = quantity of electricity used from the grid.

also be drawn for these different groups to more accurately measure consumer surplus.

## Issues in Applying the Theory

There are several complications in applying this approach in practice: data availability, the common metric to be used on the horizontal axis, the shape of the demand curve, and the way in which consumer surplus is expressed.

### *Data availability*

Although the analysis is based on just four pieces of information ($P_k$, $Q_k$, $P_e$, and $Q_e$), these are not readily come by. A recent energy household survey (or expenditure survey with a good energy module) is necessary to estimate average prices and quantities for electrified and unelectrified households. But it is also necessary to control for income differences between these two groups. The simplest way to do this is to restrict the sample to communities whose average income is within a certain range or to take a small number of subsamples with different average incomes, which is a better approach if future RE will benefit communities with a different profile than those that have already been electrified.

### *Units for the horizontal axis*

The above example puts energy on the horizontal axis. To apply the approach, a common metric is needed. Nonelectrified households rely on a variety of energy sources, often woodfuel for cooking, kerosene for lighting, and, among the better off, car batteries for TV. The mix among these varies by household. In principle, total energy consumption can be converted to a common metric such as kilowatt hour or kilograms of oil equivalent, and the average price can be calculated by dividing total consumption by energy expenditure.

There are two problems in this approach. First, the energy consumption mix varies across households, so taking a representative household might be misleading as coverage expands and different households become connected to the grid. Second, electrified households typically still use other energy sources, so the comparison is not a straightforward one between electricity and an alternative energy source. These problems might be partially sidestepped by valuing consumers separately by end use. In this case, end use-specific units can be used for the horizontal axis, such as lumens for lighting (see below) or hours for TV watching.

### *Shape of the demand curve*

The value of area C in figure H.1 clearly depends on the shape of the demand curve. The simplest assumption is to assume a linear demand curve (that is, a straight line) between the two observed points, making the calculation of area C very straightforward = $0.5(P_k - P_e)(Q_k - Q_e)$. But if the demand curve is convex to the origin, as theory suggests, then the linear demand curve overestimates the amount of consumer surplus. An alternative functional form is a constant elasticity (that is, log linear) demand curve. The equation for this demand function can be written as follows:

$$P = KQ^{\eta},$$

where $\eta$ is the elasticity and K a constant. The elasticity can then be calculated as

$$\eta = \frac{\ln(P_k) - \ln(P_e)}{\ln(Q_k) - \ln(Q_e)}.$$

Once the parameters $\eta$ and K are obtained, then area C may be calculated as

$$C = \int_{Q_k}^{Q_e} KQ^{\eta}\,dQ - (Q_e - Q_k)P_e$$
$$= \frac{K}{\eta + 1}(Q_e^{\eta+1} - Q_k^{\eta+1}) - (Q_e - Q_k)P_e.$$

Note that the deducted amount $(Q_e - Q_k)P_e$ (the amount paid for incremental consumption = area E in figure H.1) is usually included in project benefits (because the economic costs of production are deducted separately) so the second term need not be deducted, the first term giving C + E.

### *Expressing consumer surplus*

The example given here uses either the market demand curve or that for a representative household. Assume the latter. The calculation therefore gives the value (in local currency) of the increase in consumer surplus from connecting to the grid. To calculate total project benefits, this value can be multiplied by the cumulative number of households connected to the grid each year. The analysis can be a bit more sophisticated if there are different household types with different levels of consumer surplus, but this is quite a demand in terms of data. There is also the problem that not all consumption is residential, so these calculations need to be repeated for different end users (commercial, agricultural, and so forth).

The alternative approach is to express consumer surplus per kilowatt hour and then multiply the resulting value by total electricity sales each year. This approach does not, of course, bypass the problem of their being different types of consumer: the average consumer surplus per kilowatt hour should be a weighted average for the different end users. There are two problems here: (1) if the share of end users varies over time, the weighted average is no longer the appropriate one, although the resulting bias is unlikely to be large; and (2) the calculation of the average consumer surplus/kilowatt hour is itself biased, though again probably not by much.

Consider the case of three households shown in table H.1; consumer surplus rises with consumption but at a diminishing rate, a fact that arises from the shape of the demand curve. Average consumption is 25 kWh/month, the same as household 2, and corresponds to an average consumer surplus of Rs 2/kWh. Because total consumption is 75 kWh, applying this average suggests a total consumer surplus of 150, whereas the true figure is 145. The inaccurate result comes because the method of calculation implies a constant

**Table H.1: Consumer Surplus for Different Households**

| Household | Consumption (kWh/month) | Consumer surplus (Rs) |
|---|---|---|
| 1 | 20 | 40 |
| 2 | 25 | 50 |
| 3 | 30 | 55 |
| Total | 75 | 145 |

*Note:* Rs = rupees.

increase of consumer surplus with respect to consumption. The same problem arises if multiplying the number of connections by the consumer surplus per connection; such an approach also yields an estimate of a total consumer surplus of 150 in this example.

In summary, the preferred method would be to calculate consumer surplus by end user (possibly even different categories of each type of end user) and thus calculate consumer surplus based on cumulative connections for each type of end user. In practice, however, the data requirements for this approach are substantial, so a more common approach is to estimate consumer surplus per kilowatt hour (though this should be a weighted average of different end users) and multiply this amount by sales. This approach suffers from an unknown bias from the sales composition effect and an upward bias from ignoring diminishing consumer surplus as consumption rises. This bias is offset by the downward bias from ignoring growing consumer surplus as income rises. Although the balance is not known, the two cancel each other out to some extent, so the net bias will not be too great.

## Applying the Theory: Examples

### *Lighting*

Lighting is the main use of RE (see appendix D) and has been the focus of Bank efforts to calculate the consumer surplus from electricity. Indeed, the lighting benefits are often the only ones valued for residential consumption. In the 1990s, project documents typically compared the cost of lighting using a kerosene lamp with the cost of the same amount of lighting from electricity. But the ESMAP Philippines study (ESMAP 2003) proposed a new approach based on lumens, which is a measure of emitted light. Table H.2 shows the lumens emitted by some typical light sources.

**Table H.2: Wattage of Common Household Appliances/Tools**

| Appliance | Resistive load (watts) |
|---|---|
| Clock radio | 5 |
| Computer-PC | 300 |
| Deep fryer | 1,800 |
| Iron | 1,200 |
| TV, color | 300 |
| Fan | 30–70 |

Using these conversion factors and data from a household energy survey, it is possible to obtain estimates of $Q_k$ and $Q_e$ (quantity of lumens consumed for kerosene and electricity, respectively) and the corresponding prices ($P_k$ and $P_e$). This approach finds that the consumption is far higher (by a factor of 2.5 or more) and the price far lower (by a factor of X or more) for electricity than for the next lighting source (see table H.3 for examples).

Once these data are available it is a straightforward matter to calculate the change in the consumer surplus and the WTP. Table H.3 shows the results of this calculation, assuming both a linear and a log-linear demand curve, showing that assuming a linear demand curve can overestimate increase in the consumer by a factor of up to eight times.

## Overview of Bank Approaches to Measuring Electrification Benefits

Bank project documents adopt a range of approaches to valuing electricity benefits. The focus here is on approaches based on consumer surplus. A detailed review is presented in the table of ERR calculations beginning on page 136.

