ADB

Evaluation Study

Reference Number: IES: BHU 2010-27
Impact Evaluation Study
August 2010

Asian Development Bank's Assistance for Rural Electrification in Bhutan—Does Electrification Improve the Quality of Rural Life?

Independent Evaluation Department

Asian Development Bank

CURRENCY EQUIVALENTS
(as of 31 August 2010)

Currency Unit	–	ngultrum (Nu)
Nu1.00	=	$0.02131
$1.00	=	Nu46.92

ABBREVIATIONS

ADB	–	Asian Development Bank
ADF	–	Asian Development Fund
BPC	–	Bhutan Power Corporation
DMC	–	developing member country
FGD	–	focus group discussion
IEG	–	Independent Evaluation Group
JICA	–	Japan International Cooperation Agency
kWh	–	kilowatt-hour
OLS	–	ordinary least squares
PCR	–	project completion report
PSM	–	propensity score matching
PVR	–	project completion report validation report
RE	–	rural electrification
RENEP	–	Rural Electrification and Network Expansion Project
SAPE	–	sector assistance program evaluation
SREP	–	Sustainable Rural Electrification Project
TA	–	technical assistance
WTP	–	willingness to pay

GLOSSARY

bukhari	–	fuelwood based house or space heating system with smoke exhaust through chimney
chorten	–	religious structure
dzongdey	–	administrative zone
dzonkhag	–	district
gewog	–	group of villages
gup	–	village leader

NOTE

In this report, "$" refers to US dollars.

Key Words
adb, administrative zone, asian development bank, bhutan, electrified village, focus group discussion, fuelwood, ied, impact evaluation, independent evaluation department, ordinary least squares, propensity score matching, religious structure, rural electrification assistance, unelectrified village, willingness to pay

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The guidelines formally adopted by the Independent Evaluation Department on avoiding conflict of interest in its independent evaluations were observed in the preparation of this report. Daisy Garcia, research associate; Santosh Kumar, econometrician and impact evaluation specialist; Mani Pradhan, socioeconomic survey and database management specialist; and Kunzang Yonten, socioeconomic development specialist were the consultants who assisted in the study. To the knowledge of the management of Independent Evaluation Department, there were no conflicts of interest of the persons preparing, reviewing, or approving this report.

APPENDIXES

EXECUTIVE SUMMARY

Context

The Asian Development Bank (ADB) assistance to the developing member countries has been consistent with the government policies, and ADB's corporate strategies and policies. ADB has responded well to the demand from energy deficient and expanding economies by significantly increasing assistance to the energy sector, including for rural areas. The response from ADB to the demand from the developing member countries has been timely, in the form of assistance for power generation, transmission, distribution, policy reforms, and capacity building for economic growth and poverty reduction. Over time, the quality of rural electrification (RE) projects at entry has improved with better and flexible indicators in design and monitoring frameworks. However, a content analysis of 24 loans, 49 technical assistance, and 8 grant documents suggests that only 24% of loan, 7% of technical assistance, and 13% of grant project indicators met all five smart attributes—specific, measurable, achievable, relevant, and time bound. Of all the RE projects approved between 1989 and 2009, 13 had project completion reports (PCRs) and 2 PCR validation reports. Twelve of the 13 projects were rated *successful* or *highly successful*. At completion, 4 projects were considered *most likely sustainable*, 7 *likely sustainable*, and one *less likely sustainable*. One project did not have sustainability rating. The less likely sustainability for one project was associated with poor financial position of the implementing agency. Four of the 13 projects encountered implementation delays of 2 years or longer, another 4 between 1 to 2 years, and remaining 5 projects were implemented with less than 1 year delay. Nevertheless, previous evaluation studies did not go to the extent of analyzing RE impacts on rural life.

The main objective of this study is to assess the impact of two rural electrification projects funded by ADB in Bhutan: the Sustainable Rural Electrification Project (Loan 1712-BHU); and the Rural Electrification and Network Expansion Project (Loan 2009-BHU). The study undertakes two tasks: (i) evaluate the performance of the two loan projects using relevance, effectiveness, efficiency, likely impact, and sustainability criteria; and (ii) conduct a rigorous quantitative evaluation of the impacts of the same two projects covering three broad areas influencing quality of life (economic, social, and environmental) and their sustainability. In the process, the study undertook a comprehensive literature review. The study also identifies key lessons and issues, and offers recommendations for consideration by ADB management for enhancing development effectiveness of RE assistance in Bhutan.

Methodology and Data

The study was conducted in four steps. First, background research was done, which involved a comprehensive review and analysis of (i) ADB's RE portfolio and associated project documents and reports prepared by ADB and other development partners, and (ii) theoretical and methodological literature on RE impact, supplementing a 2008 World Bank Independent Evaluation Group report. Second, a detailed study design was developed, which involved creation of (i) a conceptual logic model for conducting impact evaluations based on a literature review and discussions with key informants at ADB and in Bhutan to determine impact indicators and associated variables; and (ii) one village questionnaire to take stock of community attributes, and one household questionnaire containing household energy consumption, demographic, and socioeconomic variables. The third step comprised (i) pre-testing of the questionnaires with electrified and unelectrified households in two villages in Trongsa District; and (ii) data collection based on face-to-face interviews with household heads or their designated representatives. The questionnaires were revised based on feedback from pre-testing before survey implementation and enumerators were provided with a 3-day intensive training with mock interviews in villages nearby Thimphu. The final step included (i) a random check of questionnaires for consistency and completion, (ii) data entry and verification, and (iii) data analysis using appropriate estimation procedures. Because valid baseline data was not available, primary data had to be collected. In addition, focus group discussions were held in each survey district to document qualitative information provided by the villagers.

The conceptual logic model envisaged that electricity access would increase household income and reduce expenditure on traditional energy sources such as kerosene and fuelwood (i.e., economic impact). Since RE was expected to lower consumption of kerosene and fuelwood, it was envisaged to improve indoor air quality (i.e., environmental impact). RE was also expected to result in better health due to reduced incidence of respiratory ailments and other health risks associated with use of solid fuels and fuelwood, as well as increased study time at home for children, due to better lighting, translating into improved school performance and better-quality graduates (i.e., social impacts). Due to better lighting as a result of electrification, lower incidence of crime and reduced damage by wild animals were also expected. Finally, RE was considered to have a positive impact on gender empowerment by balancing the gender roles and control over financial resources. The study assumed that nonproject factors, such as, individual, household, and village-level characteristics may also contribute in realizing the benefits of RE. The main characteristics included were age, gender, education, wealth indicator, and other household characteristics. At the village-level, availability of public goods, such as schools, hospitals, roads; size and population of the village; and distance from the district headquarter were included in the analysis. However, the study could not collect data on some of the variables such as technical measure of indoor air quality and quality of graduates and, hence, these were not analyzed.

A combination of purposive and probability sampling approaches was undertaken to design the sampling frame. Villages and/or households that were electrified under the two projects constituted the sample for treatment, and villages that are planned for electrification constituted the counterfactual or comparison areas. The study purposively selected 10 of 15 districts (*dzonkhags*) supported by ADB assistance under the two projects to ensure representation of geographically disparate and diverse communities. A total of 1,276 electrified and 822 unelectrified households were interviewed for the study, covering 71 electrified and 45 unelectrified villages. These represented about 18% of the total number of households in the 10 study districts. On average, electrified households had received electricity for a period of 4 years.

In order to ensure attribution due to ADB projects, the study used a regression-based propensity score matching method. This study used both household and village-level variables to match the households. Household-level fixed characteristics, such as age, gender, marital status, religion, education of the household head, land ownership, household size, ownership of livestock, type of house, main source of drinking water were used as the control variables. In addition, village-level variables, such as distance to district headquarter (measuring isolation of the village); area and population of the village, time taken to nearest road from the village, and availability of educational infrastructure were also incorporated into the estimation of propensity scores.

The study was conducted with some methodological limitations. In absence of baseline data, the study opted for a single difference impact evaluation method and, hence, it reflects “with and without” RE scenario and it does not augment “before and after” scenario. In addition, counterfactual villages and households may have been somewhat relatively remote compared to their treatment counterparts but are close approximation under the assumption that these were candidates for RE, at the time of project implementation. The lack of relevant data did not permit use of an instrumental variable approach in the analysis. Nevertheless, the study adopted a rigorous impact evaluation approach using qualitative results and quantitative estimates and tried to minimize observable selection bias. However, if baseline data was available, the impact of time-invariant observable characteristics could have been removed.

The study was conducted in close consultation with the Department of Energy and Bhutan Power Corporation. Key findings of the study were presented in Thimphu on 29 May 2010 during the Bhutan Country Assistance Program Evaluation consultation workshop. Relevant comments from the participants have been incorporated into the report.

Results

Rural Electrification Project Performance Evaluation. The study confirms the ratings on the overall performance of the two RE projects as *successful*.

Impact Evaluation. The study indicates that electrified households enjoy a better quality of life and most of the economic, social, and environmental outcomes are better in electrified households than in unelectrified households due to electrification. The impacts are quantifiable, visible, and positive. However, most of the impacts are modest in magnitude due to low household consumption of electricity, which is largely limited with electricity lighting, rice cooking, and water boiling. Use of electricity for income generation is limited to weaving in central and western Bhutan and poultry production in the southern Bhutan. This is not surprising, as the flow of benefits from electrification is slowly emerging and will take time to translate into substantial impacts. The findings are consistent with other studies, including the 2008 World Bank Independent Evaluation Group study.

The results suggest that economic benefits, in terms of percentage increase in income, in electrified households are higher than in unelectrified households, to a greater extent from nonfarm activities and, to a lesser extent, from farming. The plausible causes are establishing or upgrading microenterprises and small businesses, as well as nonfarm employment. Electrification also substantially reduces smoke-induced health problems, and incidences of cough, respiratory ailments, eye irritation, and headache are less prevalent in electrified than unelectrified households. The number of workdays missed due to illness is also lower in electrified households.

Children in electrified households completed more years of schooling compared to those in unelectrified households, with a more pronounced impact on girls than on boys. This is due to time savings in fuelwood collection and access to electricity. The findings also confirm that time spent on collecting fuelwood also decreases substantially in electrified households. In addition, women in electrified households play more significant roles in household decisions, particularly regarding the education of children and health of household members, than their counterparts in unelectrified areas. Women in electrified households tend to be better informed and more aware about education and health than their male counterparts, partly from increased social networking. On the other hand, men continue to dominate financial decision making, even though women tend to hold on to the cash. The finding was consistent with social norms and taboos in Bhutan. Women empowerment is a complex and evolving process, so it may be premature to witness a significant change in women status due to electrification and it would be in the interest of policy makers to observe changes in these outcomes in the long run as most of behavioral changes occur in medium to long run. Although electrification benefits are mostly realized in long run, this study was able to demonstrate positive impact of electrification on fertility, migration, and food security, though the impacts are not large enough.

The focus group discussions revealed that electrification positively affects all spheres of rural life. They stated that it helps alleviate poverty by generating employment opportunities and increasing the incomes of the poor. Participants mentioned that their quality of life is better, thanks to improved lighting, health, education, income and employment opportunities, and recreation and entertainment avenues; saved time and labor on household chores; decreased expenditure and time spent in obtaining fuel for lighting and cooking; cleaner and more hygienic home environments; and a greater sense of safety and security after dark.

Sustainability of project impacts. Project impacts are *likely to be sustainable*, subject to continued subsidy of RE from electricity export earnings. It is envisaged that the fundamentals of cross-subsidization will not change in the near future as Bhutan has committed to increasing power generation for the export market. However, domestic demand is likely to grow with modernization and urbanization.

In addition, the key challenges that Bhutan is likely to face include close monitoring of both infrastructure and environmental impacts. Regulatory framework to promote energy safety has been introduced only in 2008 and guidelines for energy efficiency for both domestic and industrial electricity consumption are yet to emerge. Furthermore, providing electricity to the remaining unelectrified households, which are located in relatively more remote villages, will be expensive. While off-grid solutions may be cost-effective, their viability has not been tested in Bhutan. Additional cost effective options need to be explored to make RE sustainable in difficult terrains and isolated mountain communities. Bhutan also needs to develop cost-effective alternatives to fuelwood for cooking and heating purposes.

Overall Assessment

The overall performance of the two Bhutan RE projects evaluated is rated *successful* based on relevance of design, effectiveness in implementation and achievement of outputs, efficiency of operations, and likely sustainability. Both projects had initial delays in construction which were overcome during implementation. As a result of assistance from ADB and other development partners, RE coverage in the country increased from 20% in 1995 to about 55% to 60% in 2009. With RE intervention in the two projects studied, this impact evaluation study finds that project impacts from RE are quantifiable, statistically positive, and visible in many aspects of quality of life in Bhutan's rural areas, However, impacts are just beginning to be realized and, at this stage, are relatively small in magnitude. This is due to low household consumption of electricity. While electrical appliance ownership has increased steadily, households are still heavily reliant on fuelwood for both cooking and heating. Willingness to pay for electricity by rural consumers is high. The domestic electricity market is also very much dependent on subsidy provisions from electricity export earnings.

Lessons and Implications

The study provides eight key lessons. First, a rigorous impact evaluation informs policymakers about attribution of outcomes and impacts more systematically. Second, country ownership is crucial to project success. RE projects in Bhutan were successful as a result of (i) the government's mandate to provide "electricity for all" by 2013, (ii) the government prioritizing RE coverage expansion, and (iii) effective coordination with five development partners active in RE. Government's broad vision to harness hydroelectric potential played an important role in expanding RE coverage from 20% in 1995 to between 55% to 60% in 2009. Third, in addition to expanding coverage, extra efforts are needed to boost domestic demand for electricity and enhance safely and efficiency in electricity use. Fourth, the existing regulatory framework needs to be strengthened to ensure that energy-efficient appliances and equipments are used by households and businesses. Fifth, when rural people directly realize benefits from RE, they are willing to pay more. Sixth, the consumption of fuelwood is not likely to decline without an enabling alternative environment and disincentive to felling trees. Seventh, the use of electricity for income-generating activities has been limited, but the potential to increase household income is high. Electricity can also be used to improve agricultural productivity. Finally, as highlighted in other impact evaluation studies, baseline data are crucial for properly evaluating the impact of any development intervention, including RE. With proper advance planning and systematic recording, much richer databases could have been created and used for impact evaluation using a double-difference method.

Recommendations for Consideration

The project outcomes and impact(s) outlined in the report and recommendation of the President should be stated clearly and specific, measurable, achievable, relevant, and time bound indicators and targets should be set. A well defined monitoring and evaluation mechanism should be put in place so that progress in achieving these targets can be periodically monitored by collecting data at the required levels, reported and followed-up by the ADB management. In both RE projects these were not followed though and as a result no baseline targets were set and hence created difficulties in evaluating impacts.

Development impact of RE is material as it helps provide a better quality of life and potential for incremental income-generating activities. ADB should continue supporting RE, however, ensuring efficiency of resource use and sustainability of project benefits. The following recommendations are made for consideration by ADB management, particularly the South Asia Regional Department (SARD):

Recommendation	Responsibility	Timing
(i) **Building on success so far, stimulate and manage household and community demand for electricity.** ADB could assist the government in (a) implementing and developing action plans for safety standards, ensuring clean and efficient energy use, and strengthening existing regulatory framework; and (b) linking electricity with income-generating activities such as food processing, irrigation services, and eco-friendly micro and small enterprises (para. 117).	SARD	From January 2011
(ii) **Ensure the sustainability of project benefits.** Sustainability of project benefits hinges on cross-subsidization of rural electrification by power export. ADB could assist the government in (a) conducting a detailed electricity demand study based on willingness to pay and affordability analysis for electricity and alternate energy sources, and determining a sound and efficient basis for setting electricity tariffs and fees for felling trees, and (b) testing viability of alternate energy sources for cooking and other household use in isolated or remote areas, thereby reducing dependency on fuelwood (para 118).	SARD	From January 2011

(iii)	**Encourage monitoring of project outcome and impacts over time.** The study provides a number of socioeconomic and environmental indicators to evaluate project outcome and impact and status of these indicators as of 2010. ADB could assist the government in monitoring progress in economic, environmental, and social impacts of rural electrification over time using these indicators as baseline or benchmark (para 119).	SARD	From January 2011

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I. INTRODUCTION

A. Background and Rationale

1. Strategy 2020 of the Asian Development Bank (ADB)[1] identifies energy as a key component of the infrastructure core area of operations. It states that ADB will continue to invest in rural infrastructure, covering irrigation and water management, rural roads, and rural electrification (RE)—services that particularly benefit women. In addition, ADB's Energy Policy[2] recognizes that Millennium Development Goal targets cannot be met without modern energy services, and that access to energy is essential to reducing poverty.

2. A recent World Bank Independent Evaluation Group (IEG) study[3] noted that quantification of RE benefits is usually restricted to lighting benefits. Other benefits are sometimes mentioned but not quantified. For example, 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 working hours once electricity becomes available. Electrification, thus, provides a small boost to some household incomes. In addition, RE benefits health services by extending clinic opening hours and strengthening the cold chain for vaccines. Electrification also reduces worker absenteeism in both health clinics and schools by improving living conditions and morale of health workers and teachers. However, the study recognized that the evidence supporting these claims is thin; hence, further analysis is required to draw definitive conclusions.

3. The development effectiveness of RE assistance is important from both quality of life[4] and socioeconomic development perspectives to justify continued investment in this subsector. However, there are only a few cases where the impact of RE intervention has been evaluated and systematically quantified by other agencies. Knowledge in this area is still evolving. ADB funded 28 RE projects in 11 countries from 1995 to 2009, but their development effectiveness has not been quantified. This impact evaluation study attempts to quantify both intended and unintended RE impacts on household welfare using primary data from Bhutan. In addition, results are expected to benefit future ADB RE assistance to its developing member countries (DMCs). Finally, this study also contributes new knowledge to the global body of literature on the impact of RE in developing countries.

B. Objectives and Scope

4. The main objective of this study was to assess the impact of two RE projects funded by ADB in Bhutan.[5] First, it reviewed the ADB RE portfolio over the past 20 years, and analyzed project design and monitoring frameworks to determine the quality of development effectiveness indicators identified at project entry. Second, it reviewed RE impact literature complementing the

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[1] ADB. 2008. *Strategy 2020: The Long-Term Strategic Framework of the Asian Development Bank, 2008–2020*. Manila.

[2] ADB. 2009. *Energy Policy*. Manila.

[3] World Bank IEG. 2008. *The Welfare Impact of Rural Electrification: A Reassessment of the Costs and Benefits*. Washington, DC: World Bank.

[4] Quality of life in this study refers to general well-being of individuals and societies. It encompass economic, environmental and social aspects of well-being.

[5] ADB. 1999. *Report and Recommendation of the President to the Board of Directors: Proposed Loan and Technical Assistance Grant to the Kingdom of Bhutan for the Sustainable Rural Electrification Project*. Manila (Loan 1712-BHU, and ADB. 2003. *Report and Recommendation of the President to the Board of Directors: Proposed Loan and Technical Assistance Grants to the Kingdom of Bhutan for the Rural Electrification and Network Expansion Project* (Loan 2009-BHU,). Manila.

World Bank IEG study (footnote 3) and determined a set of pragmatic indicators for evaluating the welfare impacts of RE, which form the conceptual basis for the impact evaluation. Third, it evaluated the performance of the two ADB loan projects using relevance, effectiveness, efficiency, likely impact, and sustainability criteria based on document reviews, analysis of available data, and interviews with key stakeholders. The study then undertook a rigorous quantitative evaluation of the same two projects covering economic, environmental, and social areas. Fourth, it provides sound baseline data for the evaluation of the RE component of the ongoing Green Power Development Project[6] in Bhutan. Finally, the study identifies key lessons from RE operations in Bhutan, and makes recommendations for strengthening project design and operations.

C. Limitation of the Study

5. This impact evaluation study covers the two ADB RE projects implemented almost concurrently and also uses areas covered by the ongoing Green Power Development Project supported by ADB and the Japan International Cooperation Agency (JICA) as counterfactuals.[7] It assumes that if resources were available, all areas would have been electrified at the same time, given their relative homogeneity in socioeconomic attributes. This approach is considered reasonable in the absence of baseline or other comparable counterfactual data. Further, the study is based on household and village survey data using multivariate regression methods. The lack of relevant data does not permit the use of an instrumental variable approach in the analysis; thus, the study employs the single-difference method for evaluating impacts. Nevertheless, the study adopts a rigorous impact evaluation approach using qualitative results and quantitative estimates.

II. AN OVERVIEW OF ADB POLICY, STRATEGY, AND OPERATIONS IN RURAL ELECTRIFICATION

A. Energy Policy and Strategy

6. The energy sector policy that originally governed the RE projects being evaluated was from 1995, which was then updated by a review in 2000.[8] The review's intent was for ADB to help create an appropriate policy and institutional environment and capacity support to develop and extend the availability of energy resources to its DMCs. It reoriented policy goals of energy sector operations to focus on (i) poverty reduction, (ii) private sector participation, (iii) regional and environment impacts, and (iv) regional cooperation. The review was later followed by the 2009 Energy Policy, which was intended to help implement Strategy 2020 goals as well.