As noted earlier, studies commonly estimate area B + C + D + E as the benefit, calling this WTP. The same terminology is used here, noting that WTP should in fact also include area A, but that area A is not part of the project benefits (that is, it is the terminology that is slightly wrong, rather than a conceptual error in the method of calculation). The following main approaches can be identified:

- Estimate WTP assuming a nonlinear demand curve or assuming a linear demand curve but taking only a percentage of the estimate for area C to allow for the overestimation. This approach conforms with what is considered by this review as best practice, although allowance should also be made for the different income

**Table H.3: Demand for Lumens from Different Energy Sources**

| Country | Quantity (kilolumens) | | Price (US$ per lumen) | | Consumer surplus | | Ratio linear/log linear |
|---|---|---|---|---|---|---|---|
| | Kerosene | Grid connection | Kerosene | Grid connection | Linear curve | Log-linear | |
| Bolivia | 7 | 90 | 0.48 | 0.04 | 21.3 | 8.6 | 2.5 |
| Lao PDR | 20 | 435 | 0.195 | 0.003 | 43.7 | 9.9 | 4.4 |
| Peru | 5 | 363 | 0.57 | 0.01 | 102.9 | 12.5 | 8.2 |
| Philippines | 4 | 204 | 0.36 | 0.0075 | 36.8 | 5.8 | 6.3 |

*Source:* Project documents.

of current and future consumers and income growth among consumers.

- Estimate WTP assuming a linear demand curve. This approach results in an overestimate of project benefits.
- Estimate WTP based on the alternative energy source, and then value the whole of expected energy consumption with electricity at that level. This approach neglects the downward sloping demand curve, resulting in a substantial overestimate of project benefits.
- Estimate benefits as the cost savings on current consumption levels (that is, area B in figure H.1). This approach underestimates project benefits, as it ignores additional consumer surplus from new consumption (area A).

## Economic Rate of Return Calculations

| | | | | | | WTP | ERR | | |
|---|---|---|---|---|---|---|---|---|---|
| Country | Project | Document | Year | Method | Comment | Estimate | IEG revised estimate | Estimate | IEG revised |
| Lao PDR | Southern Provinces Rural Electrification | ICR | 2004 | Area under linear demand curve, using three separate curves for four data points | A single curve should be used passing through the four points, assuming constant elasticity rather than linear. | 72.00 | 5.60 | 60.5 | 12.6 |
| Malawi | Power V | SAR | 1992 | Cost of avoided diesel generation | | USc33/kWh | | | |
| Indonesia | Rural Electrification Project | SAR | 1990 | | | USc15/kWh | | 15 | |
| Indonesia | Rural Electrification Project | ICR | 1995 | Linear demand curve between two points | Should use constant elasticity demand curve, and given data they had should estimate actual $Q_k$ and $Q_e$. | Residential: USc19/kWh Commercial: USc16/kWh | | | |
| Indonesia | Solar Home Systems Project | ICR | 2004 | Begins with an avoided cost estimation of CS based both on energy expenditures data and on response of TV/radio use to presence of SHS. Then computes WTP using log-linear demand curve based on average monthly energy expenditures. | | $168/million lumen hrs. | 184.56 | 40.9 | 40.9 |
| Nepal | Power Sector Efficiency Project | SAR | | Takes price currently paid as WTP for all consumption (but also does lower bound based on actual tariff). | | | | 12.1 | 6.6 |
| Peru | Rural Electrification Project | PAD | 2006 | Constant elasticity demand curve, estimated separately | Best practice PAD analysis, including Monte | TV: 2.26 S./kWh, lighting: USc111/kWh | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | for lighting and TV. Presents separate estimates for WTP by level of consumption (not clear which are used). | Carlo simulations for sensitivity analysis. | Total USc179/kWh | | | |
| Pakistan | Rural Electrification Project | SAR | 1989 | CS estimated separately for different end users, based on expenditure on current energy source. Benefits are CS, not WTP. | Overestimate as WTP declines as consumption rises, but underestimate as double count costs (as use CS not WTP); latter effect is larger. | USc10/kWh | USc13/kWh | 10.9 | 22.9 |
| Bangladesh | Rural Electrification Project III | SAR | | | | | | 34 | |
| Bangladesh | Rural Electrification Project III | SAR | 1990 | They use a discounted sales-weighted average WTP based on avoided cost estimation for kerosene and the change in CS due to a switch to electricity averaged as an upper bound, and the fiscal 1990 electricity tariff rate as the lower bound. | Insufficient data to confirm that estimates are correct | Tk6.2/kWh | | 36.5–58 | |
| Bangladesh | Rural Electrification Project III | ICR | | Similar method used as in SAR, but with benefits defined for only the first 10 kWh/month out of an average of 37 kWh/month. | | | | 95.3–102.5 | |
| Bangladesh | Rural Electrification Project II | SAR | | | | | | 12.7 | |
| Bangladesh | Rural Electrification Project II | PCR | 1995 | WTP for rural and residential consumers separately using linear demand curve | Should use constant elasticity demand curve. Limited data given to estimate this, but WTP approximately 50% that used in PCR. This lower | Residential: USc105/kWh | Residential: USc54 /kWh | 13.6 | –∞ |

*(Table continues on next page)*

**Economic Rate of Return Calculations** *(continued)*

| | | | | | | WTP | ERR | | |
|---|---|---|---|---|---|---|---|---|---|
| Country | Project | Document | Year | Method | Comment | Estimate | IEG revised estimate | Estimate | IEG revised |
| | | | | | value means net benefits are always negative (hence –∞ ERR). | | | | |
| Bangladesh | Rural Electrification Project | PCR | 1993 | WTP for rural and residential consumers separately using linear demand curve | Should use constant elasticity demand curve. Insufficient data in PCR for re-estimation. | n.a | n.a | 12.6 | n.a. |
| Bangladesh | Rural Electrification Project | SAR | | | | | | 11.4 | |
| Morocco | Rural Electrification Project II | SAR | 1990 | Benefits are revenues plus consumer surplus. No further details given. | Insufficient information to determine method or perform re-estimation | n.a | n.a | 17.8 | n.a |
| Morocco | Rural Electrification Project II | ICR | 1998 | Benefits are revenues plus consumer surplus. No further details given. | Insufficient information to determine method or perform re-estimation | n.a | n.a | 15.3 | n.a |
| Senegal | Electricity Services for Rural Areas Project | SAR/ PAD | | WTP calculated from linear and linear in log-log scale. | Insufficient information to recalculate WTP | USc72/kWh | n.a. | 28.4 | 24 |
| Sri Lanka | Energy Services Delivery Project | ICR | 2003 | Mini hydro appraisal benefits calculated using avoided cost approach, and ICR uses financial model to create financial internal rate of return to confirm ERR from PAD. Village-based hydro uses avoided cost for assessing consumer benefit, but source not given—appears to be from a | Not enough data is provided to accurately recreate net benefit stream, so levelized stream used, resulting in higher ERR. | USc57/kWh (avoided cost) for mini hydro; 0.001 Rs/lumen hour for SHS, 0.70 Rs/TV-hour for SHS | 0.001 Rs/lumen hour for SHS; 0.30 Rs/TV hour for SHS | | n.a. |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | linear demand curve. SHSs component uses log-linear demand curve to derive WTP. | | | | | |
| Bolivia | Decentralized Infrastructure for Rural Transformation | PAD | 2003 | Taken as one-quarter of $(P_k - P_e)*(Q_e - Q_k)$ to avoid overestimate using a linear demand curve. | | n.a. | n.a. | 29.1 | 29.1 |
| Cape Verde | Energy and Water Sector Reform and Development Project | PAD | 1999 | Not calculated | | n.a. | n.a. | 12 | n.a. |
| Mozambique | Energy Reform and Access Project | PAD | 2003 | For EdM grid intensification component WTP is area under semi-log demand curve times factor of 0.8 to minimize overestimation; mini-grid components estimated similarly for North Inhambane and Mocimboa da Praia for residential and commercial users, and photovoltaic component estimates also using semi-log, but for both lighting and TV/radio consumption. WTP estimates reflect weighted averages of subgroups/components. | | EdM Grid: USc13/kWh; Mini-grid: USc18/kWh (weighted avg. for residential and commercial) in N. Inhambane and also USc18/kWh in Mocimboa da Praia (estimated separately); PV: USc13/lumen-hour for TV/lighting | | 23 | 23 |
| Guinea-Bissau | Energy Project | ICR | 1998 | WTP from linear demand curve | Data for determining WTP not provided | n.a. | n.a. | n.a. | |
| Malaysia | Rural Electrification Project | PCR | 1990 | WTP not provided, but avoided cost calculated | Data for determining WTP and ERR not provided | USc58/kWh | n.a. | 26 | n.a. |

*Note:* All dollar amounts are US dollars. CS = consumer surplus; ERR = economic rate of return; ICR = Implementation Completion Report; kWh = kilowatt hour; PAD = project appraisal document; PCR = project completion report; PV = photovoltaic; Rs = rupees; SAR = staff appraisal report; S. = soles; SHS = solar home system; Tk = taka; USc = US cents; WTP = willingness to pay.