7. Strategy 2020 and 2009 Energy Policy state that ADB will engage DMCs and other bilateral and multilateral development partners to address the lack of energy in the region. ADB is committed to supporting sustainable RE efforts in DMCs that are designed to provide energy for all, especially to the rural population. ADB will focus on remote communities that are less likely to be connected to the electricity grid, and will develop small-scale demonstration projects that can be replicated in other locations, such as remote mountain villages or island

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[6] ADB. 2008. *Report and Recommendation of the President to the Board of Directors: Proposed Loans, Asian Development Fund Grant, Technical Assistance Grant, and Administration of Grant to the Kingdom of Bhutan for the Green Power Development Project*. Manila.

[7] The study recognizes that the treatment and comparison households are not the perfect match due to the radial approach taken during electrification, under which households closer to the radius from the substations were covered first. However, this was the best possible option to find counterfactual due to data limitations.

[8] ADB. 2000. *Energy 2000: Review of the Energy Policy of the Asian Development Bank*. Manila.

communities. Such projects will be packaged into larger, more bankable projects and, if feasible, be added to main energy sector projects as a special energy access component. ADB is also emphasizing energy security and facilitating transitions to low-carbon economies.

B. Rural Electrification Operations

8. From 1969 to 2009, ADB provided $29.02 billion in assistance to the region's energy sector, of which nearly 78% occurred from 1989 to 2009. Investment surged from $4.76 billion during 1980–1989 to $11.51 billion during 1990–1999 (Appendix 1, Table A1.1). From 1989 to 2009, the ADB RE portfolio reached $3.16 billion, or about 14% of the total assistance to the energy sector ($22.62 billion) for the same period. Appendix 1 (Table A1.2–A.1.6) provides a list of ADB RE projects approved from 1979 to 2009 by source of funding. Loans were mostly intended for power supply development as well as transmission and distribution network expansion, while technical assistance (TA) was for the preparation of feasibility studies and capacity enhancement. Grants were used mainly to pilot new approaches in pursuing off-grid electrification, introducing financing modalities, and building local capacities. Additional background data and explanations on ADB's RE portfolio are in Appendixes 2–4.

9. **Technical assistance.** ADB supported 50 TA projects for RE from 1989 to 2009, in the amount of $25.9 million, spread across 21 DMCs (Appendix 1, Table A1.4). Of these, 28 were classified as project preparatory, while 21 were advisory. In terms of size, Bhutan accounted for 16% or $4.2 million of the total TA for RE, followed by the People's Republic of China (12% or $3.2 million) and India (11% or $2.8 million).

10. **Grants.** ADB started extending projects financed through grants only in 2004 with the Renewable Energy and Livelihood Development Project for the Poor in Negros Occidental,[9] Philippines. The project was piloted using renewable energy sources for off-grid electrification of livelihood activities in remote areas. In total, 11 RE projects were funded by the Asian Development Fund (ADF), Japan Fund for Poverty Reduction, and Special Funds resources in the amount of $64.9 million (Appendix 1, Table A1.6). Five of these projects were approved during 2004–2006, while the rest were approved during 2007–2009. Seven DMCs were recipients of these grants: Afghanistan (one), Bhutan (two), Mongolia (one), Nepal (two), the Philippines (one), Sri Lanka (two), and Tajikistan (one). Bhutan received the biggest grant amount at $26.3 million for its Green Power Development Project,[10] which was intended to support the development of renewable energy for RE. About $25.4 million of the grant was sourced from ADF, while additional cofinancing of $1.0 million was made available by the Clean Energy Financing Partnership Facility to provide assistance in the off-grid application of renewable energy sources. With Bhutan's share, South Asia received 54.6% of total ADB grants.

C. ADB Rural Electrification Assistance in Bhutan

11. In 1995, only 20% of rural households in Bhutan were electrified.[11] ADB assistance to Bhutan for RE began with the approval of the $9.5 million RE project in the same year.[12] At the

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[9] ADB. 2003. *Report and Recommendation of the President to the Board of Directors: Proposed Grant Assistance to the Philippines for the Renewable Energy and Livelihood Development Project for the Poor in Negros Occidental*. Manila (Grant 9042-PHI, for $1.5 million, approved 3 August).

[10] ADB. 2008. *Report and Recommendation of the President to the Board of Directors: Proposed Loans, Asian Development Fund Grant, Technical Assistance Grant, and Administration of Grant to the Kingdom of Bhutan for the Green Power Development Project*. Manila.

[11] ADB. 2004. *Project Performance Audit Report: Rural Electrification Project in Bhutan*. Manila.

end of the project, ADB had financed $6.64 million of the $8.21 million actual project cost from ADF resources. The loan closed on 6 April 2000 with an 18-month delay, which was largely associated with less-than-adequate consideration of Bhutan's mountainous terrain in some aspects of technical design, procurement lags, malfunctioning of some transformers, incompatibility of some supplies ordered by the consultants, insufficient community labor, and transport delays due to heavy rains. The project provided electricity connections to 3,120 households, and distributed 567 electrification kits at a minimal charge. At the end of the project, RE in Bhutan increased to 24%.

12. ADB then approved a $9.8 million loan to finance the Sustainable Rural Electrification Project (SREP) (footnote 5) in 1999. Actual project cost was $11.6 million against the appraisal estimate of $12.5 million; ADB financed $9.0 million from ADF resources. The loan closed on 12 January 2006 with two extensions and a 22-month delay, largely associated with the supply of procured goods. According to the PCR,[13] the project provided electricity to 8,090 new rural consumers, 32% more than envisaged at appraisal. In addition, it provided off-grid electrification in the form of 100 solar panels to monasteries and other community institutions far from the existing grid.

13. ADB approved the $12.8 million Rural Electrification and Network Expansion Project (RENEP) (footnote 5) in 2003. The actual project cost amounted to $13.2 million, of which ADB financed $9.7 million. The loan closed on 19 December 2006, earlier than the expected 31 March 2007 stated at appraisal. The PCR[14] stated that the project provided access to electricity to 9,206 new consumers, 15% more than appraisal estimates.

14. In 2008, ADB approved the Green Power Development Project (footnote 6) with a focus on regional clean power trade and renewable energy access for the poor. The total project cost is estimated to be $234.45 million, of which ADB is to finance $51.00 million from ordinary capital resources, $29.00 million as a hard-term ADF loan, and $25.28 million as an ADF grant. The first two loans are to go toward the Dagachhu Hydropower Plant, and the last part to RE. Other development partners involved include the Asian Clean Energy Fund ($1.00 million for RE), Austria's export credit agency (Oesterreichische Kontrollbank, $55.46 million for the Dagachhu Hydropower Plant), Government of Bhutan ($45.01 million for the Dagachhu Hydropower Plant and $6.70 million for RE), and Tata Power ($21.00 million for the Dagachhu Hydropower Plant). The project is expected to electrify 8,767 households and facilities and provide 119 solar photovoltaic systems to schools, health clinics, monasteries, and other community facilities.

15. ADB has signaled its support for another project, which is expected to contribute to the government's goal to provide universal RE by 2013. Based on ADB estimates, RE projects will account for one-third through ADB assistance provided to Bhutan between 1995 to 2010. ADB's support for RE has contributed to economic growth, poverty reduction, and better quality of life for rural people. An overview of the projects' expected outcomes and findings is summarized in Appendix 5.

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[12] ADB. 1995. *Report and Recommendation of the President to the Board of Directors: Proposed Loan and Technical Assistance Grant to the Kingdom of Bhutan for the Rural Electrification Project* (Loan 1375-BHU, for $9.5 million, approved 24 October). Manila.

[13] ADB. 2007. *Completion Report: Sustainable Rural Electrification Project in Bhutan*. Manila.

[14] ADB. 2008. *Completion Report: Rural Electrification and Network Expansion Project in Bhutan*. Manila.

D. Other Development Partner Rural Electrification Assistance in Bhutan

16. The four other key players in Bhutan's RE subsector are the governments of Austria, India, Japan, and the Netherlands. Under the support of the Government of the Netherlands, SREP was implemented from 2003 to 2007 in six districts, and project savings were used to electrify households in the seventh district. About $6.4 million was provided for the project, and it covered 3,150 households.[15] Data provided by the Bhutan Power Corporation (BPC) suggest that 5,271 households were electrified with Government of the Netherlands funds, and another 2,053 households were electrified with Government of Austria funds. In addition, under an energy and poverty initiative, the United Nations Development Programme has financed a community-based rural energy project, whose completion report was being prepared at the time of this impact evaluation study. Japan provided parallel financing to the Green Power Development Project. There is no verifiable data to suggest how many households were electrified with assistance from the Government of India, but it is assumed that it funded the electrification of first 20% of the households prior to ADB assistance for RE.

E. Future Plans for Expanding Rural Electrification Coverage in Bhutan

17. This study estimates that RE coverage in Bhutan in 2009 was at between 55% and 60% of total rural households. However, Bhutan is endeavoring to meet the national goal of universal electrification by 2013.[16] Toward this goal, JICA is supporting electrification of 15,272 households, and ADB will support electrification of an additional 8,759 households under the Green Power Development Project. Additional support has been sought from ADB, and a project preparatory TA team is already in the field. Further, to reach its objective, the government has pursued other funding sources, including more project support from ADB and JICA. According to the Department of Energy, financing arrangements have been made for 100% electrification by 2013.[17]

F. Performance Evaluation of Rural Electrification Projects in Bhutan

18. The Independent Evaluation Department of ADB separately completed a sector assistance program evaluation (SAPE) in 2010.[18] This study also reviewed the PCRs for both completed ADB RE projects, SREP and RENEP. The performance ratings summarized in paras. 20–27 were drawn from these reports. The projects were overall rated *successful* based on four key parameters.

19. **Relevance.** Overall, this impact evaluation study rates both projects *relevant*; they were rated *highly relevant* in the PCRs. Both projects incorporated a number of lessons from the preceding project, the Rural Electrification Project. Adequate sector analysis was also undertaken, and was instrumental in formulating accompanying TA to achieve the required power sector reforms to facilitate and sustain economic growth. TA also addressed some constraints to achieving intended results. Further, the projects were consistent with the government's long-term objective of 100% electrification of the country by 2013. The projects

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[15] Bhutan Environ and Engineering Services. 2009. *Project Evaluation of Rural Electrification Project (Sustainable Rural Electrification – Phase II)*. Final Report. Thimphu.

[16] Department of Energy. 2005. *Integrated Energy Master Plan 2005–2020*. Thimphu; and Gross National Happiness Commission. 2009. *Tenth Five Year Plan*. Royal Government of Bhutan: Thimphu. According to the Master Plan for Rural Electrification, the original goal was to provide electricity access to each household by 2020, but with the implementation of 10th Five-Year Plan, 2008–2013, the government brought forwards this goal and is committed to "electricity for all" by 2013.

[17] IED has been informed by the Department of Energy that funding arrangements are already in place.

[18] ADB. 2010. *Sector Assistance Program Evaluation: Energy Sector in Bhutan*. Manila.

and their corresponding designs were also in line with ADB's country strategy and program for Bhutan,[19] which aimed to reduce poverty in rural areas through electrification by creating opportunities for employment and local economic development, and improving access to better social services such as education and health. The projects were also consistent with the ADB country operations business plan[20] for Bhutan.

20. Based on project records, field mission visits, and results of this impact evaluation study, solid project designs contributed to the achievement of the stated outcomes. As such, both projects have remained *relevant* at the time of completion and evaluation. Government ownership and participation was evident in both of these projects, as demonstrated by its commitment, availability of resources and expertise, and willingness to undergo institutional and structural changes. However, one key lesson from the Rural Electrification Project—that the availability of RE may not be a sufficient condition for the poor to move from poor to nonpoor status[21]—remained unaddressed within or outside of the projects. RE projects aimed at poverty reduction needed to be accompanied by other efforts that increased poor's access to markets, skills, and seed capital.

21. **Effectiveness.** Both projects were rated *effective* based on (i) achievement of physical outputs (i.e., number of connections), (ii) lower connection costs, (iii) high degree of government commitment and ownership, (iv) effective coordination with development partners, (v) project savings resulting from much lower bids than anticipated at appraisal, and (vi) increased capacity of national staff and lower utilization of external consultants. According to the PCRs, the projects provided electricity connections to a total of 17,296 households, and the average connection costs per household in nominal terms were $1,454 in SREP and $1,447 in RENEP.

22. This impact evaluation study, while recognizing the projects' effectiveness in achieving outputs with lower unit costs and effective coordination with development partners also highlights some of the concerns noted in the PCRs. Under SREP, solar panels were installed in areas with grid connections, although they were intended for off-grid areas. The status of these panels and their use are unknown. Also, electrification kits were provided for free to poor households, but many were never installed. Similarly, under RENEP, damaged drop-out fuse assemblies and the low uptake of free house-wiring kits by vulnerable households were some of the concerns raised. One weakness of both projects was the absence of baseline and monitoring data to quantify outcomes of income generation and employment and quality of life improvements. For instance, the PCR validation report (PVR) for RENEP reported that the report and recommendation of the President failed to include poverty-related performance indicators to measure the second outcome of the project, which was to measure success in providing opportunities for the rural poor to increase their economic productivity.

23. Overall, the projects were effectively coordinated with other development partners—the governments of Austria, Japan and the Netherlands, and the United Nations Development Programme—in defining coverage and beneficiaries. Implementation approaches also remained uniform throughout, irrespective of funding source.

24. **Efficiency.** This impact evaluation study concurs with the PVRs that both projects were *efficient* based on valid assumptions employed in computing the economic internal rates of return. The economic analyses in both projects employed similar methodologies at appraisal

[19] ADB. 2005. *Country Strategy and Program: Bhutan, 2006–2010*. Manila.
[20] ADB. 2008. *Country Operations Business Plan: Bhutan, 2009–2011*. Manila.
[21] ADB. 2004. *Performance Audit Report: Rural Electrification Project in Bhutan*. Manila.

and at the PCR stage, although with revisions in some assumptions to reflect more accurate estimates. The PCR of RENEP, for instance, adjusted the (i) actual number of beneficiaries (9,026 from 8,000), (ii) monthly household electricity consumption (65 kilowatt-hours [kWh] from 90.5 kWh), (iii) domestic growth rate (6.0% against 2.5%), and (iv) willingness to pay (WTP) based on the unsubsidized current price of kerosene (Nu44.0 per liter against Nu14.6 per liter). The efficiency rating is also supported by the cost of connection being much lower than appraisal estimates.

25. SREP was extended by 21 months because of (i) the construction of substations to make system control and data acquisition functional, and the inability of the system control and data acquisition supplier to deliver the equipment on schedule; and (ii) initial challenges regarding international bidding and shopping packages in the other components. RENEP was completed on time.

26. **Sustainability.** This study concurs with both PCR and PVR ratings of both projects as *likely to be sustainable*. A detailed discussion on sustainability is presented in Chapter V.

27. **Impact.** The project performance audit report on first ADB RE project in Bhutan concluded that the evidence was sketchy regarding the link between RE and reducing income poverty. Further, the PVR of SREP reiterated the PCR statement that insufficient project-specific data were available to assess the impact of the project on beneficiaries. A sample survey conducted by the PCR mission suggested that the project impact varied widely, depending on the location and beneficiaries. It was found that households used electricity primarily for lighting, and half also used it for cooking (primarily rice). Use of other appliances such as water boilers, refrigerators, televisions, and frying pans or curry cookers was less common. Similarly, the PVR for RENEP noted that the PCR failed to assess the achievement of two impact performance indicators: (i) increased income in rural areas, and (ii) improved education and health facilities through electrification. The lack of objective data did not permit the PCR mission to assess social and environmental impacts.

28. The PVR for SREP noted that project impacts were rated *substantial* due to (i) no negative environmental impacts, (ii) substantial benefits achieved based on a household survey, and (iii) benefits exceeding appraisal targets. The PVR for RENEP, on the other hand, noted that project impact was *modest,* based on no negative social and environmental impacts. However, extending distribution lines through dense forests to achieve higher electrification coverage may have had some negative environmental impact. This issue has not been substantiated and may require the attention of the National Environmental Commission and a separate robust analysis.

29. The impacts identified in the PCRs of the two case study projects did not quantify impacts due to lack of data, but contained general statements on perceived impacts such as improved quality of life based on increased use of various electrical appliances and better indoor air quality. The PCR for SREP stated that there is a link between electricity consumption and poverty reduction but no empirical evidence was presented. [22] In this study, a detailed impact evaluation of the projects based on a more rigorous method is presented in Chapters III and IV.

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[22] ADB. 2002. *Completion Report: Rural Electrification Project*. Manila; ADB. 2007. *Completion Report: Sustainable Rural Electrification Project*. Manila; ADB. 2008. *Completion Report: Rural Electrification and Network Expansion Project*. Manila.

III. METHODOLOGY AND DATA FOR IMPACT EVALUATION

A. Conceptual Framework

30. This impact evaluation study evaluated the impact of the SREP and RENEP on quality of life, defined in terms of economic, social, and environmental opportunities, based on a more rigorous exercise using both qualitative and quantitative data. Causal models are needed to link access to electricity with desired outcomes such as improved household health, education, income and/or energy cost saving. Based on literature reviews (Appendix 6), focus group discussions (FGDs) and key informant interviews in Bhutan, a conceptual framework demonstrating causal models were developed (Appendix 7). The IE study focused on the impact of RE in three broad areas: (i) economic, (ii) environmental, and (iii) social. Elements of each impact area are listed in the table.

31. The model envisaged that electricity access increases household income, reduces expenditure on traditional energy sources such as kerosene and fuelwood (i.e., economic impact), and improves creditworthiness. Since RE was also expected to lower consumption of fuelwood, it improves indoor air quality (i.e., environmental impact). Regarding educational impacts, RE should increase study time at home for children due to better lighting, improving their school performance. With better lighting as a result of electrification, lower incidences of crime and reduced crop damage by wild animals were also expected. Finally, the model anticipated that RE has a positive impact on gender empowerment by balancing gender roles and control over financial resources (i.e. social impact).

32. Besides the project inputs, which is access to electricity, nonproject factors, such as, individual (i.e., age, gender, religion, and education), household (i.e., wealth indicators), and village-level (i.e., location of schools and hospitals, distance from motorable road; size and population of the village; and distance from the district headquarter were included in the analysis). The data collection and analysis was based on the project outcomes and impacts illustrated in the logic model (Appendix 7). However, the study could not collect data on some of the variables, therefore, an analysis of a few of the impacts were not undertaken in the current study. Of all the project outcomes, data were not available for technical data on improved air quality, financial position of implementing agency, and quality of graduates, and hence these outcomes were not analyzed in the study.

B. Impact Evaluation Method

33. The challenge of most impact evaluation studies is to overcome possible selection bias. Compared to other infrastructure projects, electrification suffers from two sources of bias: endogeneity of program placement and household adoption of electricity. Furthermore, frequent power outages make evaluation more problematic. When the selection criteria are observable, then a regression-based approach can overcome selection bias. In the case of electrification, selection is clearly based on observables, most notably income and location. Since electrification rollout in Bhutan was phased in and adopted a radial approach around power substations, regression estimates can address causality issues if observables are adequately controlled.

34. A popular alternative to a regression-based approach in evaluation literature is matching methods. Thus, to supplement the regression analysis, matching is used because of its ability to reduce sensitivity to parametric assumptions and to employ common support (i.e., reducing the impact of outliers), thus minimizing bias in the results. It is important to note that matching is

done on the basis of observable characteristics. For this impact evaluation study, propensity score matching (PSM) technique was adopted. Propensity scores were estimated for electrified households by a logit model that potentially affected the outcomes of interest.[23] Household-level fixed characteristics, such as age, gender, marital status, religion, education of the household head, land ownership, household size, ownership of livestock, type of house, and main source of drinking water, were used as the control variables. In addition, a few village-level variables such as distance to district headquarters, area and population of the village, and availability of educational infrastructure, were also used to estimate the propensity score. In this study, both household- and village-level variables were used to match the households.[24]

C. Sampling Design and Data Collection Instruments

35. A mix of purposive and probability sampling approaches were used to design the sampling frame. Villages and/or households that were electrified under the two ADB projects constituted the sample for treatment, and villages that are going to be electrified through assistance from ADB and JICA constituted the counterfactual or comparison areas.

36. Of 20 *dzonkhags* (districts),[25] ADB RE assistance has been extended to 15, of which 10[26] were selected to achieve a geographically diverse study sample.[27] In these 10, the sampling frame consisted of 198 electrified and 277 unelectrified villages. There were 11,690 households in total, comprising 6,316 in electrified villages and 5,374 in unelectrified villages. Furthermore, the number of sampled villages in each dzonkhag was drawn in proportion to its relative share in the total number of electrified and unelectrified villages. In all, 2,098 households (1,276 electrified and 822 unelectrified) were interviewed for the study.