## Rationale

This evaluation is the fourth in IEG's current program of impact evaluations.[1] Infrastructure was selected, as the sector has not been covered in the program to date. The RE subsector was selected for the following reasons:

- It has not been the subject of an IEG evaluation since 1994.
- The 1994 IEG study found that the costs of investments in RE did not appear to be justified by the benefits, although there was need for further investigation. In response, more recent work by the Bank in the Philippines quantifies a broader range of benefits, stating that the results demonstrate the possibility that "benefits will outweigh the costs of extending electricity service" (ESMAP 2003). This evaluation will make an independent assessment of this statement and the methodology used to reach it.
- The question of the viability of these investments is of operational significance because the RE portfolio is growing in size, especially given the development community's new emphasis on renewable energy sources. Off-grid electrification was ignored in the 1994 IEG study but will be covered in this evaluation. IEG's recent review of renewable energy (which is largely off grid) concluded that the "poverty reduction impact is largely nonevaluable" on account of lack of evidence (IEG 2006). This evaluation will help fill that gap.

## Background

Energy policy and services are linked to poverty reduction by the following possible benefits (World Bank 2005):

- Increasing income
- Contributing to better health
- Supporting education
- Improving women's quality of life
- Reducing environmental harm.

Accordingly, it is argued that investment in RE can make a major contribution to achieving several of the Millennium Development Goals, notably in Africa, where coverage rates in rural areas in many countries are between 1 and 2 percent (see attachment 1). In accordance with the theory-based evaluation approach adopted in the IEG impact evaluations, the study will seek to unpack the channels though which these poverty impacts can be felt (see table I.1).

But when IEG last reviewed RE 12 years ago, it was critical of the limited benefits realized by such investments, which appeared insufficient to justify the costs (see box I.1). Despite that finding, lending for RE has grown since the mid-1990s, spurred in part by the growth of a portfolio of projects supporting renewable energy. There were just 10 projects with an RE focus in the years 1990–94, compared with 23 for 2000–04; the number of projects with an RE component grew from 14 to 42 over the same period.

In response to the IEG report, operational staff have introduced new evaluation tools to capture a broader range of benefits,[2] with results so far available for the Philippines and work ongoing in Bangladesh and Vietnam. This impact evaluation will take a critical look at these new findings, undertaking new analysis of existing and new data.

**Table I.1: Benefits from Rural Electrification**

| RE-affected input | Channel | Direct | Indirect |
|---|---|---|---|
| Lighting | Time use | Time-saving devices<br>Increased study time | Richer social life |
| | Electric lighting replaces other fuels (in principle for cooking also, but rarely in practice) | Improved indoor air quality | |
| Media access (radio, TV, and Internet) | Improved health knowledge | Health and nutrition<br>Fertility | Health and nutrition<br>Fertility<br>Entertainment |
| Fan/air conditioning | Improved living conditions | Greater comfort | |
| Facilities | Better social facilities with better equipment | | Clinics: longer hours and more equipment, including cold chain for vaccines, Internet access<br>Schools: available for adult literacy in evenings; computer facilities<br>Water pumps: cleaner water supply |
| Productive enterprise | Electrical equipment for workshops and agriculture (including lighting and pumps) | Enhanced productivity (including irrigation) | Increased income and employment<br>Longer business hours |
| Food preparation | Refrigeration and boiling water | Better nutrition and reduced ill health | |
| Community lighting | | | Improved security<br>Richer social life |

An important development in the portfolio in the last decade has been the growth of lending for off-grid electrification. These investments were not considered in the 1994 study (which was not an impact evaluation), but this new study will consider both on-grid and off-grid electrification. A final rationale is that there are few impact studies on RE.

The evaluation will be a meta-impact analysis, drawing on evidence from a number of sources. This evidence will combine new analysis of new data for one country (Lao PDR) and reanalysis of existing data for 10 others. These findings will be combined with existing evidence to form a comprehensive summary of what is known about the impact of RE, and the part played by external agencies, in particular the World Bank.

This approach departs from the single-country focus of previous IEG impact studies. This alternative approach is being used in this particular

**Box I.1: The 1994 Study *Rural Electrification in Asia***

The main findings of the 1994 IEG study were as follows:

- Ex post economic rates of return were much lower than those at appraisal, as many of the indirect and external benefits had not materialized. Notably, there was little impact on industrial development.
- RE projects ignored financial aspects. Unit investment costs for RE are much higher than for urban electrification because of lower population density and the low ratio of average demand to peak demand (rural use is concentrated in early evening, whereas urban demand is spread across the day). Cost recovery has been low (10–50 percent), thus imposing a financial burden on the electricity utility or government.
- The direct benefits of RE go to the non-poor. Even with low tariffs the poor cannot afford connection costs. The poverty-reduction benefits are thus indirect through rising rural incomes, and these effects have been found to be limited.

case to broaden the operational relevance of the study and because it is feasible in this case, given the limited range of other studies to be covered.

## Channels for the Welfare Impact of RE

The direct benefits from RE flow to households or businesses that get connections. Indirect benefits arise either from the income opportunities overspilling to others or from benefits to unconnected households from a connection in the community. For example, villagers may watch television in a community rather than household setting.

Given the difficulty of quantifying all these benefits, most studies use estimates of the WTP to capture electrification benefits. WTP is an indirect measure, assuming that how much people are willing to pay gives a good measure of the value of the benefits. However, estimating WTP requires some strong assumptions and, even if it is done correctly, it ignores the public good benefits from electrification.[3] Hence, direct measurement of the benefits, as proposed here, is to be preferred.

## Evaluation Questions

The evaluation questions address the realization of the claimed benefits of RE and the extent to which they are gained by the poor. The ultimate objective is calculation of private and social rates of return from investments in RE. Specific questions are as follows:

- What has been the growth in the coverage of RE in countries receiving Bank support? To what extent has the Bank contributed to these connections? What is the distributional profile of those taking connections? What are the unit costs of connection by type of supply to the user and to the supplier?
- What are the direct economic benefits from RE? Who gains these benefits? What are the indirect economic benefits (employment generation), and who gains them? How does the distribution of benefits change as coverage of electrification programs expands?
- What is the impact of RE on time use, and what are the welfare implications of these changes for health, education, and increased leisure?
- How does RE affect the quality of health and education services?
- How do the aggregate private benefits and the public good benefits compare to the WTP? What is the distributional profile of these benefits?
- What are the private and social rates of return from investments in RE?

## Evaluation Approach and Data Requirements

The evaluation approach mostly relies on new and existing survey data to quantify the benefits from RE. Qualitative information shall come from existing material through the desk review and Project Performance Audit Reports (PPARs) and a qualitative component in the in-depth country case study of Lao PDR.

The two main challenges in conducting an impact evaluation are contagion (the control becoming treated) and endogeneity (the selectivity bias in who is treated). Contagion takes two forms: spillover effects, which are dealt with directly in this study, and treatment in control communities, which is not an issue for an ex post analysis such as this because the control can be restricted to uncontaminated communities. Those who receive electrification (at both household and community levels) are better off than average, so there is a problem of selectivity bias. However, the determinants of selection (income and geographical location) are observed, so the bias can be removed.