37. Both quantitative and qualitative data were collected. Quantitative data were collected by administering village and household surveys. The household questionnaire collected information on various indicators pertaining to benefits of electricity; a broader village questionnaire was also administered to the *gup* (head of the village). All questionnaires were in English, but the enumerators were bilingual (English and region-specific local languages). The questionnaires' contents, survey administration, data quality assurance and estimation methods are discussed in detail in Appendix 7. Qualitative data were collected by conducting FGDs in each *dzonkhag.*

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[23] The logistic model was estimated because the outcome variable (whether household has electricity or not) is a discrete choice and is coded as one (T) or zero (C).

[24] A crucial consideration in the matching method is whether pre- or post-intervention characteristics should be used for matching. In the presence of baseline data, matching using baseline characteristics is considered superior, but all studies do not have this luxury. Matching should not be done using endogenous variables (i.e., variables that change due to a project), and only time-invariant characteristics should be used for post-treatment matching purposes. In the absence of a baseline survey, this study resorted to matching based on post-treatment variables such as household- and village-level fixed characteristics for matching electrified households with unelectrified households. Furthermore, there is also an issue regarding the level of matching, whether matching should be done at village- or household-level. In the presence of heterogeneity within the village, most studies prefer matching at the household level rather than at the village level.

[25] Bhutan is divided into four *dzongdey* (administrative zones). Each *dzongdey* is further divided into *dzongkhag* (districts). There are 20 *dzongkhags* in Bhutan.

[26] Bumthang, Chukha, Dagana, Lhuntse, Punakha, Samtse, Sarpang, Trashigang, Trongsa, and Wangdue Phodrang.

[27] Of 20 *dzonkhags*, 5 *dzonkhag* (Gasa, Haa, Samdrup Jonkhar, Tsirang, and Zhemgang) do not have any villages electrified under ADB rural electrification II and rural electrification III projects and so they were removed from the sampling frame. Moreover, four (Gasa, Haa, Tsirang, and Zhemgang) of these five districts will not be electrified under rural electrification IV or the JICA program.

IV. IMPACT EVALUATION RESULTS AND DISCUSSION

38. The impacts of RE were evaluated using selected quality-of-life indicators that were analyzed in three different ways: comparison of means, regression, and PSM. A simple difference-in-means, however, does not establish the causality and, hence, recognizing this limitation of difference-in-means the study also conducted multivariate analysis adequately controlling for factors other than the electricity. Depending on the properties of the outcome variable, either a linear or nonlinear regression approach was adopted.[28] Due to superiority of results based on matching, the differences in means are not discussed in this chapter but are presented in Appendix 8, which also contains a description of profile of electrified and unelectrified survey households. The study first estimated the impact using regression (ordinary least squares [OLS] or logit and/or probit) method with household- and village-level covariates as the control variables. Then, the regression estimates were compared to kernel PSM estimates. The matched sample passed all three different balancing tests implying that matched comparison households were good counterfactuals for the treatment (electrified) households.[29] As PSM estimates are considered superior to regression estimates, the results are discussed emphasizing PSM, but regression results are also presented for comparison purposes.

39. A number of household and village-level variables which were believed to be potentially affecting the outcomes were included in the model. First, a model with household-level variables that captured different aspects of household wealth and socioeconomic conditions was specified, and then some village-level variables were added to capture the effect of village-level variables on the outcomes. The household-level control variables used in model specification included (i) human capital assets—household size, age of the head of the household, whether head of household is literate, number of literates in the house, gender of the head of household, marital status of the head of household, and religion of the head of household; and (ii) physical assets—household's holdings of land, main source of drinking water, type of house, whether household owns cows, bulls, poultry, and horse. Similarly, village-level control variables comprised: the level of isolation of the village, as measured by the distance from the village to district headquarter (the seat of local government), size of the village measured by the area of the village, population of the village, time taken to nearest road, and availability of educational infrastructure in the village (primary school).[30] Full estimation results are presented in Appendix 9.

A. Economic

40. **Household income.** The study analyzed the impact of RE on household income using log-income as the dependent variable. Income variables expressed in log-form were used to make the distribution normal (Table 1).[31] Both the OLS regression and PSM estimates indicate that electrified households have a higher average incremental income than unelectrified households, but the incremental differences are statistically significant only for nonfarm income.

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[28] Probit estimation model was applied for outcomes that were binary (incidence of cough, eye irritation, etc.) and an ordinary least squares model was applied to outcomes that were continuous.

[29] Smith, J., and P. Todd. 2005. Does Matching Overcome LaLOnde's Critique of Nonexperimental Estimators? *Journal of Econometrics..Volume 125 (n1-2)*: pages 305–353.

[30] Alternative specifications of logit model were examined and in the final analysis, only variables that satisfied the balancing properties were included.

[31] Income distributions are generally not normal because of outliers, so log-form is used. While conducting the log-income analysis, many observations dropped out either because of missing values or zero values. Literature suggests either dropping the observations with zero income or assigning a small amount of income to them so that logarithms can be taken legitimately. Instead of dropping the observations, the study imputed the zero value of income with two to get a positive value of log-income.

Electrification increases nonfarm income by 50% (OLS estimate) to 72% (PSM estimate). However, nonfarm income accounts for only 29% of total household income in electrified and 21% in unelectrified households; hence, the impact is considered modest rather than large.

41. The study recognized that income disparity preexisted between the two groups of households because of other factors, including level of modernization, proximity to employment centers, and other economic opportunities. Survey data show that about 25% of electrified households are involved in weaving, and about 20% of them use electricity for this activity. Interestingly, during FGDs, many participants claimed that their income from weaving had more than doubled after they received electricity, and electrification had increased their income potential by facilitating microenterprise undertakings. Many participants also reported that increased nonfarm income could be associated with other microenterprise activities, in addition to weaving. Increased poultry production in Bhutan's southern districts was also cited as an example. In addition, the participants reported that many household members had acquired off-farm employment, and some felt a reduced burden in collecting fuelwood from the forests.

Table 1: Impact on Total, Farm, and Off-Farm Log-Income of Households

Annual Log Farm Income (Nu)	**Annual Log Total Income** (Nu)	**Annual Log Farm Income** (Nu)	**Annual Log Nonfarm Income** (Nu)
A. Ordinary Least Squares Regression Estimates			
Electrified	0.13	0.20	0.50[b]
t-statistics [a]	0.76	1.08	2.76
B. Kernel Propensity Score Matching Estimates			
Electrified	0.25	0.21	0.72[b]
t-statistics a	1.42	1.01	3.75

Notes: [a] t-statistics refers to Student's t-values for corresponding regression coefficient.
[b] p<.01 indicates that the coefficient is statistically significant at 1% level.
Source: Analysis of survey data.

42. However, data analysis reflecting the impact of RE on microenterprise activities did not provide any consistent results, suggesting that there are no significant differences between electrified and unelectrified households. Higher nonfarm income may be due to a larger scale of operations in electrified households, which was corroborated from the field observations during the survey and FGDs. Additionally, survey data reveal that a majority of both electrified and unelectrified households plan to use electricity for their future microenterprise activity after electrification. Electricity has not yet played any major role in increasing cropping income, with the exception of processing dairy products, particularly in the late hours of the day.

43. Another piece of qualitative information indicates that RE does result in higher incremental nonfarm income. About 70% of electrified households reported that income has increased because of electrification, 56% of them said that household income has grown because of higher nonfarm income, and about 44% said it is because of increased farm income. Furthermore, jobs outside of the households are better in electrified (5.1 months per year) than unelectrified (4.4 months per year) villages. Slightly more than 2% of electrified households also earn money from renting their rooms, while unelectrified households do not have such opportunities. Most of the tenants are government and field extension personnel posted in rural areas.

44. There is a consensus that electrification enhances opportunities for nonfarm income-generating activities. Some of the emerging opportunities observed were restaurants, bars, and

small shops that stay open late. In addition, there is future potential for cheese, butter, and meat storage in refrigerators and freezers, as well as weaving, carpentry, tailoring, carving, and sculpting. FGD participants also said that electricity is cheaper than other energy sources, including kerosene. Other benefits reported include savings from reduced laundry, need for whitewashing house, removing smoke shoots, and frequent washing of clothes. They said electricity also deters wild animals from damaging crops, reducing crop losses.

45. Overall, results are consistent with another study[32] in Bangladesh, as it also found a positive impact of RE on income, though the size of the effect is bigger in Bangladesh. Given the indirect benefits of electrification on income, the study in Bangladesh and another in Viet Nam[33] also could not pin down the mediating pathway that led to enhanced income.

46. **Fuelwood and kerosene consumption.** Previous studies have found decreased use of polluting sources of energy, such as fuelwood, kerosene, and candles, with the advent of rural electricity. Many hypothesized that the reliance on these sources falls once the households and/or villages[34] are electrified.

47. Results from this study indicate that 91% of electrified households and 96% of unelectrified households use fuelwood domestically for cooking and heating and that the difference due to electrification is statistically significant. Less than 3% of households reported the use of fuelwood for business purposes. Furthermore, there are no significant differences between electrified and unelectrified households in the use of other energy sources such as animal dung, candles, pine shavings, diesel, and dry-cell batteries either for domestic purposes or for business purposes.

48. There is a statistically significant difference between electrified and unelectrified households in kerosene use for domestic purposes (e.g., lighting and cooking). Compared to 95.21% of unelectrified households, only 42.17% of electrified households reported using kerosene for domestic purposes. According to FGD participants, differences in costs between electricity and kerosene are difficult to establish at the household level, although it is generally believed that electricity on an hour-use basis costs less than half that of kerosene. The World Bank IEG report (footnote 3) stated that moving from kerosene to electricity cut the power cost by more than one-tenth and increased consumption more than tenfold. The IEG report also suggested that a measure of light emitted (i.e., a lumen) is much higher from an electric source. For example, a candle emits about 12 lumens; a kerosene lamp, 30–80 lumens; and a 60-watt lightbulb, 730 lumens.

49. Table 2 shows the impact obtained from the OLS as well as PSM methods. The OLS coefficients suggest that the amount of fuelwood and kerosene used for domestic purposes decreases significantly in electrified villages. An average electrified household is likely to use about 583 kilograms less fuelwood and 35 liters less kerosene per year compared to an unelectrified household. PSM results are similar, suggesting that electrification has a negative impact on the annual consumption of fuelwood and kerosene. In addition, the results show that electricity reduced annual expenditure on fuelwood and kerosene, but the impacts are

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[32] S. Khandker et. al. 2009. Welfare Impacts of Rural Electrification: A Case Study from Bangladesh. *Policy Research Working Paper No. 4859*. Washington, DC: World Bank.

[33] S. Khandker et. al. 2009. Welfare Impacts of Rural Electrification: Evidence from Viet Nam. *Policy Research Working Paper No. 5057*. Washington, DC: World Bank.

[34] "Households" and "villages" are used interchangeably throughout the report, because all of the households in electrified villages are electrified. In other words, there is no selection at the household level.

statistically insignificant for fuelwood expenditure and significant for kerosene expenditure.[35] One possible reason could be that most rural households in Bhutan collect fuelwood from the forest, and transactions in the fuelwood market are informal and infrequent, thereby making the information about expenditure less reliable.

Table 2: Impact of Rural Electrification on the Use of Polluting Fuels

	Fuelwood Use (kilogram/year)	**Kerosene Use** (liter/year)
A. Ordinary Least Squares Regression Estimates		
Electrified	(582.98)[a]	(35.14)[a]
t-statistics	6.92	17.77
B. Kernel Propensity Score Matching Estimates		
Electrified	(527.41)[a]	(33.01)[a]
t-statistics	4.51	15.60

() = negative.
Note: [a] $p < 0.01$ indicates that the coefficient is statistically significant at 1% level.
Source: Analysis of survey data.

B. Health

50. The study examined the effect of RE on health risks that are associated with the exposure to smoke and pollutants, such as cough, respiratory ailments, eye irritation, and headache. The survey collected subjective data on the occurrence of these health risks; no objective data were collected or available. Another outcome that was examined is the number of workdays lost due to sickness. However, there can be many causes for illnesses, and it is difficult to know if they were caused by the use of fuelwood. The study recognized these limitations.

51. Results are reported in Table 3, and estimates suggest that RE improves health conditions and reduces the occurrence of health incidences that are associated with the use of fuelwood and other polluting sources of energy such as kerosene and candles. In addition, health workers were able to relocate themselves in the electrified villages or spend night there for their service delivery. The results from probit analysis suggest that the incidence of cough, respiratory problems, eye irritation, and headache are lower in electrified households than in unelectrified households; all estimates are significant at a 5% level of significance. The impacts vary from 2.1 percentage points to 13.4 percentage points. RE has the greatest impact on the incidence of eye irritation, as electrified households were 13.4 percentage points less likely to have suffered from eye irritation. PSM results corroborate these findings and show that the incidence of these health risks is lower in electrified households. Further, individuals in electrified households are less likely to have missed work because of illness. The result is statistically significant ($p<0.1$); however, PSM results are found to be negative and statistically insignificant.

[35] Results are not shown here, but are available upon request.

Table 3: Impact of Electrification on Health-Associated Risks

	Cough	Respiratory Ailments	Eye Irritation	Headache	Number of Workdays Missed
A. Probit Regression Estimates					
Electrified[a]	-0.021[d]	-0.054[d]	-0.134[e]	-0.038[d]	-0.952[c]
p-values	0.014	0.02	0.000	0.016	1.97
B. Kernel Propensity Score Matching Estimates					
Electrified[b]	-0.028[d]	-0.056[d]	-0.135[e]	-0.042[d]	-0.72
t-statistics	2.39	2.36	5.52	2.53	1.38

Notes: [a] Outcomes being a binary variable were estimated using a probit model, and marginal effects are reported.
[b] Average treatment effect on treated is reported.
[c] $p < 0.1$ indicates that the coefficient is statistically significant at 10% level.
[d] $p < 0.05$ indicates that the coefficient is statistically significant at 5% level.
[e] $p < 0.01$ indicates that the coefficient is statistically significant at 1% level.
Source: Analysis of survey data.

52. Recognizing that these adverse health risks may be due to several other reasons besides burning fuelwood, the survey also collected data on whether these incidences of health risks are due to smoke.[36] Results in Table 4 show that, with the exception of respiratory ailments, electrified households have lower incidences of adverse health caused by smoke. This result holds in both type of estimation (probit and PSM), but the magnitude of impacts from PSM is smaller than impacts estimated from probit. The insignificant result of the incidence of respiratory ailments is surprising and is in contrast to earlier findings in the literature (Appendix 6).

Table 4: Impact of Electrification on Smoke-Associated Health Risks

	Cough	Respiratory Ailments	Eye Irritation	Headache
A. Probit Regression Estimates				
Electrified[a]	(0.130)[c]	(0.011)	(0.155)[c]	(0.027)[c]
p-values	0.000	0.760	0.000	0.000
B. Kernel Propensity Score Matching Estimates				
Electrified[b]	(0.1190)[c]	(0.0002)	(0.1290)[c]	(0.0890)[c]
t-statistics	5.56	0.01	3.71	4.68

() = negative.
Notes: [a] Outcomes being a binary variable were estimated using a probit model, and marginal effects are reported.
[b] Average treatment effect on treated is reported.
[c] $p < 0.01$ indicates that the coefficient is statistically significant at less than 1% level..
Source: Analysis of survey data.

53. During FGDs with unelectrified households, the participants, including the elderly, stated that smoke emitted from fuelwood stoves and kerosene wick lamps caused respiratory and eye ailments, especially during winters when moisture levels and temperatures are low. They also said that the constant indoor smoke and the noxious odor of kerosene give them regular headaches, and that the provision of electricity would greatly reduce such ailments.

54. Despite improvements in physical facilities due to electrification, the use of health clinics for labor pregnancy and child delivery has not increased. This is largely associated with (i) traditional beliefs that home delivery is safe, and (ii) lack of a road network and transport services for rural residents. They said electricity facilitates better child delivery at home by improving visibility during dark hours. In addition, electrification leads to fewer health ailments.

[36] The implicit assumption is that respondents have perfect knowledge about the causes of these health risks.

Furthermore, there was a common understanding that indoor smoke had been an obstacle to maintaining clean and hygienic houses before electrification, similar to problems encountered by unelectrified households at present. Children also suffer less from skin rashes and scabies. Health and hygiene education on television in electrified households helped them become aware of the necessity of hand washing before eating and prevention measures against stomach ailments, HIV/AIDS, avian influenza, H1N1, and malaria.

C. Education

55. Electrification impacts on educational outcomes were analyzed by examining three measures of schooling: literacy, years of completed schooling, and children's study time at home. For the first two outcomes, the analysis was done separately for both sexes to examine the heterogeneous impact of electrification.

56. Marginal effect estimates indicate that the literacy rate is higher in electrified households, and a disaggregated analysis of impact on literacy reveals that only girls benefit from RE. It is difficult to compare this result with earlier findings, since no previous study estimated the impact of RE on literacy; most previous studies only looked at school enrollment and years of completed schooling as educational outcomes (footnotes 32 and 33). The effect on literacy is not significant in the PSM estimates, although the impact is positive. This may be due to the contribution of other confounding factors, such as access to schools, but not necessarily electrification. Children from unelectrified households must walk much longer to get to school (107 minutes) than those from electrified households (52 minutes), which may contribute to differences in literacy rates. This also implies that unelectrified households were located in relatively more remote locations than the electrified households.

57. The findings on years of completed schooling suggest that RE has a positive, statistically significant impact. Yet in the OLS estimation, the impact is significant only for girls (Table 5), and the PSM estimates show a similar effect. This implies that children in electrified households complete more years of schooling than those in unelectrified households, and that impacts are significant for both boys and girls. However, girls still benefit relatively more than the boys, as RE contributes to 0.65 years of additional schooling for girls and 0.41 years for boys. The impact on boys' schooling is higher (0.67 years) than the estimates reported in an earlier Viet Nam study.[37] Table 5 also shows that children's study time increases by about 25% in electrified households. This result is similar to the finding reported in the Bangladesh study (footnote 32).

58. Overall, the study indicates that RE has a positive impact on educational outcomes, and both regression and PSM estimates are consistent in the direction of impacts.[38] This may be explained by the fact that teachers preferred to stay in electrified villages because they did not need to commute daily from their original residences. This finding is supported by increase rental accommodation in electrified villages. However, RE impact on education is perceived to be only modest, as most village schools are run only during the day. According to the Ministry of Education, electricity has had positive benefits for schools, but benefits have not been quantified. According to them, RE benefits seem to be more visible at post-primary compared to primary level.

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[37] In the simple double-difference model, the study in Viet Nam found that girls' years of schooling increased by 0.386 grades. See footnote 33.

[38] OLS estimation of educational impacts includes total income and availability of educational infrastructure in the village.

Table 5: Impact of Rural Electrification on Education

	Literacy of 5–18 Year-Olds			Years of Completed Schooling			Study Time (minutes/day)
	All	Boys	Girls	All	Boys	Girls	
A. Probit or Ordinary Least Squares Regression Estimates							
Electrified	0.032[c]	0.03	0.046[c]	0.41[e]	0.28[c]	0.56[e]	10.7[e]
p-values/ t-statistics	0.09	0.25	0.086	3.88	1.84	3.78	2.92
B. Kernel Propensity Score Matching Estimates							
Electrified	0.022	0.018	0.025	0.52[e]	0.41[d]	0.64[e]	9.40[e]
t-statistics	1.07	0.62	0.86	4.33	2.47	3.77	2.75

Notes: Regression includes additional control of total income and presence of schooling infrastructure in the village. Literacy was a binary and years of completed schooling and study time were continuous variables and hence OLS and probit estimation methods were employed, respectively.

[a] The model was estimated by the probit method, and reported coefficients are marginal effects.

[b] The ordinary least square method was used.

[c] $p < 0.1$ indicates that the coefficient is statistically significant at 10% level.

[d] $p < 0.05$ indicates that the coefficient is statistically significant at 5% level.

[e] $p < 0.01$ indicates that the coefficient is statistically significant at 1% level.

Source: Analysis of survey data.

59. The impact of television as a medium of news and information cannot be overstated. An overwhelming 86.8% of electrified households, and nearly 70% of unelectrified households, agree that television is a good source of news and information. This was further corroborated during FGDs and interviews. However, nearly 50% of FGD participants also stated that television had negative impact on children's lives, particularly exposure to unwanted entertainment and temptations, and promotion of young residents migrating to urban areas.

60. The participants believed that electrification contributes to improved education for children, as they are able to travel to and from school safely and complete their homework on time, even at night under electric bulbs. They stated that children from poorer families benefit most from electricity, as they had previously not been allowed to study under kerosene lamps because of prohibitive costs to the households. More importantly, communities are able to recruit and retain better-qualified, experienced teachers in electrified villages compared to unelectrified ones. Further, teachers are happy to stay in electrified villages and can also prepare their teaching lesson plans at night.

D. Time Savings

61. The survey collected information on time spent on fuelwood collection, and results are presented in Table 6 with details provided in Appendix 8. Conceptually, RE is expected to reduce time spent on fuelwood collection, because its requirement in the household is less after electrification. Similarly, the time spent on fuelwood collection—involving cutting, transporting, and racking the fuelwood stocks—also decreases after electrification. Overall, 70% of electrified and 74% of unelectrified households stated that they must walk farther now than before to collect fuelwood partly due to government restriction and partly due to less availability in the nearby surroundings.

62. OLS and PSM estimates both show that the difference between the time taken by electrified and unelectrified households for fuelwood collection is statistically significant, and RE reduces time spent on fuelwood collection (Table 6). Electrified households save about

0.59 hours, or 35 minutes per round trip, on fuelwood collection activities.[39] Time-saving estimates are slightly lower in the PSM results (29 minutes).

63. The overall impact of RE on time spent on fuelwood collection masks the heterogeneous effect on gender. Literature suggests that women benefit more than men from RE because they bear the largest burden of fuelwood collection.[40] The study finds that, while the impact of RE on reducing fuelwood collection times is significant for both sexes, a disaggregated analysis demonstrates that women benefit more than men. For women, the reduction in time spent on fuelwood collection is 34% higher (27.6 minutes for women, and 21.6 minutes for men),

Table 6: Impact of Electrification on Time Spent on Fuelwood Collection by Gender

	All	Men	Women
A. Ordinary Least Squares Regression Estimates			
Electrified	(0.59)[a]	(0.258)[a]	(0.34)[a]
t-statistics	5.47	4.04	5.38
B. Kernel Propensity Score Matching Estimates			
Electrified	(0.48)[a]	(0.206)[a]	(0.276)[a]
t-statistics	4.07	2.96	3.98

() = negative.
Notes: Outcome is number of hours spent in collecting fuelwood yesterday. Analysis does not include children and only includes hours spent by household head and his or her spouse.
[a] $p < 0.01$ indicates that the coefficient is statistically significant at 1% level.
Source: Analysis of survey data.

64. Rural households tend to collect a significant proportion of their fuelwood during the winter, as farm work is not necessary during that time of year. In addition, winter is more conducive to fuelwood collection because of the dry weather, which facilitates travel to and from the forests. Survey data suggest that compared to summer, fuelwood consumption in winter, on average, tends to be about 42% higher in unelectrified and 48% higher in electrified households.[41] Electrified households tend to consume more fuelwood, which is contrary to expectations. This may be associated with greater use of fuelwood-based house heating systems that emit smoke through chimneys (*bukhari*). In winter, *bukharis* are used for cooking as well. However, only 22% of electrified and 18% of unelectrified households have *bukharis*. Thus, most households practice traditional methods of heating (i.e., burning fuelwood inside living areas) to cope during winters. In addition, not all households have good ventilations, and as a result, smoke tends to spread indoors, leading to health ailments.

[39] Amount of time saved is per round trip per day.
[40] Bardasi, E., and Q. Wodon. 2006. Poverty Reduction from Full Employment: A Time Use Approach. *MPRA Paper 11084*. University Library of Munich. Germany; Charmes, J. 2006. A review of empirical evidence on time use in Africa UN-sponsored surveys. In C.M. Blackden and Q. Wodon (eds.). Gender, Time Use and Poverty in Sub-Saharan Africa. *Working Paper No. 73*. World Bank: Washington, DC; GSS. 2000. Canada's General Social Survey on Time Use: Challenges and Potential. *General Social Survey on Time Use: Cycle 19*. Statistics Canada: Ottawa; Nathan, D. and G. Kelkar. 1997. Wood Energy: The Role of Women's Unvalued Labour. *Gender, Technology and Development, 1 (2)*. Sage Publications: New Delhi; Parikh, J. and V. Laxmi. 2000. Biofuels, pollution and health linkages: A Survey of Rural Tamilnadu. *Economic and Political Weekly XXXV (2000) (47)*; Blackden, M. and Q. Wodon. 2006. Gender, Time Use, and Poverty: Introduction. *MPRA Paper 11080*. University Library of Munich: Germany.
[41] One bundle of fuelwood lasts for 2.96 days in the summer and 2.09 days in the winter in unelectrified households, and for 2.48 days in the summer and 1.68 days in the winter for electrified households.

E. Gender Empowerment

65. Literature shows that RE also helps to improve women’s socioeconomic status. With electricity, women spend less time collecting fuelwood. Time saved is used to generate income and participate more actively in decision-making processes and other community and social activities. Electricity also has a considerable impact on women’s mobility, freedom in using income and savings, utilization of credit, knowledge about gender inequality issues, household work plans according to convenience, changes in attitude in terms of reducing health care disparities, and years of schooling.[42]

66. The survey contained several measures for women's empowerment.[43] Results on women's empowerment are presented in Table 7. The study finds a significant improvement in women's decision making on issues related to health care and education but not regarding finances. Both OLS and PSM estimates show that the index related to education and health decisions improved by 0.05 (5%) with electrification, and both estimates are statistically significant. The impact is statistically insignificant with respect to finances, which is not surprising as the decisions pertaining to investment, expenditure, and income-generating activities are dominated by males.

Table 7: Impact of Rural Electrification on Women's Empowerment

	Education and Health Index	Financial Decisions Index
A. Ordinary Least Squares Regression Estimates		
Electrified	0.045[a]	0.001
t-statistics	3.10	0.10
B. Kernel Propensity Score Matching Estimates		
Electrified	0.049[a]	0.006
t-statistics	2.87	0.37

Note: [a] $p < 0.01$ indicates that the coefficient is statistically significant at 1% level of significance.
Source: Analysis of survey data.

67. Gender roles tend to be dictated by traditional practices under which females oversee child care, cooking, laundry, cleaning, and purchasing daily necessities; while males are more involved in dash disbursement and management, visiting government offices, and attending local meetings. Furthermore, females dominate decisions pertaining to fuelwood collection, children’s education, family planning, income-generating activities, investment in productive activities, visiting friends and relatives outside of the village, visiting government offices, savings, and having bank accounts. No significant differences are observed between the electrified and unelectrified households.

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[42] A. Barkat et al. 2002. *Economic and Social Impact Evaluation Study of the Rural Electrification Program in Bangladesh.* Arlington, VA: Human Development Research Centre and National. Rural Electric Cooperative Association International.

[43] To measure women's empowerment, households were asked who makes decisions related to education, health care, investment, income-generating activities, household expenditure, and household savings. The possible categorical responses included male, female, both male and female, and do not know or cannot say. Female respondents were also asked whether they needed permission from their husbands to visit (i) the market, and (ii) friends or relatives. The responses for permission measures were coded on a scale of 1 to 4 (i.e., do not need permission, need permission, need to only inform, and not permitted at all). For this analysis, the women's empowerment indexes were created as follows. First, for the decision-making variables, responses were condensed to binary indicators for whether the woman participates in the decision (either decides on her own or decides jointly with her husband). Then, the empowerment index was created by taking the simple average of the responses for each decision-making question. By this method, a single measure of empowerment was generated, ranging from zero to one. A higher value of the index indicates greater women's autonomy.

68. The FGD participants expressed that access to electricity empowers women through health, education, gender equality, and domestic violence awareness programs on television. Thus, women are becoming more assertive and confident. Further, on average, women save 1.5 hours every day in cooking, which enables them to attend village meetings and voice their concerns. Although Bhutanese women enjoy equal status and the same rights as men—and, in fact, inheritance and child support laws favor women—many are required to get permission from males to visit markets and friends or relatives. More than 93% of the respondents also believe that girls and boys should be treated equally; hence, no strong sex preference of children was reported.

F. Fertility

69. Electricity is considered to reduce fertility resulting from longer waking hours due to more light in the night and enabling household members to be involved in household chores and some income generating activities. This contributes to reduced reproductive activities. Exposure to television may also affect fertility indirectly through increased knowledge about health programs and family planning. The World Bank IEG study (footnote 3) found that, of nine surveyed countries, electrification significantly reduced the total fertility rate[44] in eight, with effects ranging from a low of 0.04 children in Nicaragua to about 2.00 in Senegal.

70. About 98% of the households in this impact evaluation study were electrified after 2000.[45] The average number of years of electrification for survey households is 4. Before turning to fertility outcome, impact on ownership of television and other electronic media was analyzed, because improved health knowledge via television is an important channel of fertility reduction. As shown in Appendix 8, ownership of televisions is mainly concentrated in electrified households (33.59% versus 1.64%), and radio ownership is concentrated in unelectrified households. About 65% of unelectrified households have radios, which can be operated by dry-cell batteries, compared to 55% of electrified households.[46] Difference-in-means estimates in Appendix 8 show that these differences are significant for both assets. However, to ascertain if electrification caused the increased ownership of televisions, the regression method is used to examine this (see Appendix 9 for the full estimation model). Results suggest that electrification has a significantly positive impact on television ownership and a negative impact on radio ownership. One possible explanation for this negative impact may be that after electrification, households switch to televisions, subject to affordability.

71. Four fertility measures were then used in the analysis: (i) number of children born in the last 5 years, (ii) number of children born in the last 3 years, (iii) a binary variable for having children within 5 years of the survey, and (iv) a binary variable for having children within 3 years of the survey.[47] The explanatory variables were similar to those used throughout this analysis.

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[44] Fertility outcomes were measured as total children born as a ratio to the total fertility rate for that age group of women, using 5-year age ranges starting at age 20.

[45] Five and 17 households were electrified in 1991 and 1992, respectively.

[46] Some televisions can be operated by vehicular batteries, but this is more expensive and uncommon. Solar energy can be another source of power. These may be some reasons why some households in unelectrified villages also own televisions.

[47] The survey did not collect comprehensive data related to women's pregnancy history; therefore, many mother-level variables that may affect fertility are not available (e.g., knowledge about contraceptives used, age of marriage, birth order, and gender of first child). The study uses variables available in a typical household survey to estimate the impact on fertility, which is not always the best way to estimate fertility effect. However, given the paucity of evidence on rural electrification’s impact on fertility, this study may provide valuable information and be of interest to policy makers.

Both the OLS and PSM estimates indicate that electrified households have lower fertility rates than unelectrified households. The household electrification variable is negative in all cases and statistically significant in most cases. PSM results suggest that electrified households have 0.05 fewer children within 5 years and 0.04 fewer children within 3 years of the survey. The probability of having a child decreases by 5% within 5 of the survey and 4% within 3 years in electrified households. These estimates of fertility decline are similar to the estimates found in Bangladesh (0.07), Nicaragua (0.07), and Peru (0.08) (footnote 3).[48]

72. To assess the association between television and fertility, an additional regression analysis was performed by including television as an explanatory variable. The results indicate that even after including television as an extra covariate, fertility coefficients are consistent with hypothesis that it helps in reducing fertility, though the relationships are statistically insignificant (Table 8). Moreover, coefficients for television are negative in all four specifications, and the effect is statistically significant except for the outcome for children born 3 years before the survey.

73. Qualitative discussions during the FGDs provide anecdotal evidence of reduced fertility due to electrification. Participants mentioned that without electricity, there is not much for people to do after it became dark. As such, they engage in reproductive activities more frequently, leading to more children. In general, the use of contraceptives was reported to be very low.

Table 8: Impact of Rural Electrification on Total Fertility

	Number of Children Born		Children Born (Yes = 1)	
	5 Years before the Survey	**3 Years before the Survey**	**5 Years before the Survey**	**3 Years before the Survey**
A. Ordinary Least Squares Regression Estimates				
Electrified	(0.051)[a]	(0.035)	(0.053)[b]	(0.035)[b]
t-statisitcs	1.87	1.60	0.02	0.04
B: Kernel Propensity Score Matching Estimates				
Electrified	(0.055)	(0.043)[a]	(0.049)[b]	(0.039)[b]
t-statistics	1.63	1.77	2.16	1.96

() = negative.
Notes: [a] $p < 0.1$ indicates that the coefficient is statistically significant at 10% level.
[b] $p < 0.05$ indicates that the coefficient is statistically significant at 5% level.
Source: Analysis of survey data.

74. Almost half of electrified and unelectrified households feel that electricity contributes to smaller family size or better family planning. Instead of engaging in sexual activities, electrified household members can be involved in productive or recreational activities such as watching television, reading, playing *yum* (a dice game), or completing chores after dark. Besides, electrified household members are more aware of the importance and methods of family planning because of frequent family planning awareness campaigns broadcast on television.

G. Environment

75. Fuelwood consumption in Bhutan, at 1.22 tons per capita, is one of the highest in the world. It accounts for about 77% of total energy consumption and virtually all noncommercial energy consumption, as forest resources provide an abundant and readily available source of

[48] Estimates may not be comparable across studies because of different measures of fertility. However, the studies suggest that electrification has negative effect on fertility.

energy (footnote 5). RE is expected to reduce deforestation, which was corroborated by the findings reported in Appendix 8. The survey data find that, on average, households cut 1.49 trees per year for fuelwood requirements and 0.58 trees for other requirements. It also finds that electrified households cut fewer trees than unelectrified households.

76. In Table 9, OLS and PSM results suggest that RE reduces the number of trees cut for fuelwood purposes. Compared to unelectrified households, electrified households cut about 0.27 fewer trees per year for their fuelwood requirements. No such significant effects are found for trees cut for nonfuelwood requirements. It also seems that RE has a substantial effect on deforestation, as impacts range from 0.46 to 0.41 fewer trees, depending on the estimation method. Given that the average annual consumption of trees for all purposes is 2.07, consumption of 0.41 fewer trees means a 20% reduction in the number of trees cut. It should, however, be noted that switching from fuelwood to electricity will take time and depends on enabling environments.

Table 9: Impact of Rural Electrification on Deforestation

	Yearly Consumption of Trees for Fuelwood	Yearly Consumption of Trees for Other Purposes	Yearly Consumption of Trees (total)
A. Ordinary Least Squares Regression Estimates			
Electrified	(0.30)[a]	(0.156)	(0.457)[a]
t-statistics	6.96	1.60	4.22
B. Kernel Propensity Score Matching Estimates			
Electrified	(0.27)[a]	(0.144)	(0.414)[a]
t-statistics	4.80	1.33	3.43

() = negative.
Notes: [a] $p < 0.01$ indicates that the coefficient is statistically significant at 1% level.
Source: Analysis of survey data.

77. The study recognized Bhutan's commitment to maintaining forest cover at 60% of total land area, as per the country's constitution. Rural households are required to apply to cut down trees (up to four per household per year) to their *gups*, who forward the applications to the district forest office. The district forest office identifies and marks the trees to be cut down and notifies the *gups*, who notify the applicants. The applicants are required to pay a permit fee of Nu60–Nu90, depending on the number of trees, which is not large enough to deter cutting and protect forests. If households require wood for construction, renovation, or other purposes, they must apply for permits in the same manner, but for such cases, households must specify what the wood is to be used for along with the precise quantity required.

78. While the number of trees cut by electrified households (1.40) is fewer than unelectrified ones (1.62), total fuelwood collection is higher for electrified households when deadwood is included. Unelectrified households cut down 0.68 tree, and electrified households cut down 0.52 tree per year for other requirements, probably because more unelectrified households have semi-permanent house structures than electrified households and thus need to repair their houses more frequently. Overall, the number of trees cut down over the past 5 years has remained static (reported by 58%) or even increased (14%).

79. While FGD participants advised that the number of trees felled had decreased by more than 50%, this perception cannot be substantiated by survey data, which show only a 20% reduction. However, a decrease in dependence on kerosene for lighting because of electricity has also meant that participants consume less of this fossil fuel, which decreases their carbon footprint and contributes to a more sustainable environment. Additionally, participants said that

before electrification, the principal source of news and entertainment was their dry-cell battery-operated radios. They would consume about six batteries every month, and over the years, the number of exhausted batteries piled up. The exhausted batteries would be disposed of by throwing them in forests, rivers, or streams, contaminating the environment. After electrification, the use of such batteries has almost been eliminated in the electrified households, thereby decreasing the negative impact on the environment.

80. Some participants also revealed that land clearing for distribution lines has had some negative environmental impacts, although this has not been adequately researched and documented. This requires a separate exercise, preferably based on a geographic information system assessment. Time and resource limitation did not permit investigation of this issue in this study.

H. Other Impacts

81. The survey also asked respondents about other impacts due to electrification. Some of these impacts, however, may not be directly attributable to RE. Hence, these should be interpreted with caution. These impacts rely on a combination of quantitative estimates, descriptive statistics, and findings from FGDs.

82. **Rural–urban migration.** A previous study[49] in Bhutan showed qualitatively that youth preferences about village life have changed, and the vast majority of surveyed households wanted to stay in villages, singling out electricity for this preference. However, this may not hold true if households are living at a subsistence level, and if there are not enough economic opportunities in the rural areas. Lack of jobs may push marginal households to migrate from rural areas to urban areas in search of employment.

83. This impact evaluation survey collected two sets of information on migration: (i) if anyone migrated in past 5 years, and (ii) how many migrants each household had. Overall, about 39% of households reported that at least one person had migrated to towns, of which 41% of households were electrified and 36% unelectrified. According to difference-in-means results, the difference in migrating propensity across the electrified and unelectrified households is statistically significant (Table 11); however, regression estimates are insignificant. PSM results indicate that the probability of migration is higher in electrified households, and the effect is significant at a 10% level of significance. Members of electrified households are 4.1 percentage points more likely to migrate, and the absolute number of migrants is also higher in electrified households. Although FGD participants believed that the trend in migration has slowed in recent years, the survey results do not provide evidence to support this perception. Given that this study does not find any direct impact on microenterprise activity, it is possible that rural people may have moved to towns in search of employment. The results suggest that electrification has not halted the flow of people from rural to urban areas in search of better livelihoods. One of the possible reasons may be few economic opportunities and widespread poverty in rural areas of Bhutan.

[49] A. Obrecht. 2006. *Impact Study Rural Electrification II – Bhutan*. Project No. EZA: 2145-00/2002 Subcontract 4. Kommission für Entwicklungsfragen: Osterreich.

Table 10: Impact of Electrification on Migration, Credit, and Food Security

	Migration in Last 5 Years (1= Yes) (1)	Number of Migrants (2)	In Debt (1= Yes) (3)	Food Security[a] (1=Yes) (4)
A. Ordinary Least Squares or Probit Regression Estimates				
Electrified	0.030	0.079	0.0295[c]	0.042[d]
t-statistics	1.32	1.26	1.98	2.76
B. Kernel Propensity Score Matching Estimates				
Electrified	0.041[b]	0.119[b]	0.043[d]	0.045[d]
t-statistics	1.74	1.79	2.71	2.74

Notes: [a] Food security is a binary variable for households having enough resources to meet annual food requirements. In debt implies that the respondent household had debt at the time of survey and migration in last 5 years implies someone in the household had migrated out of household to other areas or towns.

[b] $p < 0.1$ indicates that the coefficient is statistically significant at 10% level.

[c] $p < 0.05$ indicates that the coefficient is statistically significant at 5% level.

[d] $p < 0.01$ indicates that the coefficient is statistically significant at 1% level.

Source: Analysis of survey data.

84. **Creditworthiness.** Survey data reveal that electrified households have better resource endowment than unelectrified ones, implying that the former has higher creditworthiness. The average amount of outstanding loans for electrified households (Nu48,622) is 79% higher than for unelectrified households (Nu27,145). Both the OLS regression and PSM estimates given in Table 10 indicate that electrified households are more likely to have outstanding debt than unelectrified households, and the difference is statistically significant under both approaches. Difference-in-means estimate indicate that the difference in the amount of debt is also significant.

85. About 47% of households used the loans for house repairs, because electricity gives them incentive to improve their housing conditions because of less smoke and indoor air pollution. The percentage of electrified households using loans for house repairs is higher (51%) than unelectrified households (38%). Some government officials in Bhutan are concerned that electrification may push households into debt as they borrow to buy entertainment goods such as televisions and electrical gadgets. However, this study does not find evidence of that. Results reported in Appendix 8 suggest that a low percentage of households took out loans to buy electrical appliances, and the difference between electrified and unelectrified households is not significant. However, nearly two-fifths of unelectrified households revealed that they would have to borrow funds for internal wiring if their villages were electrified, and nearly 30% of the households would have to borrow money to purchase electrical appliances. The survey responses also revealed cash shortages in unelectrified households. Informal credit is still more prevalent than that from formal institutions, partly because of household locations. Poorer households are more prone to informal market interest rates, which are up to 60% per year in rural areas.

86. **Food security.** Next, the study considered a more general measure of well-being: food security. Ensuring food security is complex and needs a combination of policies at the household, national, and global level to ensure access to food for everyone. However, this study is limited in assessing the impact on a full spectrum of food security and mainly relies on respondents' subjective assessment of their food security.