### In-depth country case study

An in-depth country study comprising a household survey and a qualitative study will be conducted in Lao PDR, which has had four RE projects, one of which is ongoing.

In Lao PDR, IEG will commission a structured survey with a sample of 1,200–1,500 households, following up a survey ESMAP conducted in 1997. A qualitative study of the impact of RE shall also be undertaken.

### Desk reviews

Desk reviews will be undertaken for the following countries:[4]

- *Bangladesh:* The Bank has supported three RE projects in the 1990s and a fourth project with an RE component. There is a continuing program. Along with the Bank, USAID was the main financer of the program and undertook one of the most substantial RE impact evaluations of any program anywhere in the world. In addition, there are PPARs of the last two Bank projects. RE was covered in the IEG impact study, and Bangladesh shall be included among the countries in which analysis of DHS data is carried out (see below).
- *Philippines:* The Bank supported RE through two projects in the 1990s, for which there are PPARs. The only ESMAP study on economic and social benefits published so far is for the Philippines (2003). The Philippines is also among the countries included for analysis of DHS data.
- *Ghana:* RE was supported through two Bank projects, one of which has a PPAR. Ghana is also among the countries included for analysis of DHS data, and new analysis of the LSMS (a household income and expenditure survey) data will be undertaken regarding test scores and possibly rural enterprises.
- *Sri Lanka:* Sri Lanka has a well-documented RE program, especially its experience with off-grid electrification. The Bank has supported four RE projects in the country. A survey was undertaken in 2002 as part of the EnPoGen project; IEG may reanalyze this rich but underexploited data set.[5]

The case study evidence shall be synthesized on a thematic basis. The synthesis will also include impact studies conducted for other countries.

### Further analysis of DHS data

The DHS contain data on a range of health and fertility outcomes, as well as output measures on knowledge and practice. The household data contain a variable on electrification (though not the source) and variables that can be used to construct an asset index to proxy for income (which needs to be controlled for).[6] Several countries have DHS data for more than one year, which will allow analysis of the changing distributional pattern of access to electricity.

Because the DHS questionnaire is standardized across countries, the data are suitable for pooling—or at the very least in realizing economies of scale in estimating the same models for multiple data sets. Whether pooling the data will strengthen the analysis will be determined once the country-level analysis is completed.

The countries to be included in this analysis are Bangladesh, the Philippines, Indonesia, Ghana, Vietnam, Pakistan, Morocco, Uganda, Guinea, and Senegal. All these countries have received Bank support for RE. For each country a mini desk review will be undertaken to provide the country context.

### Review of PPARs

A review shall be made of PPARs for RE projects completed since the 1994 IEG review. These cover (see attachment 2 for a complete list): Bangladesh, Ghana, India, Indonesia, Kenya, Lao PDR, Mozambique, Níger, Pakistan, the Philippines, and Sri Lanka (and one for Uganda, which is currently being prepared).

### *Review of existing impact evaluations*

This review will be conducted early in the study to inform the evaluation design, but the results will also be utilized. The identified studies come from three sources:[7]

- **ESMAP:** Quantification of benefits for the Philippines and women's time-use in India, and other pieces of ongoing work (for example, study time in Ecuador and indoor air quality in India)
- **EnPoGen (Energy, Poverty, and Gender):**[8] Country case studies for China, Indonesia, and Sri Lanka produced in 2003
- **USAID:** Impact studies for USAID's support to RE in Bangladesh (Barkat and others 2002) and Colombia (Davis and Saunders 1978).

### *The meta-analysis*

This meta-analysis draws together the evidence from the approximately 20 countries included in the study. A matrix will be constructed in which the research questions (or more detailed questions derived from those questions) are the rows and the countries are the columns. As many cells as possible will be filled, but using only those findings based on technically rigorous methods. Thus, a summary of all available evidence on each question can be made in a systematic manner.

## Collaboration with Other Agencies and Peer Review

Collaboration shall be sought with relevant government officials or research institutions in the country selected for in-depth analysis. Funding from the Norwegian Agency for Development Cooperation (Norad) partnership has been sought. Norad is embarking on its own impact study of RE, and possibilities for collaboration shall be sought, at least at the level of sharing approaches and findings. The study has been discussed with staff of ESMAP and the Global Environment Facility, and we shall share findings as they emerge.

Advice from both internal and external peer reviewers will be sought on intermediate and final findings.

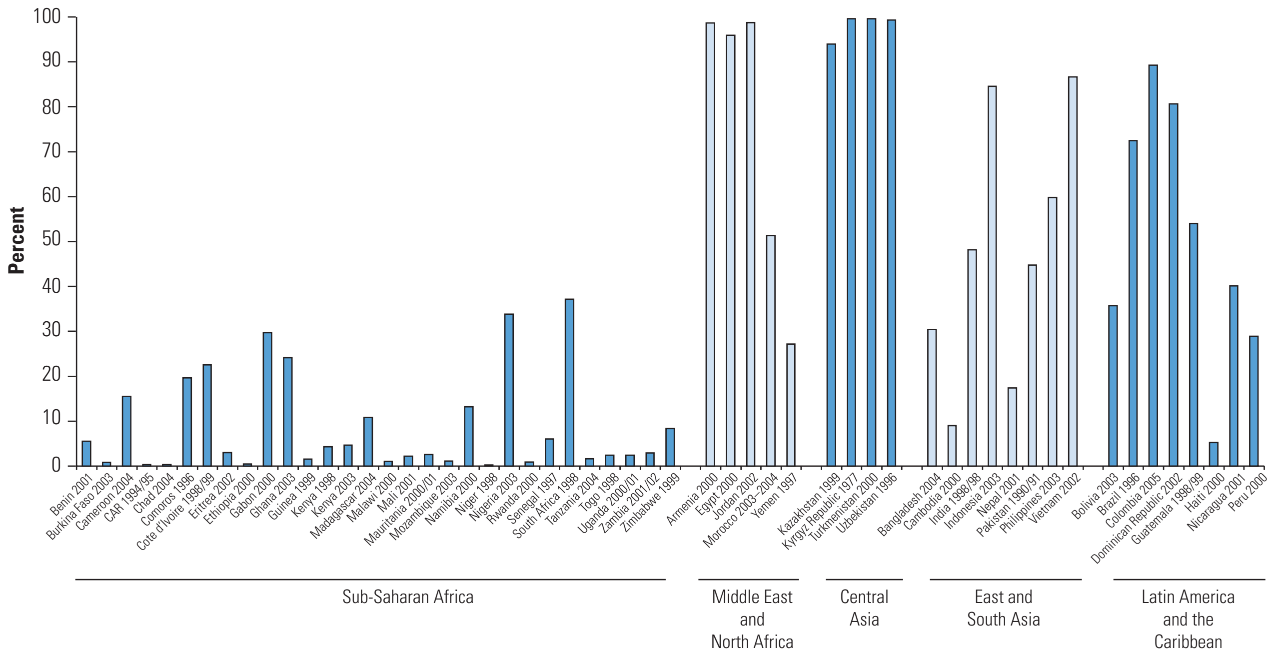
## Schedule and Task Management

The schedule for the study is as follows:

- Inception phase, June–September 2006: Development of approach and design papers, and visit to selected case study country (possibly October); review of existing impact evaluations
- Preparatory phase: September–October 2006: Questionnaire design and collection of materials
- Desk reviews: September–December 2006
- Analysis of existing data sets: October–November 2006
- Survey: fielded by December 2006, with clean data by February 2007
- Data analysis and synthesis: February–March 2007
- Report writing: First draft by mid-April, final report to CODE by June 2007
- Dissemination: September–December 2007. Dissemination includes the usual report distribution internally and externally, plus presentations to targeted agencies with an interest in RE (for example, USAID, Norad, and the Swiss aid agency Seco). Additional publications from the study shall be prepared as part of dissemination.