87. Since food security is highly correlated with household income, income was added as an additional covariate to discern RE's impact on food security. Previous analyses did not control for household income, as income itself is an impact of electrification. Both estimates (regression

and PSM) indicate that electrified households are more likely to have enough resources to meet their annual food requirement than unelectrified households (Table 10). The difference is highly significant under both estimations. It is plausible to expect that electrified households can smooth out the transitory fluctuations in food supply and have enough resources to be food secure because of access to higher income and credit. The perception about food insecurity (from about 10%–15% of the respondents) was underestimated and contradicted the level of malnutrition reported in other reports. Nevertheless, the pre-monsoon months of May and June are critical periods for food deficit in the households. A primary coping strategy reported by the households includes assistance from neighbors, reconfirming that social safety nets are strong in rural villages and that villagers depend on each other in times of need. Key factors cited for food insecurity include insufficient landholdings, crop failure, and predators. Electrification has no bearing on the first two reasons, but in some cases, it serves as deterrent to wild predators, primarily through better lighting and use of electric fences.

88. **Housing structures.** In general, electrified households have stronger housing structures than unelectrified households. Members from electrified households said, during FGDs, that it used to be very difficult to maintain a clean house without electricity. They had no incentive to improve the structure of their houses because the interior would be smoke-filled, with soot-stained ceilings and walls. Many of them renovated and strengthened the structure of their houses only after they received electricity.

89. **Drinking water and hygiene**. Drinking water sources are almost the same for electrified and unelectrified households, with the majority having private taps outside of their houses. This is because of the government's drive, through its rural water supply scheme, which provides assistance and subsidy to 95% of the rural population. However, there are more taps inside electrified households than unelectrified ones, because electrified houses are better structured, and indoor taps are considered more convenient to use with improved visibility. In an effort to promote rural health and hygiene, the government also encourages the construction and use of proper toilets in rural villages through mass awareness campaigns and demonstrations. This has led to almost all rural households having private outdoor pit latrines. Therefore, there is not much of a difference in hygiene between electrified and unelectrified households. However, the superior indoor Indian flush toilet (as compared to the outdoor pit latrine) is more prevalent in electrified houses, which can be associated with improved indoor plumbing and lighting from electricity. In unelectrified households, people prefer outdoor pit latrines because they provide better visibility.

90. **Appliance ownership.** The survey confirms that electrified households own more appliances than unelectrified households. A notable trend is the increasing ownership of electric rice cookers among electrified households. Rice is the staple diet of most Bhutanese, so rice cookers (owned by 86% of electrified households) are ubiquitous, even in the most remote areas of the country. Rice cookers are not only seen as convenient, but have decreased the consumption of fuelwood for cooking. Apart from rice cookers, other noteworthy appliances owned in electrified households are mobile phones (72%), electric water boilers (48%), televisions (34%), tape recorders (35%), fans (15%), refrigerators (15%), and electric heaters (5%). In unelectrified households, the predominant appliances, apart from the traditional cooking stoves (90%), are radios or transistors (65%), mobile phones (58%), and tape recorders (13%) that are sparingly used and must be charged in the closest electrified village. *Bukharis* are largely installed in larger houses owned by respondents in both electrified and unelectrified villages and are generally located in the colder high-altitude regions. There are no defined safety or efficiency standards for various electrical appliances.

91. **Security.** According to the FGD participants, a common rural crime is the vandalism and burglary of religious artifacts, and precious and semi-precious items from *chortens* (enclosed religious structures). Nearly 57% of the electrified households agree that such crimes decreased because of electrification, and 53% of unelectrified households also concur that electrification substantially deceases such crime. Further, wild animals damage and consume crops; some studies estimated that farmers lose more than 40% of their crops to wild animals. Bhutan's law and religion forbids people from killing wild animals. Three-fifths of electrified and unelectrified households agree that crop damage by wild animals can be reduced through electrification of households and farm properties. In addition, there is near unanimity that electricity provides personal safety and security to household members and their property. One in 12 electrified households experienced fire mishaps before electrification, primarily because of accidental toppling of kerosene bottle lamps. Further, 2.2% of electrified households also had accidents arising from electrification.

92. **Access to institutions.** Results suggest that electricity-based mobile phone charging facilities enhance contacts between villagers and *gups* for resolving local or legal disputes, without which they would have to travel long distances to establish communication. FGD participants also commended services provided by the energy supplier, BPC, for fixing technical faults, meter reading, issuing power bills, and collecting payments at their doorsteps. Previously, they had to travel several hours to purchase kerosene for lighting purposes and often returned empty-handed because kerosene was unavailable. In their opinion, transaction costs—both in terms of cash and time—are greatly reduced with the provision of electricity. BPC also established a toll-free telephone line, and responses from their technicians do not take more than 4 hours at any time. Overall, power outages are uncommon. Nearly 55% of the respondents experience power outages only once a month, and just 3% suffer such problems twice a day. About 4% reported that response time from BPC took more than 7 days, primarily due to their remote locations.

93. **Social interaction and recreation.** FGD participants revealed that RE has brought a tremendous change in their social lives, giving them self-esteem. Before electrification, they felt neglected by the government, especially those who had some experience with the world outside of their dark villages (such as migrant workers or those who visited electrified villages and urban centers). In most cases, the feeling of remoteness has been replaced by positive identification with the new, improved conditions of village life after electrification. Participants, particularly from southern Bhutan, said that electrification has improved their social relationships with family, friends, and neighbors. Villagers now celebrate *Dashain* and *Diwali* (Hindu festivals) with electric lights and music, and dance late into the night. These festivals are occasions when even family members working and living outside their villages come home to be with their families. Further, some participants mentioned that before electrification, they were too engaged in their farm activities during the day and had little time for social interaction with family and friends. Electricity now enables them to visit their friends and family members even after dark, thereby strengthening social ties. According to participants, electricity has provided them with a sense of security, safety, and peace of mind at night, which has emboldened them to socialize after dark.

V. SUSTAINABILITY OF PROJECT IMPACTS

94. The benefits of the two ADB projects, SREP and RENEP, were evaluated as *likely to be sustainable* based on findings reported in their PCRs and PVRs. This was based on the assumption that the government will continue its commitment to provide subsidies for electricity consumption, and will receive funding from commercial operations and electricity export

revenues. Electricity is assumed to be in abundance in Bhutan and is the chief export commodity of the country, accounting for over 45% of national revenue.

95. Because of the subsidies, the domestic electricity tariff in Bhutan is the lowest in Asia; hence, the general perception is that the tariff is reasonable. In addition, the lifeline block is generous (80 kWh per month) under which consumers pay only Nu0.75 per kWh. Based on the household survey conducted for the study, 85% of the electrified households stated that they are happy with the current electricity charges. However, nearly 42% of the electrified households reported increases in their electricity bills in the past 5 years, primarily associated with greater use of electrical appliances and marginal increase in electricity tariff every 3 years by BPC, although no change was made to the lifeline block in the tariff revision in 2007. In 2010, Bhutan Electricity Authority approved a new tariff structure effective from 1 August 2010, according to which the lifeline block has been increased from 0kwh–80kwh/month to 0kwh–100kwh/month with 13.3% increase in unit price chargeable to the consumers. The basis for tariff revision has not been revealed and hence the impact it would have on the lowest quintile in particular remains yet to be determined.

96. When asked about their WTP for electricity, 84% of electrified households are willing to pay higher costs for regular electricity service. This suggests that rural beneficiaries are generally aware of the benefits and savings arising from electricity. Of those willing to pay higher prices, 72% are willing to bear an additional 10% increase in their unit power cost. However, 14% are not willing to pay higher charges because either they have limited need or less disposal income. Similarly, 96% of unelectrified households are willing to have their houses electrified. About 30% of households are willing to pay Nu2,001–Nu4,000 for their household connection and internal wiring. One in seven households is willing to pay more than Nu9,000. Only one in six households (considered to be the bottom tier on the poverty index) can afford up to Nu1,000 for the same purpose. Thus, WTP is highly correlated with household income. Similarly, 34% of the respondents are willing to pay monthly electricity bills of Nu26–Nu 50; 27%, Nu51–Nu100; and 11% up to Nu25. One in 10 respondents is willing to pay more than Nu300 per month in electricity bills. These results should be interpreted with caution, however, as indicative WTP may be on low side for unelectrified households.

97. Customer satisfaction with BPC is also very high based on short response time, minimum power interruptions, and consolidated management of issuing electricity bills and revenue collection. For example, 55% of the respondent households reported power outages only once a month, followed by 13% once a week. Nevertheless, 3% experienced outages twice a day, and 8% once a day. This is more prevalent in the two southern geogs of Samtse and Samdrup Jongkhar districts, which depend on power supply from India.

98. Electricity consumption in rural Bhutan is largely limited to lighting, rice cooking, and water boiling. Average consumption is far below the lifeline block, and more than 80% of the electrified households fall into this category. Based on actual consumption data for the past 12 months, the western region consumes, on average, 84 kWh per month, followed by central (57%), southern (55%), and eastern (48%). Similarly, only limited seasonal variation is observed, which ranges from 54 kWh per month in June to 71 kWh per month in November.

99. The study team observed that in most of the households, little effort is made to promote the use of energy-efficient appliances. No restrictions are in place with respect to type of appliances sold in the markets. In addition, several households interviewed are reluctant to use electricity for longer hours because they perceive that such use would increase their costs. These households use electricity for only basic needs, after which they tend to revert to

kerosene lamps. For the first time, Bhutan Electricity Authority formulated Safety Code for 2008 and Safety Regulation 2008.[50] These are yet to be implemented, supported by guidelines. Both documents do not cover electricity safety at home issues. There is a need to promote safety as well as energy efficiency at the household level in a more systematic manner.

100. The SAPE of Bhutan's energy[51] sector highlights three key areas regarding sustainability of the sector: (i) promoting institutional reforms and good governance, (ii) improving access to electricity, and (iii) mobilizing investments for hydropower sector. The SAPE recognizes BPC's (i) improved managerial performance through adoption of modern utility management practices such as enterprise resource planning, integrated inventory control, budget control, and a management information system; (ii) successful experience in managing construction of high-voltage power distribution lines and RE schemes; (iii) ability to attract and retain competent and motivated staff with performance-based incentives; (iv) steady improvement in operational performance in terms of transmission and distribution losses, and improved reliability indicators; and (v) financial sustainability since 2006. The SAPE concludes that subject to continued availability of royalty energy to BPC for domestic supply at a discount to the export prices, BPC is likely to remain financially sustainable. It also recognizes that the Department of Energy has built adequate institutional capacity by retaining a competent set of civil servants.

101. The SAPE notes that RE requires continued cross-subsidies from power exports and urban and industrial consumers because of (i) the high cost of connecting rural consumers because of difficult terrain and low population density in rural areas, (ii) low consumption in rural areas, and (iii) lower tariffs applicable to rural consumers as the average consumption in rural households is far below the lifeline block of 80 kWh per month. This would exert extra pressure on government resources for continued subsidies to domestic consumers, both through higher cost of last-mile connections, as well as lower tariffs. Nevertheless, the additional power generation in the pipeline is likely to ensure that adequate revenues are generated to ensure continued subsidy.

102. The findings from this study suggest that both ADB RE projects are *likely to be sustainable* based on (i) the government's thrust and commitment to RE, which ensures that sufficient funds are transferred to BPC to support it; (ii) revenues from electricity exports, which are expected to further increase given the commissioning of the Tala Hydropower Plant and the outputs from the Green Power Development Project, which aims to increase energy sales to India through the Dagachhu Hydropower Plant; (iii) regular reviews conducted on the tariff structure; (iv) under the cross-subsidy scheme, the proportion of the total projected increase in the number of rural household consumers is not expected to exceed 10% of BPC's total sales; thus, given the limited projected sales to rural consumers, it is unlikely that the subsidies will greatly affect BPC's operations; (v) the adequate provision of budget for operation and maintenance, which is essential, especially for the distribution networks; (vi) the high quality of materials and equipment incorporated in the projects being well-suited for their intended purposes; (vii) the institutional benefits of unbundling the power sector in the country; (viii) the use of renewable natural resources, such as hydropower, to generate electricity; and (ix) the positive financial performance of BPC from 2006 to 2008. The study, however, also recognizes that in the light of the government's commitment to provide electricity for all by 2013, the continued subsidy for households at some point is expected to exert extra pressure on the

[50] BEA. 2008. *Safety Code 2008*. Bhutan Electricity Authority: Thimphu; and BEA. 2008. *Safety Regulation 2008*. Bhutan Electricity Authority: Thimphu

[51] ADB. 2010. *Sector Assistance Program Evaluation: Energy Sector in Bhutan*. Manila.

government, particularly when the pace of urbanization and consumption increase at a rapid rate.

VI. KEY FINDINGS, LESSONS, AND RECOMMENDATIONS

A. Overall Assessment and Key Findings

103. **Overall performance.** The overall performance of the two ADB RE projects are *successful* based on relevance of design, effectiveness in implementation and achievement of outputs, efficiency of operations, and likely sustainability. As a result of assistance from ADB and other development partners, RE coverage in the country increased from 20% in 1995 to about 55%–60% in 2009. This impact evaluation study finds that the projects' impacts are quantifiable, statistically significant and positive, and visible in many aspects of quality of life, but the impacts are just beginning to be realized and are now relatively small in magnitude. This is due to low household consumption of electricity, which is largely limited to lighting, water boiling, rice cooking, and television viewing. While electrical appliance ownership has increased steadily, households are still heavily reliant on fuelwood for both cooking and heating. In addition, there are no set standards for safety and energy efficiency, while rural consumers' WTP is high. Further, the domestic electricity market is dependent on subsidy provisions from electricity export earnings.

104. **Quality of life.** This impact evaluation study provides empirical evidence to suggest that electrification leads to a better quality of rural life. While electrification has served as a means rather than an end, its impact has been multifold. Some key economic impacts include better income opportunities in nonfarm activities, including home-based small scale industries such as weaving; off-farm employment; and reduced household expenditure on energy. Better indoor air quality has translated into improved health status perceptions and more time under better lighting for children to study at home. The environment is positively affected in two ways—somewhat fewer trees are felled for fuelwood, and the use of pollutant energy sources such as kerosene and fuelwood have been reduced. The results also support the argument that electrification helps reduce total fertility and improve gender empowerment, particularly pertaining to decisions related to education of children and health of household members. The magnitude of impact is, however, small due to early stage of electrification. Additional perceived indirect impacts from electrification include improved creditworthiness and food security in households (through increased nonfarm income). Electrification is also found to contribute to better physical facilities within the households, enhanced sense of physical security of lives and property, and improved opportunities for social interaction.

105. There is more potential to improve the quality of rural life by promoting and encouraging demand for electricity by the households though home-based income-generating activities with value additions through processing or other cottage industries. At the same time, migrating from fuelwood to electricity will take some time, and its pace will depend on an enabling policy environment and effectiveness of awareness campaign.

106. **Sustainability of project impacts.** Under the present policy, project impacts are *likely to be sustainable,* subject to continued subsidies from power export earnings. It is envisaged that the fundamentals of cross-subsidization will not change in the near future, as Bhutan has committed to increase power generation for the export market. However, over time, domestic demand is likely to increase with modernization and urbanization. In addition, key future challenges include close monitoring of both infrastructure and environmental impacts. Regulatory framework to promote energy safety has just been introduced but not effectively

implemented and guidelines for energy efficiency for both domestic and industrial electricity consumption need to be developed. Furthermore, providing electricity to the remaining unelectrified households will be expensive compared to previous electrification phases. While off-grid solutions may be cost-effective, their viability has not been tested. Anecdotal evidence provided in the PCRs of the two projects do not provide convincing arguments supporting efficacy of solar panels due to lack of technical support from BPC. Additional cost-effective options need to be explored to make RE sustainable in difficult terrain and isolated mountain communities.

B. Lessons and Issues

107. **A rigorous impact evaluation informs policymakers about attribution of outcomes and impacts more systematically.** It helps to understand what works and what does not under a given condition. It is, however, not an exclusive decision-making criteria but the evaluation ratings can be used as an evidence to support resource allocation to relevant programs and activities.

108. **Country ownership is crucial for the project success.** RE projects in Bhutan were successful as a result of (i) the government's social mandate to provide electricity for all by 2013, (ii) the government according top priority to RE coverage expansion, and (iii) the ability to coordinate with the five donors active in RE. The government's broad vision to harness hydroelectric power potential also played an important role in expanding RE throughout Bhutan.

109. **Expanding coverage is not adequate, extra efforts are needed for boosting demand for electricity.** Although RE has expanded significantly since 1995, household electricity use has largely been limited to lighting, rice cooking, and water boiling. Although trends are emerging for other electric appliances, including televisions, the pace has been slow and largely concentrated in larger centers. Relatively assured access for fuelwood from forests at a nominal permit costs have been a disincentive for electrified households to migrate from fuelwood to electricity. People do not yet see electricity as a full substitute for traditional energy sources. As a result, an overwhelming majority of households still rely on fuelwood for cooking and heating purposes.

110. **The regulatory framework needs to be strengthened to ensure that energy-efficient appliances and tools are used by households and businesses.** Electric appliances are freely imported or brought into the country from various sources. There is no consumer information, guidelines, or regulations regarding safety and energy efficiency of such appliances. Most consumers end up purchasing less energy-efficient appliances because of lower initial costs. With adequate informed safety and efficiency measures, households can still enjoy greater benefits at a modest cost. There is substantial scope for mass awareness about safety and efficient use of electricity and associated appliances and tools, both by businesses as well as household consumers.

111. **When rural people directly realize benefits from rural electrification, they are willing to pay more.** With increased awareness, more villages and households are opting for electrification and are willing to pay higher tariffs as well as substantial amounts for initial connections to the electricity grid. For example, 72%of survey households are willing to pay 10% increase in the unit price of electricity.

112. **Fuelwood consumption is not likely to decline unless there is an enabling environment and disincentive to felling trees.** While it is reported that cutting down trees for

fuelwood and other uses is managed with the requirement to seek approval from district forest offices, the permit cost is nominal and does not serve as a deterrent to felling trees. As a result, an overwhelming majority of households still use fuelwood for cooking purposes, partly due to the cheap cost of getting permits and to meet dual heating and cooking requirements. There is a need to look at alternatives to fuelwood for cooking and heating since the distance and time to collect fuelwood has been steadily increasing in recent years.

113. **The use of electricity for income-generating activities has been very limited, but the potential to increase household income is quite high.** RE is, of course, a necessary, but not sufficient, condition for expanding income opportunities. Unless substantive complementary investments in improving parallel infrastructure are made, such as access roads, market development, irrigation systems, skills development, and services, the demand for electricity is likely to remain below lifeline block in Bhutan in the foreseeable future for most of the households. There is also substantive scope and potential opportunity for improving agricultural productivity and value addition through the use of electricity.

114. **Baseline data are crucial for properly evaluating impact of any development intervention.** Lack or loss of data is a major challenge in conducting impact evaluation studies and sustainability analyses of projects. Lack of a designated depository for collected data, loss of data during organizational restructuring, and no back-up for data collected by consultants, forced this study to opt for a quasi-experimental approach using a single-difference method. With proper advance planning and systematic recording, much richer databases could have been created and used for impact evaluation using a double-difference method.

C. Recommendations

115. The project outcomes and impact(s) outlined in the report and recommendation of the President should be stated clearly and specific, measurable, achievable, relevant and time bound targets should be set. A well defined monitoring and evaluation mechanism should be put in place so that progress in achieving these targets can be periodically monitored by collecting data at the required levels, and are reported and followed-up by the ADB management. In both RE projects these were not followed though and as a result no baseline targets were set and hence it created difficulties in evaluating impacts. In the future projects, ADB should require that SMART indicators are periodically monitored, reported and followed-up in a systematic manner, both during project implementation and after project completion. This will strengthen evidence base for development effectiveness of ADB assistance.

116. Development impact of RE is material as it helps provide a better quality of life and potential for incremental income-generating activities. ADB should continue supporting RE, however, ensuring efficiency of resource use and sustainability of project benefits.

117. **Building on success so far, stimulate and manage household and community demand for electricity.** Electricity has tremendous potential to increase household income and quality of rural life. The ADB projects have achieved the first step by expanding RE coverage significantly in Bhutan. Now, ADB could help boost demand for electricity at the household level, ensure safety of electrical appliances and tools, and encourage the use of energy-efficient appliances. ADB could assist the government in (i) developing action plans for risk assessment and institutionalizing safety standards, (ii) ensuring clean and efficient energy use, (iii) strengthening existing regulatory framework; and (iv) linking electricity with income-generating activities such as food processing, irrigation services, and eco-friendly micro and small enterprises. Programs for the replacement of ordinary light bulbs with compact fluorescent

lamps, processing of high-value horticultural products, and irrigation services based on water pumps to increase agricultural productivity may be implemented. In addition, ADB should encourage the government to launch interagency awareness programs to boost household demand for safe, efficient use of electricity.