The evaluation will be carried out by a team of IEG staff and consultants with the assistance of in-country consultants for the survey under the task management of Howard White.

## Attachment 1: Rural Electrtification Coverage (DHS Data)




## Attachment 2: Available PPARs for Review

| Country | Project name | Fiscal years | ICR outcome rating | PPAR rating | Loan size (millions) |
|---|---|---|---|---|---|
| Bangladesh | Third Rural Electrification | 1990–2000 | HS | HS | 105.0 |
| Ghana | Fifth Power Project | 1990–97 | S | MS | 40.0 |
| India | Renewable Resources Development | 1993–2002 | S | S | 190 |
| Indonesia | Kecamatan Development Project | 1998–2002 | HS | MS | 225 |
| Kenya | Geothermal Development and Energy Pre-Investment Project[a] | 1989–96 | S | S | 40.7 |
| Lao PDR | Provincial Grid Integration Project | 1993–99 | S | U | 36 |
| Mozambique | Urban Household Energy Project | 1989–98 | U | MS | 22 |
| Niger | Energy Project | 1988–97 | S | MS | 31.5 |
| Pakistan | Rural Electrification Project | 1990–97 | U | U | 160.0 |
| Philippines | Rural Electrification Revitalization Project | 1992–98 | U | U | 91.3 |
| Philippines | Energy Sector Project | 1990–96 | S | MU | 390 |
| Sri Lanka | Energy Services Delivery Project | 1997–2003 | S | HS | 24.2 |
| Sri Lanka | Second Power Distribution and Transmission Project | 1992–98 | S | MS | 50 |

*Note:* HS = highly satisfactory, MS = moderately satisfactory, MU = moderately unsatisfactory, S = satisfactory, U = unsatisfactory.
a. RE component was a study.

## Chapter 1

1. World Bank Group Historical Chronology http://siteresources.worldbank.org/EXTARCHIVES/Resources/WB_Historical_Chronology_1944_2005.pdf.

2. Rural electrification (RE) is not precisely defined but may often include some areas that are at the very least peri-urban, either because, as in Bangladesh, villages are very large or, as in Ghana, RE programs include district towns that serve surrounding areas.

3. These countries were Bangladesh, Ghana, Lao PDR, Morocco, Nepal, Nicaragua, Peru, the Philippines, Senegal, and Sri Lanka.

4. These countries were Bangladesh, Ghana, Indonesia, Morocco, Nepal, Nicaragua, Peru, the Philippines, and Senegal.

5. These data sets were of variable quality. The ESMAP survey of the Philippines (ESMAP 2003) has been the best designed to date, though unfortunately the complete data set is no longer available, which restricted some of the analysis. The Lao PDR survey was based on the Philippines survey, but problems in survey design and execution also limited the analysis (for example, the agricultural production and time use modules). The Sri Lanka survey had a rather different focus and thus had limited usefulness for impact analysis. A recommendation of this report is for more tailor-made surveys to assess the impact of RE programs.

6. Income may be regarded as endogenous with respect to electrification, creating a problem if data prior to electrification are not available. However, income may be instrumented either with assets or, if these are also thought to be endogenous, then fixed household characteristics such as education and sex of household head.

## Chapter 2

1. Cost recovery policies were embodied in the policy statements in Operational Manual 2.25: "Cost recovery policies for public sector projects: general aspects" (March 1977) and 3.72 "Energy, Water Supply, and Telecommunications" (September 1978), though these made allowance for flexible application with below-cost recovery charges permissible on distributional grounds.

2. Projects excluded were those belonging to the following categories: projects for power plant construction with little or no grid extension, even when this plant would eventually supply rural areas; projects for rehabilitation of existing electricity infrastructure only; projects that did not seem to contain a specific RE aspect, even where these cover large areas; and projects with no project appraisal document.

3. One issue is the substantial scale of investments needed against available International Development Association resources, which limits the Bank's ability to tackle RE in Africa. But it should also be recognized that unit costs in many African countries are high and rural population densities and incomes low, so structural inefficiencies need to be addressed before RE can be tackled on a financially sustainable basis.

4. The fact that a smaller percentage of projects have institutional development (ID) components than have ID objectives suggests some mismatching of objectives and components. But examination of projects with ID objectives but no ID category shows specific reasons, such as multisectoral projects whose ID components were classified as "nonelectrification."

5. The 120 projects do not include all RET projects, because some of these do not qualify as RE. IEG's review of RETs listed 65 projects for the period 1990–2005 (IEG 2006). Although many of these activities are relatively new to the Bank, the exception has been hydropower. This has been a major investment line for the Bank that had declined in recent years because of mounting pressure against large dams. During the three decades up to 1995, the Bank financed 110

hydroelectric projects in 50 countries (Besant-Jones 1995). From 1970 to 1985 the Bank was involved in an estimated 3 percent of the new dam projects around the world, but this had fallen to 0.6 percent by March 2001 (World Commission on Dams 2001).

6. From the International Bank for Reconstruction and Development (IBRD), $2.2 million, and from GEF $0.7 million for off-grid and $31.2 for grid extension for Southern Provinces Rural Electrification Project; and $6.13 million from IBRD and $3.75 from GEF for off-grid for the Rural Electrification Project.

7. In the Implementation Completion Report prepared by operational staff, projects are rated on a four-point scale—"highly unsatisfactory," "unsatisfactory," "satisfactory," and "highly satisfactory." IEG independently verifies these ratings based on a desk review, and in 25 percent of cases carries out its own fieldwork, the findings from which are reported in a Project Performance Assessment Report. The ratings given here are those from IEG's database.

8. The increased focus on welfare objectives is not a driving factor behind deteriorating performance—projects with welfare objectives perform no worse on average than other projects.

9. A review of best practice approaches to reducing the costs of grid extension is given in ESMAP (2000).

## Chapter 3

1. A more comprehensive picture is given by plotting the whole distribution, as is done in a Lorenz curve. These curves are given in appendix C.

2. Pan-territorial pricing means that customers in remote areas will enjoy these low charges once they are connected to the grid, benefiting from cross subsidies in the service provider's tariff structure. For this reason, schemes to market off-grid sources are usually unsuccessful if a community believes it will be connected to the grid in the near future.

3. Watt peak is the wattage of the solar panel at maximum (peak) performance.

4. In appendix C extensive growth is defined as growth achieved by extending electricity to previously unconnected communities and when intensive expansion reaches households in already connected households. The analysis shows that most of the increase in coverage comes from extensive growth—only once a majority of communities are connected does intensive growth play a more important role.

5. Bangladesh, Nepal, Peru, and the Philippines.

## Chapter 4

1. "It is not easy for [women] to watch TV in other people's houses after dusk, defying the purdah barrier" (Siddiqui 2000, p. 253).

2. It is surprising that average consumption for lighting is less in the Philippines than in Lao PDR. This may be a seasonal effect. The Philippines survey took place in June/July, when daylight hours are at their peak of around 12.5 hours. The timing of the Lao PDR survey is not known, but if it were early in the year, then daylight at the time of the survey could be 1.5 hours less. For a household using just two 60-watt bulbs, this difference in daylight hours would account for a difference of 5.4 kWh per month of electricity use for lighting.

3. The most detailed treatment of this topic is Winther's (2005) anthropological study of RE in Zanzibar. In a discussion of fear of witchcraft among those acquiring electrical goods, a footnote reveals that the anthropologist herself and her husband switched to cooking with kerosene because of the frequent electric shocks they and their cook received from the heating plate.

## Chapter 5

1. This would not be so if distributional weights were being used.

2. Estimates of a constant elasticity curve passing through PQ combinations for grid electrified and non-electrified pass below the PQ combinations obtained for PQ combinations for off-grid electrified and non-electrified. Where both sets of data are available for a single country, then a kinked demand curve could be estimated, which would show the WTP for grid connections to be higher than that for off grid.