118. **Ensure sustainability of project benefits.** The sustainability of project benefits to a large extent depends on continuation of cross-subsidization of RE by power export in Bhutan. Over time, domestic demand is likely to increase and, hence, it would exert extra pressure on the government to set aside additional resources for this purpose. With the increased household demand and new tariff structure introduced effective from 1 August 2010 for electricity over time, the requirements for subsidy funds are expected to grow. A detailed analysis of current and potential demand for electricity would be useful for planning purposes. It would be desirable that subsidy is targeted to those who cannot afford to pay their electricity bills. ADB could assist the government in conducting an electricity demand study based on WTP and affordability analysis for electricity, as well as other energy sources. Such a study can assist the government to determine a sound and efficient basis for setting electricity tariff and felling trees for household and commercial use. In addition, efforts are also needed to test viability of alternate energy sources, particularly for cooking and heating in different parts of the country. Findings from this evaluation confirms that WTP for electricity is quite high both in unelectrified and electrified areas. Furthermore, creating and managing additional demand for electricity through increased consumption but using energy-efficient devices can also ensure long-term sustainability of the project benefits. It would also encourage consumers to diversify electricity use from consumption to production purposes.

119. **Encourage monitoring of project benefits over time.** RE project benefits are evolving and are at the initial stage in Bhutan and these are likely to increase over time with increased demand for better quality of life and economic activities. In this study, a number of socioeconomic and environmental indicators to evaluate project impact and their status in 2010 have been established. Using the indicators and data from this study as baseline or benchmark, ADB could assist the government in monitoring progress in economic, environmental, and social impacts of RE over time for completed, ongoing, and planned new projects. Management may consider incorporating indicators such as household income (farm and nonfarm), employment, household expenditure on and consumption of different energy sources, incidence and intensity of smoke-related health ailments, time spent by adults and children in learning within and outside home, quality of graduates, permits issued for felling trees for household and business purposes, type and quality of asset ownership, changes in gender roles in household decision-making, damage due to theft or wildlife, etc. in ongoing and planned RE projects in Bhutan and other DMCs.

PORTFOLIO OF ADB RURAL ELECTRIFICATION PROJECTS

Table A1.1: ADB Assistance in the Energy Sector in Bhutan, 1969–2009
($ million)

	1969–1979				1980–1989				1990–1999				2000–2009			
Subsector	Loans	TA	Grants	Total	Loans	TA	Grants	Total	Loans	TA	Grants	Total	Loans	TA	Grants	Total
Conventional energy	344.3	0.6	0.0	345.0	1,527.7	5.2	0.0	1,533.0	2,381.2	17.1	0.0	2,398.3	1,180.7	11.1	0.0	1,191.8
Transmission and distribution	607.3	0.6	0.0	607.9	2,081.1	3.8	0.0	2,084.9	3,876.6	23.5	0.0	3,900.1	4,676.5	31.5	334.9	5,042.9
Energy sector development	79.5	83.4	0.0	162.9	696.2	11.6	0.0	707.9	1,991.7	38.3	0.0	2,030.0	2,419.6	39.2	33.5	2,492.3
Energy utility services	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	70.0	0.0	0.0	70.0	0.0	1.0	4.0	5.0
Energy efficiency and conservation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	850.0	6.2	3.0	859.2	433.2	372.1	8.5	813.7
Large hydropower	483.9	2.2	0.0	486.1	284.7	1.8	0.0	286.5	1,608.3	10.2	0.0	1,618.5	667.0	11.9	0.0	679.0
Pipelines	12.2	0.2	0.0	12.4	141.3	1.6	0.0	142.9	526.0	2.7	0.0	528.7	230.0	7.6	5.0	242.6
Renewable energy	2.7	0.1	0.0	2.8	32.3	1.6	0.0	33.9	100.0	3.1	0.0	103.1	565.0	29.1	48.8	642.9
Total	1,529.9	87.1	0.0	1,617.0	4,763.4	25.7	0.0	4,789.1	11,403.8	101.1	3.0	11,507.9	10,172.0	503.5	434.6	11,110.1

ADB = Asian Development Bank, TA = technical assistance.
Source: ADB loan, TA, and grant databases.

Table A1.2: ADB Loans for Rural Electrification, 1989–2009
($ million)

Loan No.	Project Name	No. of Projects	Funding Source	Amount ($ million)	Date Approved	Purpose
Afghanistan		1		26.5		
2165	Power Transmission and Distribution		ADF	26.5	14-Apr-05	transmission and distribution
Bangladesh		5		534.9		
1356	Rural Electrification		ADF	50.0	30-May-95	distribution and capacity building
1884	West Zone Power System Development		ADF	60.2	17-Dec-01	transmission and distribution
1885	West Zone Power System Development		OCR	138.7	17-Dec-01	transmission and distribution
2038	Power Sector Development Program (Program Loan)		OCR	100.0	10-Dec-03	generation, transmission, distribution and reforms
2039	Power Sector Development Program (Project Loan)		OCR	186.0	10-Dec-03	
Bhutan		5		106.9		
1375	Rural Electrification		ADF	7.5	19-Sep-95	distribution and capacity building
1712	Sustainable Rural Electrification		ADF	10.0	25-Nov-99	distribution and capacity building
2009	Rural Electrification and Network Expansion		ADF	9.4	30-Sep-03	generation and distribution
2463	Green Power Development		OCR	51.0	29-Oct-08	generation
2464	Green Power Development		ADF	29.0	29-Oct-08	generation
Cambodia		2		64.3		
2052	Greater Mekong Subregion Transmission		ADF	44.3	15-Dec-03	transmission, distribution and capacity building
2261	Second Power Transmission and Distribution		ADF	20.0	4-Oct-06	transmission, distribution and capacity building
India		2		119.4		
2592	Assam Power Sector Enhancement Investment Program - Tranche 1		OCR	60.3	27-Nov-09	transmission, distribution and capacity building
2596	Himachal Pradesh Clean Energy Development Investment Program - Tranche 2		OCR	59.1	8-Dec-09	generation and capacity building
Indonesia		1		161.0		
1982	Renewable Energy Development Sector		OCR	161.0	19-Dec-02	generation, distribution and financing
Lao People's Democratic Republic		3		64.0		
1308	Nam Ngum-Luang Prabang Power Transmission (Supplementary)		ADF	4.0	30-Aug-94	transmission and distribution
1558	Power Transmission and Distribution		ADF	30.0	30-Sep-97	transmission and distribution
2005	Northern Area Rural Power Distribution		ADF	30.0	18-Sep-03	distribution and capacity building
Nepal		3		166.0		
1011	Seventh Power		ADF	51.0	11-Jan-90	transmission and distribution
1732	Rural Electrification, Distribution and Transmission		ADF	50.0	21-Dec-99	generation
2587	Energy Access and Efficiency Improvement		ADF	65.0	27-Nov-09	transmission, distribution and capacity building
Pakistan		2		60.0		
2552	Energy Efficiency Investment Program - Tranche 1		OCR	40.0	22-Sep-09	transmission, distribution and capacity building
2553	Energy Efficiency Investment Program - Tranche 1		ADF	20.0	22-Sep-09	transmission, distribution and capacity building
People's Republic of China		2		200.0		
1644	Yunnan Dachaoshan Power Transmission		OCR	100.0	27-Nov-98	transmission and distribution
1901	Shen-Da Power Transmission and Grid Rehabilitation		OCR	100.0	20-Dec-01	distribution and capacity building
Sri Lanka		4		314.3		
1021	Power System Expansion (Sector Loan)		ADF	74.3	31-May-90	transmission and distribution
1414	Second Power System Expansion (Sector)		ADF	80.0	14-Dec-95	transmission and distribution
2518	Clean Energy and Access Improvement		OCR	135.0	14-Apr-09	generation, transmission, distribution and DSM
2519	Clean Energy and Access Improvement		ADF	25.0	14-Apr-09	generation, transmission, distribution and DSM
Thailand		1		100.0		
1429	Rural Electrification		OCR	100.0	23-Jan-96	distribution
Viet Nam		3		1,153.9		
1585	Central and Southern Viet Nam Power Distribution		ADF	100.0	27-Nov-97	transmission, distribution and capacity building
2517	Renewable Energy Development Network Expansion and Rehabilitation for Remote Communes Sector		ADF	151.0	30-Mar-09	generation and financing
2610	Mong Duong 1 Thermal Power Project - Tranche 2		OCR	902.85	21-Dec-09	generation
	Total	34		3,071.15		

ADB = Asian Development Bank, ADF = Asian Development Fund, DSM = demand side management, OCR = ordinary capital resources.
Source: ADB loan, technical assistance, and grant databases.

Table A1.3: Financing Sources of ADB Loans for Rural Electrification, 1989–2009
($ million)

Loan No.	Country	Project Name	Funding Source and Amount ($ million) ADF	OCR
2165	AFG	Power Transmission and Distribution	26.5	
1356	BAN	Rural Electrification	50.0	
1884	BAN	West Zone Power System Development	60.2	
1885	BAN	West Zone Power System Development		138.7
2038	BAN	Power Sector Development Program (Program Loan)		100.0
2039	BAN	Power Sector Development Program (Project Loan)		186.0
1375	BHU	Rural Electrification	7.5	
1712	BHU	Sustainable Rural Electrification	10.0	
2009	BHU	Rural Electrification and Network Expansion	9.4	
2463	BHU	Green Power Development		51.0
2464	BHU	Green Power Development	29.0	
2052	CAM	Greater Mekong Subregion Transmission	44.3	
2261	CAM	Second Power Transmission and Distribution	20.0	
2592	IND	Assam Power Sector Enhancement Investment Program - Tranche 1		60.3
2596	IND	Himachal Pradesh Clean Energy Development Investment Program - Tranche 2		59.1
1982	INO	Renewable Energy Development Sector		161.0
1308	LAO	Nam Ngum-Luang Prabang Power Transmission (Supplementary)	4.0	
1558	LAO	Power Transmission and Distribution	30.0	
2005	LAO	Northern Area Rural Power Distribution	30.0	
1011	NEP	Seventh Power	51.0	
1732	NEP	Rural Electrification, Distribution and Transmission	50.0	
2587	NEP	Energy Access and Efficiency Improvement	65.0	
2552	PAK	Energy Efficiency Investment Program - Tranche 1		40.0
2553	PAK	Energy Efficiency Investment Program - Tranche 1	20.0	
1644	PRC	Yunnan Dachaoshan Power Transmission		100.0
1901	PRC	Shen-Da Power Transmission and Grid Rehabilitation		100.0
1021	SRI	Power System Expansion (Sector Loan)	74.3	
1414	SRI	Second Power System Expansion (Sector)	80.0	
2518	SRI	Clean Energy and Access Improvement		135.0
2519	SRI	Clean Energy and Access Improvement	25.0	
1429	THA	Rural Electrification		100.0
1585	VIE	Central and Southern Viet Nam Power Distribution	100.0	
2517	VIE	Renewable Energy Development Network Expansion and Rehabilitation for Remote Communes Sector	151.0	
2610	VIE	Mong Duong 1 Thermal Power Project - Tranche 2		902.85
		Total	937.2	2,134.0
		% of Total	31%	69%

ADB = Asian Development Bank, ADF = Asian Development Fund, AFG = Afghanistan, BAN = Bangladesh, BHU = Bhutan, CAM = Cambodia, IND = India, LAO = Lao People's Democratic Republic, NEP = Nepal, OCR = ordinary capital resources, PAK = Pakistan, PRC = People's Republic of China, SRI = Sri Lanka, THA = Thailand, VIE = Viet Nam.
Source: ADB loan, technical assistance, and grant databases; and reports and recommendations of the President.

Table A1.4: ADB Technical Assistance for Rural Electrification, 1989–2009

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TA No.	TA Title	No. of Projects	Type	Funding Source	Amount	Date Approved	Purpose
Afghanistan		3			2,300,000		
4318	National Power Transmission Grid		PP	TASF	750,000	26-Feb-04	financial services preparation
4461	Poverty Reduction and Rural Renewable Energy Development		AD	PRF	750,000	3-Dec-04	generation and financial services preparation
4662	Small to Medium-Sized Hydropower Development		PP	TASF	800,000	3-Oct-05	generation
Bangladesh		3			598,000		
2338	Solicitation for Private Sector Implementation of the Meghnaghat Power		AD	TASF	211,000	30-May-95	distribution and capacity building
2338	Solicitation for Private Sector Implementation of the Meghnaghat Power (Supplementary)		AD	TASF	222,000	12-Mar-97	distribution and capacity building
2338	Solicitation for Private Sector Implementation of the Meghnaghat Power (Supplementary)		AD	TASF	165,000	3-Aug-98	distribution and capacity building
Bhutan		6			4,245,000		
2043	Power System Development		PP	JSF	245,000	29-Dec-93	distribution
2400	Institutional and Financial Development of Department of Power		AD	TASF	400,000	19-Sep-95	capacity building
2912	Second Rural Electrification		PP	JSF	600,000	19-Nov-97	distribution and financial services preparation
3825	Rural Electrification and Network Expansion		PP	JSF	700,000	21-Dec-01	capacity building and financial services preparation
4766	Accelerated Rural Electrification		AD	TASF	700,000	28-Feb-06	capacity building and financial services preparation
4916	Bhutan Power Development		PP	JSF	1,600,000	29-Jan-07	reforms and financial services preparation
Cambodia		2			880,000		
3256	Update of Power Rehabilitation II Project Preparation Study		PP	TASF	150,000	17-Sep-99	financial services preparation
4078	Power Distribution and Greater Mekong Subregion Transmission		PP	TASF	730,000	10-Jan-03	financial services preparation
Cook Island		2			340,000		
1102	Power System Reinforcement in Rarotonga		PP	SSTA	90,000	10-Jan-89	financial services preparation
2264	Outer Islands Power Development Study		PP	JSF	250,000	27-Dec-94	generation, reforms and financial services
Fiji		1			400,000		
3961	Rural Electrification		PP	JSF	400,000	30-Oct-02	financial services preparation
India		3			2,800,000		
4242	Institutional Development for Rural Electrification		AD	UK	400,000	10-Dec-03	reforms and financial services preparation
7099	Integrated Renewable Energy Development		PP	TASF	1,400,000	21-Jul-08	distribution
7378	Capacity Development of the Assam Power Sector Utilities		CD	TASF	1,000,000	18-Nov-09	transmission and distribution
Indonesia		1			800,000		
4054	Power Welfare Scheme		AD	Denmark	800,000	19-Dec-02	financing
Lao People's Democratic Republic		5			2,043,000		
1080	Xieng Khouang and Sayaburi Power Transmission Study		PP	TASF	85,000	3-Jan-89	financial services preparation
1082	Institutional Improvement to EdL Luang Prabang		AD	TASF	198,000	3-Jan-89	capacity building
2479	Power Transmission and Distribution		PP	JSF	250,000	18-Dec-95	transmission and distribution
3087	Northern Area Rural Power Distribution		PP	JSF	510,000	14-Oct-98	capacity building and financial services preparation
7227	Small and Mini Hydroelectric Development		PP	Finland	1,000,000	14-Jan-09	generation
Maldives		2			200,000		
1338	Second Power System Development		PP	TASF	100,000	13-Jul-90	financial services preparation
1944	Third Power System Development		PP	TASF	100,000	2-Sep-93	financial services preparation
Mongolia		1			400,000		
3965	Renewable Energy Development in Small Towns and Rural Areas		AD	Denmark	400,000	4-Nov-02	generation, capacity building and financial services preparation
Nepal		2			1,050,000		
2911	Rural Electrification and Distribution Improvement		PP	JSF	450,000	14-Nov-97	transmission, distribution and financial services preparation
4493	Rural Electrification and Renewable Energy		PP	JSF	600,000	17-Dec-04	financial services preparation
Philippines		4			2,350,000		
3422	Rural Electrification Institutional Strengthening		AD	TASF	750,000	23-Mar-00	capacity building and reforms
3516	Rural Electrification		PP	JSF	600,000	10-Oct-00	financial services preparation
4174	Rehabilitation of Renewable Energy Projects for Rural Electrification and Livelihood Development		AD	Denmark	450,000	16-Sep-03	reforms and financial services preparation
7012	Rural Electric Cooperatives Development		PP	JSF	550,000	11-Dec-07	financial services preparation
People's Republic of China		5			3,185,000		
2100	Rural Energy Development Study		AD	JSF	500,000	16-Jun-94	capacity building and financial services preparation
3105	Institutional Reform of Yunnan Electric Power Group Corporation		AD	JSF	785,000	27-Nov-98	distribution and capacity building
4309	Renewable Energy for Poverty Reduction		AD	TASF/ Denmark	600,000	19-Dec-03	reforms and financial services preparation
4649	Alternative Energy Supply for Rural Poor in Remote Areas		AD	Other	500,000	21-Sep-05	capacity building, reforms and financial services preparation
4935	Gansu Rural Clean Energy Development		AD	Denmark-E2	800,000	1-Jun-07	capacity building and financial services preparation
Republic of Marshall Island		2			400,000		
2041	Outer Islands Power Development Study		PP	JSF	200,000	29-Dec-93	financial services preparation
2415	Ebeye Power Expansion Study		PP	TASF	200,000	3-Oct-95	generation and distribution and reforms
Sri Lanka		2			1,045,000		
1307	Rural Electrification Development		AD	JSF	445,000	31-May-90	reforms and financial services preparation
4262	Rural Electrification and Network Expansion		PP	TASF	600,000	16-Dec-03	financial services preparation
Tajikistan		1			800,000		
4423	Development of Community Based Micro-Hydropower Supply in Remote Rural Areas		AD	PRF	800,000	5-Nov-04	reforms and financial services preparation
Thailand		1			600,000		
2886	Rural Electrification and System Improvement		PP	JSF	600,000	3-Oct-97	financial services preparation
Tonga		1			300,000		
2694	Institutional Development of the Tonga Electric Power Board and for Rural Electrification		AD	Other	300,000	3-Dec-96	distribution and capacity building
Uzbekistan		2			650,000		
4173	Off-Grid Renewable Energy Development		AD	Denmark	350,000	15-Sep-03	reforms and financial services preparation
4709	Rural Renewable Energy Development		PP	Finland	300,000	2-Dec-05	capacity building and financial services preparation
Viet Nam		1			508,000		
2470	Central and Southern Viet Nam Power Distribution		PP	JSF	508,000	12-Dec-95	distribution and capacity building
	Total	50			25,894,000		

AD = advisory, ADB = Asian Development Bank, CD = capacity development, JSF = Japan Special Fund, PP = project preparatory, PRF = Poverty Reduction Cooperation Fund, SSTA = small-scale technical assistance, TA = technical assistance, TASF = Technical Assistance Special Fund, UK = United Kingdom.

Source: ADB loan, TA, and grant databases.

Table A1.5: Financing Sources of ADB Technical Assistance for Rural Electrification, 1989–2009

TA No.	Country	TA Name	Funding Source and Amount ($ million)			
			TASF	JSF	SSTA	Others
A. PPTA - 28 projects						
4318	AFG	National Power Transmission Grid	0.750			
4662	AFG	Small to Medium-Sized Hydropower Development	0.800			
2043	BHU	Power System Development		0.245		
2912	BHU	Second Rural Electrification		0.600		
3825	BHU	Rural Electrification and Network Expansion		0.700		
4916	BHU	Bhutan Power Development		1.600		
3256	CAM	Update of Power Rehabilitation II Project Preparation Study	0.150			
4078	CAM	Power Distribution and Greater Mekong Subregion Transmission	0.730			
1102	COO	Power System Reinforcement in Rarotonga			0.090	
2264	COO	Outer Islands Power Development Study		0.250		
3961	FIJ	Rural Electrification		0.400		
7099	IND	Integrated Renewable Energy Development	1.400			
1080	LAO	Xieng Khouang and Sayaburi Power Transmission Study	0.085			
2479	LAO	Power Transmission and Distribution		0.250		
3087	LAO	Northern Area Rural Power Distribution		0.510		
7227	LAO	Small and Mini Hydroelectric Development				1.000
1338	MLD	Second Power System Development	0.100			
1944	MLD	Third Power System Development	0.100			
2911	NEP	Rural Electrification and Distribution Improvement		0.450		
4493	NEP	Rural Electrification and Renewable Energy		0.600		
3516	PHI	Rural Electrification				0.600
7012	PHI	Rural Electric Cooperatives Development		0.550		
2041	RMI	Outer Islands Power Development Study		0.200		
2415	RMI	Ebeye Power Expansion Study	0.200			
4262	SRI	Rural Electrification and Network Expansion	0.600			
2886	THA	Rural Electrification and System Improvement		0.600		
4709	UZB	Rural Renewable Energy Development				0.300
2470	VIE	Central and Southern Viet Nam Power Distribution		0.508		
B. ADTA - 21 projects						
4461	AFG	Poverty Reduction and Rural Renewable Energy Development				0.750
2338	BAN	Solicitation for Private Sector Implementation of the Meghnaghat Power	0.211			
2338	BAN	Solicitation for Private Sector Implementation of the Meghnaghat	0.222			
2338	BAN	Solicitation for Private Sector Implementation of the Meghnaghat	0.165			
2400	BHU	Institutional and Financial Development of Department of Power	0.400			
4766	BHU	Accelerated Rural Electrification	0.700			
4242	IND	Institutional Development for Rural Electrification				0.400
4054	INO	Power Welfare Scheme				0.800
1082	LAO	Institutional Improvement to EdL Luang Prabang	0.198			
3965	MON	Renewable Energy Development in Small Towns and Rural Areas				0.400
3422	PHI	Rural Electrification Institutional Strengthening	0.750			
4174	PHI	Rehabilitation of Renewable Energy Projects for Rural Electrification and Livelihood Development				0.450
2100	PRC	Rural Energy Development Study		0.500		
3105	PRC	Institutional Reform of Yunnan Electric Power Group Corporation		0.785		
4309	PRC	Renewable Energy for Poverty Reduction	0.600			
4649	PRC	Alternative Energy Supply for Rural Poor in Remote Areas				0.500
4935	PRC	Gansu Rural Clean Energy Development				0.800
1307	SRI	Rural Electrification Development		0.445		
4423	TAJ	Development of Community Based Micro-Hydropower Supply in Remote Rural Areas				0.800
2694	TON	Institutional Development of the Tonga Electric Power Board and for Rural Electrification				0.300
4173	UZB	Off-Grid Renewable Energy Development				0.350
C. CDTA - 1 project						
7378	IND	Capacity Development of the Assam Power Sector Utilities	1.000			
		Total	9.161	9.193	0.090	7.450
		No. of projects	19	17	1	13

ADB = Asian Development Bank, ADTA = advisory technical assistance, AFG = Afghanistan, BAN = Bangladesh, BHU = Bhutan, CAM = Cambodia, CDTA = capacity development technical assistance, COO = Cook Islands, FIJ = Fiji Islands, IND = India, INO = Indonesia, JSF = Japan Special Fund, LAO = Lao People's Democratic Republic, MLD = Maldives, MON = Mongolia, NEP = Nepal, PHI = Philippines, PPTA = project preparatory technical assistance, PRC = People's Republic of China, RMI = Republic of the Marshall Islands, SRI = Sri Lanka, SSTA = small-scale technical assistance, TA = technical assistance, TAJ = Tajikistan, TASF = Technical Assistance Special Fund, THA = Thailand, TON = Tonga, UZB = Uzbekistan, VIE = Viet Nam.