3. More were examined, but it is not always possible to determine the method being employed.

4. To increase understanding of the methodology, ESMAP produced "A Primer on Consumer Surplus and Demand: Common Questions and Answers" (Peskin 2006).

5. The figure of 1.6 million is commonly cited (for example, Ahmed and others 2005), but the higher figure of 2 million is given in the survey of Larson and Rosen (2000).

6. Rather than RE, the strides that have been made in this area are through the adoption of improved wood stoves (which also have higher efficiency) or the spread of liquefied petroleum gas.

7. Immunization is instrumented as it is endogenous with respect to child nutrition.

8. However, other studies suggest there may be time savings in cooking (ESMAP 2004).

9. For an elaboration of this argument in the context of a project in South Africa to electrify rural schools, see Bedford (1997b).

10. This is not the approach used in the ESMAP study, which simply attributes the current value of incremental higher earnings from higher educational attainment to the household. That procedure is incorrect, because it is not adults currently in the labor market who earn more as a result of electrification but the children who will go on to earn more in the future. The IEG calculation is based on these future earnings. Specifically, the incremental earnings are assumed to occur from ages 16 to 60, which are discounted back to their present value. This PV is then converted to a monthly "annuity." The IEG analysis for the Philippines also adjusts for the overestimate of the educational impact of electrification resulting from the single difference approach, assuming it to be one year rather than two.

11. Time should be valued at its opportunity cost, which clearly depends on whose time it is. This study takes average income per capita as the opportunity cost (rather than the wage) to allow for the distribution of household tasks across all household members. Clearly a more age- and sex-specific analysis would be preferable, but the data do not allow that.

12. The figures reported here for the Philippines are lower than those in the ESMAP report. The latter report found no significant impact on business revenue from multivariate analysis (although there was for hours worked) and so used single difference estimates. These are certainly an overestimate, partly because of the superior location of households in electrified villages. An imperfect control group is provided by businesses in electrified villages that do not use electricity in their business (which may still overestimate the electrification effect because of other differences in characteristics). It is not clear how the ESMAP study allowed for the proportion of households having a home business.

13. The difference in lumen capacity (the lumen power of all lightbulbs owned by the household) is rather less, as SHS households are far more likely to use energy-efficiency compact fluorescent lightbulbs. However, the data collected do not allow an accurate calculation of this figure (or the more relevant figure of lumen hours).

## Appendix F

1. Income is the variable of interest, but because it is endogenous, it is instrumented using education of head of the household and construction material of walls, roof, and floor of the house.

2. The ESMAP study (2003) also found that households spend more time running sari-sari shops (retail shops) than other home-based businesses. Furthermore, female household heads were found to spend more hours engaged in home business activity than males, and older adults spend less time than younger adults. Compared with household heads who are unemployed or working part time, fully employed household heads were found to spend about two hours more per day running their home businesses. The ESMAP study also found a direct relationship between the hours spent working in a home business and the amount of household income from other sources.

## Appendix G

1. The agency index is the simple sum of indicators of whether the woman has final say on her own and her children's health care; household purchases for large items and daily needs; what should be cooked each day; and visits to family, friends, or relatives.

2. The k knowledge variable for men was a simple average of three to four separate questions from the survey: (1) the contraceptive knowledge variable, (2) knowledge of timing of ovulation in three of the four cases and the pregnancy problem in one, (3) recognition of diarrhea problems, and/or (4) cough problems.

## Appendix H

1. This would not be so if distributional weights were being used.

## Appendix I

1. The previous evaluations have been IEG 2004, 2005, and forthcoming.

2. The study was undertaken under the auspices of ESMAP, a technical assistance program of the World Bank and UNDP, with the secretariat based in the Bank's Washington, DC, headquarters.

3. The problems in this approach, and the alternative "cost-savings" approach, are detailed in the ESMAP study on the Philippines (ESMAP 2003).

4. The choice of case study countries is still under review. Indonesia may be substituted for the Philippines. The latter is included, as it is the subject of the ESMAP study, but the Bank's operations in the country have made little direct contribution to RE coverage.

5. The report relies on bivariate tabulations and so does not control for other determinants of the outcome variables (Massé 2003). The data will allow multivariate analysis, which will do so.

6. These asset indices usually contain items such as ownership of a radio and TV. Because these variables are a function of electrification status, they will be excluded from the indices.

7. GEF has made some estimates of impact at both local and global levels that shall be included in the review, but GEF has not used intensive field-level data collection.

8. This was a World Bank research initiative to better understand the links between energy and poverty, for which case studies were undertaken in the three countries mentioned.

# BIBLIOGRAPHY


Ahmed, Kulsham, Yewande Awe, Douglas F. Barnes, Maureen L. Cropper, and Masami Kojima. 2005. *Environmental Health and Traditional Fuel Use in Guatemala.* Washington, DC: World Bank.

Bardasi, Elena, and Quentin Wodon. 2006. "Measuring Time Poverty and Analyzing Its Determinants: Concepts and Applications in Guinea." *Economics Bulletin* 10 (12): 1–7.

Barkat, Abul, S.H. Khan, M. Rahman, S. Zaman, A. Podder, S. Halim, N.N. Ratna, M. Majid, A.K.M. Maksud, A. Karim, and S. Islam. 2002. *Economic and Social Impact Evaluation Study of the Rural Electrification Program in Bangladesh.* Arlington, VA: Human Development Research Centre and NRECA International, Ltd.

Barnes, Douglas, ed. 2007. *The Challenge of Rural Electrification: Strategies for Developing Countries.* Washington, DC: Resources for the Future.

———. 1988. "Electric Power for Rural Growth: How Electricity Affects Rural Life in Developing Countries." *Rural Sociology* 54 (1): 132–135.

Barnes, D. F., and H. Binswanger. 1986. "Impact of Rural Electrification and Infrastructure on Agricultural Changes, 1966–1980." *Economic and Political Weekly (India)* 21: 26–34.

Bedford, Laura. 1997a. "An Assessment of the Process of the Electrification of Clinics in Region E of the Eastern Cape." Energy & Development Research Centre Report, University of Cape Town, South Africa.

———. 1997b. "An Assessment of the Process of the Electrification of Schools in Region E of the Eastern Cape." Energy & Development Research Centre Report, University of Cape Town, South Africa.

Berrie, Tom. 1993a. "Energy Efficiency and Conservation in the Developing World: The World Bank's Role." World Bank Policy Paper, World Bank, Washington, DC.

———. 1993b. "The World Bank's Role in the Electric Power Sector." World Bank Policy Paper, World Bank, Washington, DC

Besant-Jones, John. 2006. "Reforming Power Markets in Developing Countries: What Have We Learned?" Energy and Mining Sector Board Discussion Paper No. 19, World Bank, Washington, DC.

———. 1995. "Attracting Finance for Hydroelectric Power." Energy Note 3, World Bank, Washington, DC.

Bhattacharyya, S.C. 2006a. "Energy Access Problems of the Poor in India: Is Rural Electrification a Remedy?" *Energy Policy* 34 (18): 3387–3397.

———. 2006b. "Universal Electrification: Will the New Electrification Programme Succeed in India?" *OPEC Review* 30 (2): 105–123.

———. 1997. "Electrification of Clinics and Schools in the Former Transkei: Pre-Electrification Study in Nmceba, Ludeke, AmaNdengane and AmaNtshangase." Energy & Development Research Centre Report, University of Cape Town, South Africa.

Binswanger, H., and Shahidur Khandker. 1993. "How Infrastructure and Financial Institutions Affect Agricultural Output and Investment in India." *Journal of Development Economics* 41: 337–366.

Blackden, C. Mark, and Quentin Wodon, eds. 2006. *Gender, Time Use, and Poverty in Sub-Saharan Africa.* Washington, DC: World Bank.

Brodman, J. 1982. "Rural Electrification and the Commercial Sector in Indonesia." Discussion Paper D-73L, Resources for the Future, Washington, DC.