Source: ADB loan, TA, and grant databases.

Table A1.6: ADB Grants for Rural Electrification, 1989–2009

Grant No.	Project Name	No. of Projects	Source of Funding	Amount ($ million)	Date Approved	Purpose
Afghanistan		1		23.5		
0004	Power Transmission and Distribution		ADF	23.5	14-Apr-05	transmission and distribution
Bhutan		3		27.3		
0119	Green Power Development		CEFPF	1.0	29-Oct-08	distribution
0119	Green Power Development		ADF	25.3	29-Oct-08	distribution
9093	Rural Electricians Training Program		JFPR	1.0	25-May-06	
Mongolia		1		2.4		
9139	Demonstration Project for Improved Electricity Services to the Low-Income		JFPR	2.4	9-Sep-09	transmission, distribution, capacity building and financial services preparation
Nepal		2		4.5		
0182	Energy Access and Efficiency Improvement		CCF	0.3	27-Nov-09	transmission and distribution
0183	Energy Access and Efficiency Improvement		CEF	4.2	28-Nov-09	transmission and distribution
Philippines		1		1.5		
9042	Renewable Energy and Livelihood Development Project for the Poor in		JFPR	1.5	19-Jan-04	generation, distribution, financing and reforms
Sri Lanka		2		3.7		
0149	Clean Energy and Access Improvement		SF	2.2	6-Oct-09	distribution
9045	Power Fund for the Poor		JFPR	1.5	7-Apr-04	capacity building and financing
Tajikistan		1		2.0		
9089	Community-Based Rural Power Supply		JFPR	2.0	15-Mar-06	generation, reforms and DSM
	Total	11		64.9		

ADB = Asian Development Bank, ADF = Asian Development Fund, CCF = Climate Change Fund, CEF = Clean Energy Fund, CEFPF = Clean Energy Financing Partnership Facility, DSM = demand side management, JFPR = Japan Fund for Poverty Reduction, SF = special fund.
Source: ADB loan, technical assistance, and grant databases.

DESIGN ATTRIBUTES OF RURAL ELECTRIFICATION PROJECTS IN DEVELOPING MEMBER COUNTRIES

A. Quality at Entry: Project Design

1. Design and monitoring frameworks in 24 loan documents for 28 rural electrification projects of the Asian Development Bank (ADB) were reviewed. They indicated that the loans addressed rural electrification through various components, such as through (i) construction of power plants to generate electricity for on-grid or off-grid application, (ii) expansion and rehabilitation of transmission and distribution lines, (iii) introduction of reforms in terms of tariff setting and private sector participation, (iv) preparation of feasibility studies and detailed engineering design for power systems and facilities, (v) provision of soft loans for electricity connections, and (vi) enhancement of local capacities for efficient operation of local power utilities. Classification of projects by impact, outcome, and output classification is summarized in Tables A2.1–A2.3.

Table A2.1: List of Rural Electrification Loan Projects Demonstrating Primary and Secondary Impacts, 1989–2009

A. Primary Impact Areas	Loans
1. Economic growth	Loan 1011 (NEP): Seventh Power
	Loan 1021 (SRI): Power System Expansion (Sector Loan)
	Loan 1308 (LAO): Nam Ngum-Luang Prabang Power Transmission (Supplementary)
	Loan 1356 (BAN): Rural Electrification
	Loan 1375 (BHU): Rural Electrification
	Loan 1414 (SRI): Second Power System Expansion (Sector)
	Loan 1429 (THA): Rural Electrification
	Loan 1558 (LAO): Power Transmission and Distribution
	Loan 1429 (VIE): Rural Electrification
	Loan 1585 (VIE): Central and Southern Viet Nam Power Distribution
	Loan 1644 (PRC): Yunnan Dachaoshan Power Transmission
	Loan 1732 (NEP): Rural Electrification, Distribution and Transmission
	Loan 1884 (BAN): West Zone Power System Development
	Loan 1901 (PRC): Shen-Da Power Transmission and Grid Rehabilitation
	Loan 1982 (INO): Renewable Energy Development Sector
	Loan 2005 (LAO): Northern Area Rural Power Distribution
	Loan 2009 (BHU): Rural Electrification and Network Expansion
	Loan 2038 (BAN): Power Sector Development Program (Program Loan)
	Loan 2052 (CAM): Greater Mekong Subregion Transmission
	Loan 2165 (AFG): Power Transmission and Distribution
	Loan 2261 (CAM): Second Power Transmission and Distribution
	Loan 2464 (BHU): Green Power Development
	Loan 2517 (VIE): Renewable Energy Development Network Expansion and Rehabilitation for Remote Communes Sector
	Loan 2518 (SRI)
2. Poverty reduction	Loan 1356 (BAN): Rural Electrification
	Loan 1375 (BHU): Rural Electrification
	Loan 1558 (LAO): Power Transmission and Distribution
	Loan 1585 (VIE): Central and Southern Viet Nam Power Distribution
	Loan 1712 (BHU): Sustainable Rural Electrification
	Loan 1732 (NEP): Rural Electrification, Distribution and Transmission

B. Secondary Impact Areas	
1. Improved quality of life	Loan 1901 (PRC): Shen-Da Power Transmission and Grid Rehabilitation Loan 2517 (VIE): Renewable Energy Development Network Expansion and Rehabilitation for Remote Communes Sector
2. Improved governance	Loan 1884 (BAN): West Zone Power System Development Loan 2038 (BAN): Power Sector Development Program (Program Loan)
3. Reduced environmental impacts	Loan 1901 (PRC): Shen-Da Power Transmission and Grid Rehabilitation Loan 1982 (INO): Renewable Energy Development Sector
4. Increased private sector participation	Loan 2052 (CAM): Greater Mekong Subregion Transmission Loan 2463 (BHU): Green Power Development
5. Promote regional cooperation	Loan 2052 (CAM): Greater Mekong Subregion Transmission Loan 2464 (BHU): Green Power Development

ADB = Asian Development Bank.
Source: ADB reports and recommendations of the President.

Table A2.2: List of Rural Electrification Loan Projects Demonstrating Outcomes (1989–2009)

Outcome (Purpose)	**Loans**
1. Increased household incomes	Loan 1375 (BHU): Rural Electrification Loan 1429 (THA): Rural Electrification Loan 1712 (BHU): Sustainable Rural Electrification Loan 1732 (NEP): Rural Electrification, Distribution and Transmission Loan 1992 (INO): Renewable Energy Development Sector Loan 2005 (LAO): Northern Area Rural Power Distribution Loan 2009 (BHU): Rural Electrification and Network Expansion Loan 2464 (BHU): Green Power Development Loan 2517 (VIE): Renewable Energy Development Network Expansion and Rehabilitation for Remote Communes Sector
2. Better living conditions (including extended study times among children, better sanitation and hygiene, better lighting, and access to information)	Loan 1414 (SRI): Second Power System Expansion (Sector) Loan 1712 (BHU): Sustainable Rural Electrification Loan 2005 (LAO): Northern Area Rural Power Distribution Loan 2009 (BHU): Rural Electrification and Network Expansion Loan 2518 (SRI): Clean Energy and Access Improvement
3. Capacity building (including upgrading of operations and business procedures)	Loan 2261 (CAM): Second Power Transmission and Distribution
4. Electricity service access and connections	Loan 1011 (NEP): Seventh Power Loan 1021 (SRI): Power System Expansion (Sector Loan) Loan 1558 (LAO): Power Transmission and Distribution Loan 1585 (VIE): Central and Southern Viet Nam Power Distribution Loan 1732 (NEP): Rural Electrification, Distribution and Transmission Loan 1901 (PRC): Shen-Da Power Transmission and Grid Rehabilitation Loan 2165 (AFG): Power Transmission and Distribution Loan 2005 (LAO): Northern Area Rural Power Distribution Loan 2009 (BHU): Rural Electrification and Network Expansion Loan 2038 (BAN): Power Sector Development Program (Program Loan) Loan 2052 (CAM): Greater Mekong Subregion Transmission

Outcome (Purpose)	**Loans**
5. Power sector development (including physical infrastructure development, additional power capacities, system loss reduction, institutional development of electric utilities, energy security, energy trading, and use of indigenous energy resources)	Loan 1011 (NEP): Seventh Power Loan 1021 (SRI): Power System Expansion (Sector Loan) Loan 1308 (LAO): Nam Ngum-Luang Prabang Power Transmission (Supplementary) Loan 1356 (BAN): Rural Electrification Loan 1375 (BHU): Rural Electrification Loan 1644 (PRC): Yunnan Dachaoshan Power Transmission Loan 1884(BAN): West Zone Power System Development Loan 1982 (INO): Renewable Energy Development Sector Loan 2165 (AFG): Power Transmission and Distribution Loan 2464 (BHU): Green Power Development Loan 2518 (SRI): Clean Energy and Access Improvement
6. Environmental protection (reduced greenhouse gas emissions)	Loan 1982 (INO): Renewable Energy Development Sector Loan 2464 (BHU): Green Power Development

ADB = Asian Development Bank.
Source: ADB reports and recommendations of the President.

Table A2.3: List of Rural Electrification Loan Projects with Defined Outputs, 1989–2009

1. Construction, upgrade, or rehabilitation of generation system, transmission, and distribution network	Loan 1011 (NEP): Seventh Power Loan 1021 (SRI): Power System Expansion (Sector Loan) Loan 1308 (LAO): Nam Ngum-Luang Prabang Power Transmission (Supplementary) Loan 1356 (BAN): Rural Electrification Loan 1375 (BHU): Rural Electrification Loan 1414 (SRI): Second Power System Expansion (Sector) Loan 1429 (THA): Rural Electrification Loan 1558 (LAO): Power Transmission and Distribution Loan 1585 (VIE): Central and Southern Viet Nam Power Distribution Loan 1644 (PRC): Yunnan Dachaoshan Power Transmission Loan 1732 (NEP): Rural Electrification, Distribution and Transmission Loan 1884 (BAN): West Zone Power System Development Loan 1901 (PRC): Shen-Da Power Transmission and Grid Rehabilitation Loan 2005 (LAO): Northern Area Rural Power Distribution Loan 2009 (BHU): Rural Electrification and Network Expansion Loan 2038 (BAN): Power Sector Development Program (Program Loan) Loan 2052 (CAM): Greater Mekong Subregion Transmission Loan 2165 (AFG): Power Transmission and Distribution Loan 2261 (CAM): Second Power Transmission and Distribution Loan 2517 (VIE): Renewable Energy Development Network Expansion and Rehabilitation for Remote Communes Sector Loan 2518 (SRI): Clean Energy and Access Improvement
2. Electricity connections	Loan 1011 (NEP): Seventh Power Loan 1021 (SRI): Power System Expansion (Sector Loan) Loan 1308 (LAO): Nam Ngum-Luang Prabang Power Transmission (Supplementary) Loan 1356 (BAN): Rural Electrification Loan 1375 (BHU): Rural Electrification Loan 1414 (SRI): Second Power System Expansion (Sector) Loan 1429 (THA): Rural Electrification Loan 1558 (LAO): Power Transmission and Distribution Loan 1712 (BHU): Sustainable Rural Electrification Loan 1732 (NEP): Rural Electrification, Distribution and Transmission Loan 1982 (INO): Renewable Energy Development Sector Loan 2005 (LAO): Northern Area Rural Power Distribution Loan 2009 (BHU): Rural Electrification and Network Expansion

	Loan 2038 (BAN): Power Sector Development Program (Program Loan) Loan 2052 (CAM): Greater Mekong Subregion Transmission Loan 2165 (AFG): Power Transmission and Distribution Loan 2464 (BHU): Green Power Development Loan 2517 (VIE): Renewable Energy Development Network Expansion and Rehabilitation for Remote Communes Sector Loan 2518 (SRI): Clean Energy and Access Improvement
3. Fossil-fuel substitution and fuel importation savings	Loan 1982 (INO): Renewable Energy Development Sector Loan 2464 (BHU): Green Power Development
4. System loss reduction	Loan 1011 (NEP): Seventh Power Loan 1732 (NEP): Rural Electrification, Distribution and Transmission Loan 2038 (BAN): Power Sector Development Program (Program Loan)
5. Energy efficiency and conservation	Loan 1901 (PRC): Shen-Da Power Transmission and Grid Rehabilitation
6. Private investments in the power sector	Loan 1884 (BAN): West Zone Power System Development
7. Capacity building and support	Loan 1901 (PRC): Shen-Da Power Transmission and Grid Rehabilitation Loan 1732 (NEP): Rural Electrification, Distribution and Transmission

ADB = Asian Development Bank.
Source: ADB reports and recommendations of the President.

B. Impact

2. The review indicated that 6 project loans featured economic growth and poverty reduction, 17 had economic growth, and only 1 had poverty reduction as the primary impact or goal statement. Similarly, the portfolio had five secondary impact or goal statements, which included (i) improved governance (two), (ii) improved quality of life (two), (iii) reduced environmental impact (two), (iv) increased private sector participation (two), and (v) promotion of regional cooperation (two). Details are provided in Table A2.1.

C. Outcome

3. Half of the project loans defined more than one intended outcome (i.e., purpose) in achieving the goals of economic growth and poverty reduction. These outcomes were related to (i) increasing household income and productivity (9); (ii) providing better living conditions (5); (iii) building local capacities in the provision of electricity services (1); (iv) expanding electricity access and connections (11); (v) promoting power sector development (11); and (vi) ensuring environmental protection (2) (Table A2.2). The provision of reliable and affordable electricity supply, especially in remote areas, was expected to foster pro-poor and balanced economic growth.

4. Similarly, increased electrification was envisaged to result in better living conditions, as communities shifted from the use of traditional fuels (i.e., fuelwood for cooking and kerosene for lighting) to electrical equipment. Also, better hygiene and improved health services were to result from well-lit clinics, well-equipped medical personnel, and well-preserved medicines and/or vaccines. Capacity building was expected to promote efficiency and effectiveness in the provision of electricity services, which would result in better power tariff collection and improved financial conditions among electric utilities. It was also expected to help field the necessary skills and technologies to sustain rural electrification efforts.

5. The expansion of electricity coverage was also expected to create power demand, increase the sales of electricity, and generate additional revenues to power companies. Power sector development was to expand the use of indigenous energy resources, which would then reduce fuel imports and ensure energy security. For energy-exporting countries like Bhutan, it was likewise expected to result in greater national income from the sector. Rural electrification projects that were to tap renewable energy resources also would contribute to economic development as they generated income from carbon trading (as a result of greenhouse gas emission reduction). Simultaneously, they aimed to minimize negative impacts on the environment and to promote resource sustainability. A list of loans with outcome statements appears in Table A2.2.

D. Outputs (Components)

6. Outputs [1] under rural electrification projects were classified into (i) construction, upgrading, or rehabilitation of power systems (21); (ii) electricity connections (19); (iii) fuel importation savings (2); (iv) system loss reduction (3); (v) energy conservation (1); (vi) private investments in the power sector (1); and (vii) capacity building and support (2) (Table A2.3). Of the 24 loan documents reviewed, 19 had two or more outputs. One project loan had four outputs: construction of substations, new rural household connections, system loss reduction, and computerization of database management for the power utility's asset inventory.

[1] ADB. 2007. *Guidelines for Preparing a Design and Monitoring Framework.* Manila. Outputs (i.e., components) are the physical categories of results, goods, and services that should be produced or delivered during project implementation.

ANALYSIS OF DESIGN AND MONITORING FRAMEWORK INDICATORS FOR RURAL ELECTRIFICATION PROJECTS

1. A content analysis of project design and monitoring framework indicators (covering 24 project loan documents, 49 technical assistance [TA] papers, and 8 grant proposals) representing 86 rural electrification projects of the Asian Development Bank (ADB) from 1989 to 2009 revealed that the use of indicators to assess the performance and accomplishments of assistance became apparent only on projects that were approved from 1998 onwards. From 1989 to 1997, only one TA project[1] and two loans[2] used design and monitoring frameworks in the project documents. Therefore, 19 out of 20 TA reports and 7 out of 9 loan documents approved from 1989 to 1997 did not use indicators. All of the grant proposals had design and monitoring frameworks and associated indicators since the beginning of grant assistance in 2004.

2. The review suggests that since 1998, design and monitoring frameworks for both loan and TA projects have significantly improved, because they became more goal- and objective-oriented. Meanwhile, the choice and use of indicators also became more flexible. In the 81 project documents under review, 547 indicators were used—119 for goals and/or impacts (45 for loans, 44 for TA projects, and 30 for grants), 120 for outcome and/or purpose (63 for loan, 47 for TA projects, and 10 for grants), and 308 for measuring outputs (101 for loans, 116 for TA projects, and 91 for grants).

3. The adopted indicators were analyzed using specific, measurable, achievable, relevant, and time-bound (SMART) criteria; and the results given in Table A3.1 suggest that 24% of loan, 7% of TA projects, and 13% of grants met all five attributes. Overall, the quality of indicators has somewhat improved over time, but varied by level and, hence, require further enhancement. Of the 119 impact indicators, 37% were specific, 75% measurable, 83% achievable, 92% relevant, and 39% time-bound. For outcomes (120 indicators), 42% were specific, 60% measurable, 77% achievable, 85% relevant, and 44% time-bound. Similarly, of the 304 output indicators, 26% were specific, 54% measurable, 69% achievable, 76% relevant, and 46% time-bound. Tables A3.2 and A3.3 summarize results of the design and monitoring framework indicator analysis.

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1 ADB. 1997. *Technical Assistance to Thailand for Rural Electrification and System Improvement Project*. Manila (TA 2886-THA, for $600,000, approved 3 October 1997).

2 ADB. 1997. *Report and Recommendation of the President to the Board of Directors: Proposed Loan to Lao People's Democratic Republic for the Power Transmission and Distribution Project*. Manila (Loan 1558-LAO, for $30 million, approved 30 September); and ADB. 1997. *Report and Recommendation of the President to the Board of Directors: Proposed Loan to Socialist Republic of Viet Nam for the Central and Southern Viet Nam Power Distribution Project*. Manila (Loan 1585-VIE, for $100 million, approved $27 million).

Table A3.1: Summary of Indicator Analysis Based on SMART Criteria

Type of Assiatnce	Compliant with SMART criteria No.	Compliant with SMART criteria %	Less Compliant with SMART criteria No.	Less Compliant with SMART criteria %	Total No. of Indicators
A. Loans					
Impact (Goals)	10	22%	35	78%	45
Outcomes (Purpose)	22	35%	41	65%	63
Outputs (Components)	18	18%	83	82%	101
Subtotal	50	24%	159	76%	209
B. Technical Assistance					
Impact (Goals)	9	20%	35	80%	44
Outcomes (Purpose)	4	9%	43	91%	47
Outputs (Components)	2	2%	114	98%	116
Subtotal	15	7%	192	93%	207
C. Grants					
Impact (Goals)	5	17%	25	83%	30
Outcomes (Purpose)	8	80%	2	20%	10
Outputs (Components)	4	4%	87	96%	91
Subtotal	17	13%	114	87%	131

% = percentage; DMF = design and monitoring framework; No. = number; RRP = report and recommendation of the President; SMART = specific, measurable, achievable, relevant, and time-bound.
Source: DMF indicator, RRPs, and Independent Evaluation Department analysis.