Cecelski, Elizabeth. 2004. "Re-Thinking Gender and Energy: Old and New Directions." ENERGIA/EASE Discussion Paper, Leusden, the Netherlands.

———.1992. "Energy and Rural Women's Work: Crisis, Response, and Policy Alternatives." *International Labor Review* 126 (1): 41–64.

Charmes, Jacques. 2006. "A Review of Empirical Evidence on Time Use in Africa from UN-Sponsored Surveys." In *Time Use and Poverty in Sub-Saharan Africa*, ed. C.M. Blackden and Quentin Wodon, 39–72. Washington, DC: World Bank.

Chaudhury, Nazmul, and Jeff Hammer. 2003. "Ghost Doctors: Absenteeism in Bangladeshi Health Facilities." World Bank Research Working Paper 3065, World Bank, Washington, DC.

Davis, J.M., and John Saunders. 1978. *Rural Electrification: An Evaluation of Effects on Economic and Social Changes in Costa Rica and Colombia.* Boulder, CO: Westview Press.

Davis, Mark. 1997a. "A Financial and Economic Analysis of Two Electrification Projects." Energy & Development Research Centre Report, University of Cape Town, South Africa.

———. 1997b. "The Financial Impacts of Rural Electrification: Draft Report." Energy & Development Research Centre Report, University of Cape Town, South Africa.

———. 1995. "Electricity Consumption Growth in Newly Electrified Settlements." Energy & Development Research Centre Report, University of Cape Town, South Africa.

Dutta, S. 2005. "Energy as a Key Variable in Eradicating Extreme Poverty and Hunger: A Gender Perspective on Empirical Evidence on MDG#1." DFID Discussion Paper, U.K. Department for International Development, London.

ESMAP (Energy Sector Management Assistance Program). 2004. "Power Sector Reform and the Rural Poor in Central America." ESMAP Report 297/04, World Bank, Washington, DC.

———. 2003. "Rural Electrification and Development in the Philippines: Measuring the Social and Economic Benefits." ESMAP Report 255/03, World Bank, Washington, DC.

———. 2002. "Energy Strategies for Rural India: Evidence from Six States." ESMAP Report 258/02, World Bank, Washington, DC.

———. 2000. "Reducing the Cost of Grid Extension for Rural Electrification." ESMAP Report 227/00, World Bank, Washington, DC.

Fluitman, F. 1983. "The Socio-Economic Impact of Rural Electrification in Developing Countries: A Review of Evidence." World Employment Programme Research Working Paper 126, International Labour Office, Geneva.

Foley, Gerald. 1993. "Rural Electrification in Mozambique, Tanzania, Zambia, and Zimbabwe: Synthesis Report from the SEI/BUN Workshop on Rural Electrification." Energy, Environment and Development Series No 16, Stockholm Environment Institute, Stockholm, Sweden.

Foster, Vivien, and Tito Yepes. 2006. "Is Cost Recovery a Feasible Objective for Water and Electricity? The Latin American Experience." World Bank Policy Research Working Paper 3943, Washington, DC.

Gordon, Adele. 1997. "Facilitating Education in Rural Areas of South Africa: The Role of Electricity and Other Sources of Energy." Energy & Development Research Centre Report, University of Cape Town, South Africa.

Greacan, Chris. 2003. "Small Is Pitiful: Micro-Hydroelectricity and the Politics of Rural Electricity Provision in Thailand." Presented at "Politics of the Commons: Articulating Development and Strengthening Local Practices," Chiang Mai, Thailand, July 11–14.

Green, Donna. 2005. "The Politics of Environmental Technology Choice for Rural Electrification in Thailand." *Conservation and Society* 3 (2): 265–279.

GSS (Ghana Statistical Service). 2000. *Ghana Living Standards Survey: Report of the Fourth Round.* Accra: Ghana Statistical Service.

Hutton, G., E. Fehfuess, F. Tediosi, and S. Weiss. 2006. *Evaluation of the Costs and Benefits of Household Energy and Health Interventions at Global and Regional Levels.* Geneva: World Health Organization.

IEG (Independent Evaluation Group). Forthcoming. *An Impact Evaluation of India's Second and Third Andhra Pradesh Irrigation Projects: A Case of Poverty Reduction with Low Economic Returns.* IEG Study Series. Washington, DC: World Bank.

———. 2006. *New Renewable Energy: A Review of the World Bank's Assistance.* IEG Study Series. Washington, DC: World Bank.

———. 2005. *Maintaining Momentum to 2015: An Impact Evaluation of External Support to Maternal and Child Health and Nutrition in Bangladesh.* IEG Study Series. Washington, DC: World Bank.

———. 2004. *Books, Buildings, and Learning Outcomes: An Impact Evaluation of World Bank Support to Basic Education in Ghana.* IEG Study Series. Washington, DC: World Bank.

———. 2003. *Power for Development: A Review of the World Bank Group's Experience with Private Participation in the Electricity Sector.* IEG Study Series. Washington, DC: World Bank.

———. 1994. *Rural Electrification in Asia: A Review of Bank Experience.* IEG Study Series. Washington, DC: World Bank.

Jadresic, A. 2000. "A Case Study on Subsidizing Rural Electrification in Chile." In *Energy Services for the World's Poor.* Washington, DC: World Bank.

James, Bronwyn. 1997. "Current Limited Supplies of Electricity in the Context of South African Rural Areas." Energy & Development Research Centre Report, University of Cape Town, South Africa.

———. 1996a. "An Assessment of the Pre-Electrification Process in the Tambo Village Pilot Project." Energy & Development Research Centre Report, University of Cape Town, South Africa.

———. 1996b. "Criteria Used for the Selection of Electrification Projects in Rural Areas." Energy & Development Research Centre Report, University of Cape Town, South Africa.

———. 1995. "The Impacts of Rural Electrification: Exploring the Silences." Energy & Development Research Centre Report, University of Cape Town, South Africa.

James, Bronwyn, and Pamela Ntutela. 1997. "Rural Households' Response to the 2.5A Electricity Supply Option in the Tambo Village Pilot Project." Energy & Development Research Centre Report, University of Cape Town, South Africa.

Kjellström, Bjorn, Maneno Katyega, Henry Kadete, Dolf Noppen, and Abu Mvungi. 1992. "Rural Electrification in Tanzania: Past Experience—New Approaches." Energy, Environment and Development Series No.15, Stockholm Environment Institute, Stockholm, Sweden.

Kline, Ronald. 2002. "Resisting Development, Reinventing Modernity: Rural Electrification in the United States before World War II." *Environmental Values* 11: 327–344.

Komives, K., Vivien Foster, Jonathan Halpern, and Quentin Wodon. 2005. *Water, Electricity and the Poor: Who Benefits from Utility Subsidies?* Washington, DC: World Bank.

Larson, Bruce A., and Sydney Rosen. 2000. *Household Benefits of Indoor Air Pollution Control in Developing Countries.* Washington, DC: USAID.

Laxmi, Vijau, Jyoti Parikh, Shyam Karmakar, and Pramod Dabrase. 2003. "Household Energy, Women's Hardship, and Health Impacts in Rural Rahastan, India: Need for Sustainable Energy Solutions." *Energy for Sustainable Development* 7 (1): 50–68.

Luckin, Bill. 1990. *Questions of Power: Electricity and Environment in Inter-War Britain.* Manchester, United Kingdom: Manchester University Press.

Mariam, H. 1992. "Rural Electrification in Ethiopia." In *Rural Electrification in Africa,* ed. V. Ranganathan. London: Zed Books, Ltd.

Massé, Réné. 2003. "Impacts of Rural Electrification on Poverty and Gender in Sri Lanka." Country Study, World Bank, Washington, DC.

Mbewe, A. 1992. "Rural Electrification in Zambia." In *Rural Electrification in Africa,* ed. V. Ranganathan. London: Zed Books, Ltd.

Meier, T. 2001. *Mini Hydropower for Rural Development: A New Market-Oriented Approach to Maximize Electrification Benefits—With Special Focus on Indonesia.* Berlin: Lit-Verlag.

Mensah-Kutin, Rose. n.d. "Gender and Rural Electrification in Ghana." Unpublished doctoral dissertation, Centre for West African Studies, University of Birmingham, United Kingdom.

Nathan, Dev, and Govind Kelkar. 1997. "Wood Energy: The Role of Women's Unvalued Labor." *Gender, Technology, and Development* 1 (2): 205–224.

National Rural Electric Cooperation Association. 1982. "Productive Uses of Electricity in Rural Areas." Paper prepared for the workshop, Dhaka, Bangladesh, Nov. 15–19.

Parikh, J. 2005. *The Energy, Poverty, and Gender Nexus in Himachal Pradesh, India: The Impact of Clean Fuel Access Policy on Women's Empowerment.* New Delhi: Integrated Research and Action for Development.

Parikh, J., and Laxmi, V. 2000. "Biofuels, Pollution and Health Linkages—A Survey of Rural Tamil Nadu." *Economic and Political Weekly*, November 18.

Peskin, Henry M. 2006. "A Primer on Consumer Surplus and Demand: Common Questions and Answers." ESMAP Knowledge Exchange Series No. 5, World Bank, Washington, DC.

Piampiti, Suwanlee, Twatchai Yongkittikul, Laddwal Rodmanee, and Vanawipha Pasandhanatovn. 1982. "Demographic and Economic Impact of Rural Electrification in Northeastern Thailand." National Institute of Development Administration Report, Bangkok, Thailand.

Ramasedi, B. R. 1992. "Rural Electrification in Botswana." In *Rural Electrification in Africa,* ed. V. Ranganathan, 112–140. London: Zed Books, Ltd.

Rogerson, Christian Myles. 1997. "Rural Electrification and the SMME Economy in South Africa." Energy & Development Research Centre Report, University of Cape Town, South Africa.

Ross, Fiona, Richard Matzopoulos, and Rozett Phillips 1997. "The Role of Rural Electrification in Promoting Health in South Africa." Energy & Development Research Centre Report, University of Cape Town, South Africa.

Saunier, G., ed. 1992. *Rural Electrification Guidebook for Asia and the Pacific*. Bangkok: Asian Institute of Technology.

Shonder, J.A., and T.J. Wilbanks. 1996. *Final Evaluation of the Central American Rural Electrification Support Project (CARES).* Washington, DC: USAID.

Siddiqui, Kamal. 2000. *Jagatpur 1977–1997: Poverty and Social Change in Bangladesh.* Dhaka, Bangladesh: University Press Ltd.

Singh, D. 1997. "Renewable Energy for Village Electrification." International Centre for Application of Solar Energy Report, New Delhi, India.

Thom, Cecile. 1996. "Pre-Electrification Research in Mafefe: Energy Use, Livelihoods, Power Relations and the Electrification Process." Energy & Development Research Centre Report, University of Cape Town, South Africa.

Thom, Cecile, M. Davis, and M. Borchers. 1995. "Review of South African Experience in Rural Electrification." Energy & Development Research Centre Report, University of Cape Town, South Africa.

Tomkins, R. 2001. "Extending Rural Electrification: A Survey of Innovative Schemes." In *Contracting for Public Services: Output-Based Aid and Its Applications,* ed. P. J. Brook and S. M. Smith, 47–56. Washington, DC: World Bank.

Valencia, Alfonso Carrasco, Kimmo J. Juvas, and Maija Seppo. 1990. *Electrification and Rural Development—Electrification Project in the Rural Areas of Cusco, Peru.* Helsinki: International Development Agency, FINNIDA.

Walubengo, D., and Onyango, A. 1992. *Energy Systems in Kenya: Focus on Rural Electrification—Kengo Regional Wood Energy Programme for Africa.* Nairobi: KENGO.

Wentzel, Marlett, and C. Wood. 1997. "A Post-Electrification Study of the Mafefe Electrification Project." Energy & Development Research Centre Report, University of Cape Town, South Africa.

Winther, Tanja. 2005. "Current Styles: Introducing Electricity in a Zanzibari Village." Unpublished doctoral dissertation, Department of Social Anthropology, University of Oslo.

World Bank. 2006. "Peru—Rural Electrification Project." Project Appraisal Document Report No. 32686-PE, World Bank, Washington, DC.

———. 2005. "Energy and Poverty: Myths, Links, and Policy Issues." Energy and Mining Sector Board Working Notes, World Bank, Washington, DC.

———. 2002. Renewable Energy Toolkit. http:// web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTENERGY/EXTRETOOLKIT/0,,contentMDK:20768499~menuPK:2069822~pagePK:64168427~piPK:64168435~theSitePK:1040428,00.html.

———. 2001a. "Brazil—Rural Poverty Alleviation Project: State of Ceara." Implementation Completion and Results Report No. 23397, World Bank, Washington, DC.

———. 2001b. "The World Bank's Energy Program: Poverty Reduction, Sustainability, and Selectivity." Energy and Mining Sector Board Paper, World Bank, Washington, DC.

———. 2000. *Fuel for Thought: An Environmental Strategy for the Energy Sector.* Washington, DC: World Bank.

———. 1996. *Rural Energy and Development: Improving Energy Supplies for Two Billion People.* Washington, DC: World Bank.

———. 1995. "Indonesia—Second Rural Electrification Project." Staff Appraisal Report No. 12920-IND, World Bank, Washington, DC.

———. 1993a. "Energy Efficiency and Conservation in the Developing World." Policy Paper, World Bank, Washington, DC.

———. 1993b. "The World Bank's Role in the Electric Power Sector: Policies for Effective Institutional, Regulatory, and Financial Reform." Working Paper, World Bank, Washington, DC.

———. 1992. *World Development Report: Development and the Environment.* Washington, DC: World Bank.

———. 1986. "Indonesia Rural Electrification Review." East Asia and Pacific Regional Office Working Paper, World Bank, Washington, DC.

———. 1975. "Rural Electrification." Working Paper No. PUB-517, World Bank, Washington, DC.

World Commission on Dams. 2001. http://siteresources.worldbank.org/INTWRD/903857-1112344791813/20424164/WB&WCDQ&A.pdf.

# THE WORLD BANK GROUP

***WORKING FOR A WORLD FREE OF POVERTY***

The World Bank Group consists of five institutions—the International Bank for Reconstruction and Development (IBRD), the International Finance Corporation (IFC), the International Development Association (IDA), the Multilateral Investment Guarantee Agency (MIGA), and the International Centre for the Settlement of Investment Disputes (ICSID). Its mission is to fight poverty for lasting results and to help people help themselves and their environment by providing resources, sharing knowledge, building capacity, and forging partnerships in the public and private sectors.

# THE INDEPENDENT EVALUATION GROUP

***ENHANCING DEVELOPMENT EFFECTIVENESS THROUGH EXCELLENCE AND INDEPENDENCE IN EVALUATION***

The Independent Evaluation Group (IEG) is an independent, three-part unit within the World Bank Group. IEG-World Bank is charged with evaluating the activities of the IBRD (the World Bank) and IDA, IEG-IFC focuses on assessment of IFC's work toward private sector development, and IEG-MIGA evaluates the contributions of MIGA guarantee projects and services. IEG reports directly to the Bank's Board of Directors through the Director-General, Evaluation.

The goals of evaluation are to learn from experience, to provide an objective basis for assessing the results of the Bank Group's work, and to provide accountability in the achievement of its objectives. It also improves Bank Group work by identifying and disseminating the lessons learned from experience and by framing recommendations drawn from evaluation findings.

IEG
Independent Evaluation Group

THE WORLD BANK

ISBN 978-0-8213-7367-5
SKU 17367