Table A3.2: Summary of Indicator Analysis Used for Goals in Rural Electrification Projects
(%)

	Indicators			SMART Criteria									
		No. of	% of	Specific		Measurable		Achievable		Relevant		Time-bound	
Project Document	Total	SMART	SMART	No.	%	No.	%	No.	%	No.	%	No.	%
Loans	45	10	22%	12	27%	23	51%	28	62%	38	84%	20	44%
Technical Assistance	44	9	20%	10	23%	36	82%	43	98%	43	98%	14	32%
Grants	30	5	17%	22	73%	30	100%	28	93%	29	97%	12	40%
Total	119	24	20%	44	37%	89	75%	99	83%	110	92%	46	39%

SMART = specific, measurable, achievable, relevant, and time-bound.
Source: Independent Evaluation Department analysis.

Table A3.3: Summary of Indicator Analysis Used for Outcomes in Rural Electrification Projects
(%)

	Indicators			SMART Criteria									
				Specific		Measurable		Achievable		Relevant		Time-bound	
Project Document	Total	No. of SMART	% of SMART	No.	%	No.	%	No.	%	No.	%	No.	%
Loans	63	22	35%	34	54%	38	60%	44	70%	52	83%	35	56%
Technical Assistance	47	4	9%	7	15%	25	53%	39	83%	41	87%	9	19%
Grants	10	8	80%	9	90%	9	90%	9	90%	9	90%	9	90%
Total	120	34	28%	50	42%	72	60%	92	77%	102	85%	53	44%

SMART = specific, measurable, achievable, relevant, and time-bound.
Source: Independent Evaluation Department analysis.

Table A3.4: Summary of Indicator Analysis Used for Outputs in Rural Electrification Projects

	Indicators			SMART Criteria									
				Specific		Measurable		Achievable		Relevant		Time-bound	
Project Document	Total	No. of SMART	% of SMART	No.	%	No.	%	No.	%	No.	%	No.	%
Loans	99	18	18%	34	34%	53	54%	63	64%	77	78%	52	53%
Technical Assistance	114	2	2%	12	11%	63	55%	95	83%	99	87%	69	61%
Grants	91	4	4%	34	37%	48	53%	53	58%	55	60%	19	21%
Total	304	24	8%	80	26%	164	54%	211	69%	231	76%	140	46%

SMART = specific, measurable, achievable, relevant, and time-bound.
Source: Independent Evaluation Department analysis.

PERFORMANCE OF PROJECTS IN THE RURAL ELECTRIFICATION PORTFOLIO

1. At the end of 2009, only 13 loan projects of the Asian Development Bank (ADB) had project completion reports (PCRs) or project performance audit reports (PPARs). The results from their analysis are presented in Table A4 and are summarized as follows under four key evaluation parameters.

A. Relevance

2. Eight of the 13 project loans[1] were considered *highly relevant*, while the other five were *relevant,* as they supported the corresponding government's priority in establishing basic infrastructure and promoting economic development, particularly in rural areas. Whether they developed new strategies or supported existing initiatives in the subsector, these projects were in line with government plans and ADB sector objectives. Relevant lessons from previous ADB operations were considered in the project designs, such as (i) linking the strategic focus with government strategies and priorities, (ii) emphasizing capacity building, and (iii) coordinating with development partners that contributed to the projects' success. In one case,[2] where there was no prior lending in the subsector for a long time due to its poor performance and the lack of political will to introduce substantive reforms, the project was highly appreciated as it supported a change in the business environment, created model sector agencies through capacity building, and amplified rural electrification coverage.

B. Effectiveness

3. Only three[3] of the 13 project loans were *highly effective* in achieving outcomes, as they exceeded both physical and financial targets. The rest were *effective*, despite their failures to meet the appraised financial targets and/or had delays in implementation, since they achieved their primary objectives of spurring economic development and reducing poverty, especially in rural areas.

C. Efficiency

4. Only one project loan (footnote 2) was *highly efficient* in achieving outcome and outputs, because it nearly doubled the economic internal rate of return at completion. Nine[4] were considered *efficient,* as they were completed within the projected costs and the physical facilities constructed reached full operational capacities prior to completion. The rest,[5] on the other hand, were rated *satisfactory.*

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[1] These are Power System Expansion (Sector Loan) (Loan 1021-SRI), Nam Ngum-Luang Prabang Power Transmission (Supplementary) (Loan 1308-LAO), Rural Electrification (Loan 1375-BHU), Second Power System Expansion (Sector) (Loan 1414-SRI), Yunnan Dachaoshan Power Transmission (Loan 1644-PRC), Sustainable Rural Electrification (Loan 1712-BHU), Shen-Da Power Transmission and Grid Rehabilitation (Loan 1901-PRC), and Rural Electrification and Network Expansion (Loan 2009-BHU).

[2] Rural Electrification (Loan 1356-BAN).

[3] These are Power System Expansion (Sector Loan) (Loan 1021-SRI), Rural Electrification (Loan 1356-BAN), and Rural Electrification and Network Expansion (Loan 2009-BHU).

[4] These are Seventh Power (Loan 1011-NEP), Nam Ngum-Luang Prabang Power Transmission (Supplementary) (Loan 1308-LAO), Rural Electrification (Loan 1356-BAN), Second Power System Expansion (Sector) (Loan 1414-SRI), Power Transmission and Distribution (Loan 1558-LAO), Central and Southern Viet Nam Power Distribution (Loan 1585-VIE), Yunnan Dachaoshan Power Transmission (Loan 1644-PRC), Sustainable Rural Electrification (Loan 1712-BHU), and Shen-Da Power Transmission and Grid Rehabilitation (Loan 1901-PRC).

[5] Power System Expansion (Sector Loan) (Loan 1021-SRI), Rural Electrification (Loan 1375-BHU), and Rural Electrification (Loan 1429-THA).

D. Sustainability

5. According to the PCRs, four project loans[6] were rated *likely to be sustainable,* because they displayed good-quality technical operation and maintenance, as well as long-term sustainability potential. These projects had capacity-building components in their design, which enabled smooth project turnover to sustain the activities beyond the period of assistance. Seven project loans[7] were rated *likely to be sustainable,* but some issues were raised, specifically in the areas of power utilities' financial management and power tariffs, as well as some technical challenges. Two project loans in Sri Lanka,[8] despite their 5-year implementation gap, suffered from the power utility's ailing financial conditions. This implies that unless serious financial reforms are put in place, future rural electrification projects in the country will be at risk.

6. Similarly, the sustainability of the two loan projects in Bhutan[9] depends on government subsidies to power consumers. If these subsidies dry up, the power utility's financial performance will immediately deteriorate, which could affect the operation and maintenance of the rural electrification system. However, because Bhutan benefits from exporting power to India, consumer subsidies should remain financed. Similarly, Seventh Power in Nepal was considered *less likely to be sustainable* as it is dependent on government subsidies because of the power utility's weak financial position. In contrast, the likelihood of sustainability of a project loan in Lao People's Democratic Republic[10] depends on technical modifications, given the susceptibility of the rural electrification system to natural occurrences like lightning strikes. Setbacks on the system are compounded by the variability of voltage due to higher ground resistance in which periodic maintenance is required. Failure to undertake maintenance is likely to result in power failures that could take several weeks to resolve.

E. Implementation Delays and Success Rates

7. Four of the 13 project loans[11] encountered more than 2-year implementation delays. Among the reasons cited were the unfamiliarity of executing agency with ADB procurement procedures and problems encountered during the delivery of necessary equipment. Another four project loans[12] experienced 1–2-year delays due to (i) the ADB approval processing of required supplementary financing, (ii) construction problems, (iii) geographical difficulties, and

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[6] These are Rural Electrification (Loan 1356-BAN), Rural Electrification (Loan 1429-THA), Central and Southern Viet Nam Power Distribution (Loan 1585-VIE), and Shen-Da Power Transmission and Grid Rehabilitation (Loan 1901-PRC).

[7] These are Power System Expansion (Sector Loan) (Loan 1021-SRI), Nam Ngum-Luang Prabang Power Transmission (Supplementary) (Loan 1308-LAO), Loan Second Power System Expansion (Sector) (Loan 1414-SRI), Power Transmission and Distribution (Loan 1558-LAO), Yunnan Dachaoshan Power Transmission (Loan 1644-PRC), Sustainable Rural Electrification (Loan 1712-BHU), and Rural Electrification and Network Expansion (Loan 2009-BHU).

[8] Power System Expansion (Sector Loan) (Loan 1021-SRI), and Second Power System Expansion (Sector) (Loan 1414-SRI).

[9] Rural Electrification (Loan 1375-BHU), and Sustainable Rural Electrification (Loan 1712-BHU).

[10] Nam Ngum-Luang Prabang Power Transmission (Supplementary) (Loan 1308-LAO).

[11] These are Seventh Power Seventh Power (Loan 1011-NEP), Power System Expansion (Sector Loan) (Loan 1021-SRI), Power Transmission and Distribution (Loan 1558-LAO), and Central and Southern Viet Nam Power Distribution (Loan 1585-VIE).

[12] These are Nam Ngum-Luang Prabang Power Transmission (Supplementary) (Loan 1308-LAO), Rural Electrification (Loan 1356-BAN), Rural Electrification (Loan 1375-BHU), and Sustainable Rural Electrification (Loan 1712-BHU).

(iv) natural calamities. The remaining five project loans,[13] on the other hand, were completed with less than 1-year implementation delays, which were primarily associated with slow loan project effectiveness. Overall, 2 project loans[14] were rated *highly successful* (15.3%) while 10[15] were *successful* (76.9%), and 1 project loan (Loan 1308-LAO) was considered *partially successful* (7.7%) at project completion because of noncompliance with loan covenants.

[13] These are Second Power System Expansion (Sector) (Loan 1414-SRI), Rural Electrification (Loan 1429-THA), Yunnan Dachaoshan Power Transmission (Loan 1644-PRC), Sustainable Rural Electrification (Loan 1712-BHU), and Rural Electrification and Network Expansion (Loan 2009-BHU).

[14] These are Rural Electrification (Loan 1356-BAN), and Rural Electrification and Network Expansion (Loan 2009-BHU).

[15] These are Seventh Power (Loan 1011-NEP), Power System Expansion (Sector Loan) (Loan 1021-SRI), Rural Electrification (Loan 1375-BHU) Project, Second Power System Expansion (Sector) (Loan 1414-SRI), Rural Electrification (Loan 1429-THA), Power Transmission and Distribution (Loan 1558-LAO), Central and Southern Viet Nam Power Distribution (Loan 1585-VIE), Yunnan Dachaoshan Power Transmission (Loan 1644-PRC), Sustainable Rural Electrification (Loan 1712-BHU), and Shen-Da Power Transmission and Grid Rehabilitation (Loan 1901-PRC).

Table A4: Summary of Findings on the Implementation of ADB Project Loans for Rural Electrification
(1989–2009)

			Ratings					
Loan No.	Country	Project Name	Relevance	Effectiveness	Efficiency	Sustainability	Implementation Delays	Success Rating
1011	NEP	Seventh Power	Relevant	Effective	Efficient	Less likely	4 years	Successful
1021	SRI	Power System Expansion (Sector Loan)	Highly relevant	Highly effective	Satisfactory	Likely	2 years and 6 months	Successful
1308	LAO	Nam Ngum-Luang Prabang Power Transmission (Supplementary)	Highly relevant	Effective	Efficient	Likely	13 months	Partly successful
1356	BAN	Rural Electrification	Relevant	Highly effective	Efficient	sustainable	1 year	Highly successful
1375	BHU	Rural Electrification	Highly relevant	Effective	Satisfactory	sustainable	1 year and 3 months	Successful
1414	SRI	Second Power System Expansion (Sector)	Highly relevant	Effective	Efficient	Likely	8 months	Successful
1429	THA	Rural Electrification	Relevant	Effective	Satisfactory		3 months	Successful
1558	LAO	Power Transmission and Distribution	Relevant	Effective	Efficient	Likely	2 years	Successful
1585	VIE	Central and Southern Viet Nam Power Distribution	Relevant	Effective	Efficient	sustainable	2 years and 5 months	Successful
1644	PRC	Yunnan Dachaoshan Power Transmission	Highly relevant	Effective	Efficient	Likely	6 months	Successful
1712	BHU	Sustainable Rural Electrification	Highly relevant	Effective	Efficient	Likely	22 months	Successful
1901	PRC	Shen-Da Power Transmission and Grid Rehabilitation	Highly relevant	Effective	Efficient	sustainable	11 months	Successful
2009	BHU	Rural Electrification and Network Expansion	Highly relevant	Highly effective	Highly efficient	Likely	6 months	Highly successful

ADB = Asian Development Bank, BAN = Bangladesh, BHU = Bhutan, LAO = Lao People's Democratic Republic, NEP = Nepal, PCR = project completion report, PCR-VR = project completion report validation report, PRC = People's Republic of China, SRI = Sri Lanka, THA = Thailand, VIE = Viet Nam.
Sources: ADB project completion reports and project completion validation reports.

EXPECTATIONS AND ACCOMPLISHMENTS OF RURAL ELECTRIFICATION PROJECTS IN BHUTAN

Project Design Expectations Based on Reports and Recommendations of the President	Project Outcomes and Impacts Based on Project Completion Reports	Evaluation Comments
A. Loan 1375-BHU:Rural Electrification Project		
The primary objective of the project was to provide indigenously generated hydropower to the domestic market in Bhutan to promote economic development, reduce the need for firewood, and lower expenditure on imported kerosene. The project envisaged significant social impacts due to electrification such as (i) the availability of a renewable, convenient form of energy for lighting, motive power, and heating; (ii) availability of water pumping and telecommunications infrastructure; (iii) employment in small industries due to availability of motive power; and (iv) substitution of electricity as a source of energy for cooking and heating, thereby reducing fuelwood consumption, smoke emissions, and smoke inhalation.	The envisioned social impacts in the RRP were partly attained. First, access to electricity for 2,982 new households increased the rural electrification rate from 20% to 24%. This improved convenience and enhanced the quality of life in project areas as seen in home activities, such as reading with a good light and using flat irons. Second, the project promoted small-scale commercial activities such as retail shops, which generated employment. Third, there have been no recorded negative environmental impacts during or after project completion. On the contrary, the project had positive environmental impacts, as firewood consumption was reduced by about 75% in the project areas, arresting the forest cover depletion. Air pollution was substantially eliminated with the use of electrical appliances in a majority of households that purchase electricity. This has also led to an improvement in sanitation and prevented smoke-related negative health impacts. The PCR did not mention the availability of water pumping and telecommunications infrastructure as envisioned in the RRP.	**PPAR** The PPAR confirmed the PCR findings. At the time of the PPAR, there were already 3,120 households electrified aside from the 567 electrification kits that were distributed. Beneficiaries were unanimous in agreeing that the availability of electricity improved their quality of life. Self-employment became evident as people are now engaged in income-generating activities at night, which includes weaving, carpentry, carving, and tailoring. The operation of small industries, such as rice, oil, and flour mills, due to electricity has also provided opportunities for employment and income generation. The PPAR also confirmed that electricity has slowly replaced firewood for cooking and heating, thus reducing firewood consumption, air pollution, and smoke inhalation. **IES** There is no evidence to support that firewood consumption has been reduced by 75%. The increased level of employment also cannot be verified.
B. Loan 1712-BHU: Sustainable Rural Electrification Project		
The goal of the project was to reduce poverty and increase economic growth, particularly in identified rural areas. To achieve this, the project's specific objectives were to (i) provide opportunities for income-generating activities; (ii) generate employment through expansion of cottage and small industries; (iii) improve the quality of rural life; and (iv) provide quality education and health services to rural people, particularly the poor and vulnerable groups.	The project provided electricity to 8,090 new rural consumers. However, the PCR noted the difficulty of estimating its poverty and economic growth impacts given the absence of baseline data. Completed studies on the rural electrification socioeconomic impact In Bhutan has been based on "with-and without-" rather than "before-and after-" household electrification surveys. A with- and without- survey conducted as part of the PPTA provided socioeconomic data on unelectrified project areas. However, survey data have been aggregated to district level, and were insufficient to form the baseline for a credible before- and after- survey. The PCR relied on a visit to a beneficiary village to confirm the PPTA	**PVR** The physical targets of the project were achieved. However, the absence of baseline information resulted in a reliance on an earlier socioeconomic survey under the PPTA and the visit to one village by the PCR mission team. The PVR noted that although the benefits were not quantified, the PCR mission confirmed that the socioeconomic benefits attributable to rural electrification were achieved in the project. The PVR also noted that the project design failed to incorporate monitoring and evaluation beyond project implementation. **IES** There is insufficient information to

Project Design Expectations Based on Reports and Recommendations of the President	Project Outcomes and Impacts Based on Project Completion Reports	Evaluation Comments
	survey findings, which it found to be consistent. In relation to the project objectives PCR revealed that (i) adoption and provision of income-generating opportunities depended on a particular location, (ii) impact in terms of employment generation was not known, and (iii) quality of life was improved had based on the use of various electrical appliances and better air quality.	assess impact and poverty reduction. The extent of income-generating activities and employment created cannot be quantified. There is no adequate basis to make a definitive statement of the impact on the quality of life, other than anecdotal evidence.
C. Loan 2009-BHU: Rural Electrification and Network Expansion Project		
The project's goal was to improve the quality of life of rural residents by (i) expanding the delivery of electricity from existing national hydropower stations to improve their living standards, conditions for education, and health service delivery; and (ii) providing opportunities to increase their economic productivity, thus creating jobs and raising income. The project envisaged that electrification would provide additional income-generating opportunities for households to improve incomes by establishing new businesses and/or expanding current ones. Some of the potential examples cited for income generation included establishment of small-scale cottage industries; mini food processing; increased efficiency in small trades such as carpentry and tailoring; and establishment of small shops, bars, and restaurants. Women were expected to benefit through additional lighting, reduced time spent on collecting fuelwood, use of rice cookers that reduce indoor smoke pollution, and increased light and/or motive power for home-based income-generating activities such as weaving. Replacing kerosene with electricity was expected to provide a cleaner environment, indoor living conditions, and health.	The expansion and delivery of electricity to selected rural areas was achieved. At completion, the project connected 9,206 consumers in eight districts consisting of 8,857 household consumers, with the balance comprising commercial, social, and government sector consumers such as schools, basic health units, and monasteries. The economic benefits were assumed to comprise both nonincremental and incremental benefits where the former was calculated using various assumptions. The PCR found that Bhutan Power Corporation's ability to analyze project impacts was constrained by a lack of objective data, which was partly attributed to its failure to implement a poverty impact survey at appraisal. However, given that there is an established link between poverty reduction and electricity consumption, the PCR considered that a robust analysis of project beneficiary electricity consumption would have been a good substitute for a poverty impact survey and could have led to more reliable and objective conclusions. Data on project beneficiaries were also seen as contributing to improving the accuracy of the economic analysis used for the assessment of project efficiency, planning future rural electrification projects, and managing demand for electricity.	**PVR** The PVR acknowledged that electrification of 9,206 rural consumers was the most significant output of the project. However, two impact performance indicators, increased income and improved health and education facilities, were not assessed by the PCR. Meanwhile, similar to previous loans, no negative environmental externalities were observed during or after project completion. **IES** There is no valid basis to make any statement on project impact, including establishing a link between electrification and poverty reduction. The PCR recommendation for a robust analysis to establish causality would have been useful.

D. Loan 2464-BHU: Green Power Development Project[a]
The project has two components: (i) regional clean power trade, and (ii) renewable energy access for the poor. Under the first component, the Dagachhu Hydropower Plant aims to export power from Bhutan through the existing grid to India. The second component will provide access to electricity sourced from hydropower to 8,767 households and facilities with grid extensions, and electricity sourced from solar energy to 119 remote public facilities (e.g., schools, health clinics, and other community facilities) on an off-grid basis. The impact of the project is to sustain the country's inclusive economic growth by promoting cross-border power trade and electricity access. As an outcome, the power sector is to improve the coverage of distribution and expand electricity export through clean power development in a sustainable manner. Investment for the plant will generate a long-term revenue stream for Bhutan to finance its enormous development needs in social infrastructure, such as health and education, as well as economic infrastructure facilities like roads and electricity supplies. They will form the basis of rural development and poverty reduction in the country. Investment for rural electrification will improve access to electricity by rural households and small businesses, and replace more expensive and polluting kerosene and fuelwood with renewable hydropower and solar energy. It will make social interventions to the poor and improve the standard of living and quality of life of people living in rural areas. The Dagachhu plant will generate export revenues, which will be used for subsidies to maintain low-cost power supplies to rural electrification, while exporting power to India through which cross-border cooperation and regional energy efficiency will be enhanced. To learn from the past projects and meet a covenant for project performance and benefit monitoring mechanism, in 2009, ADB and project management agreed to set up and agreed with traceable and measurable periodic benefit monitoring indicators. It did not include social indicators such as income growth on the ground that it cannot be realized clearly during project implementation period and it would require sizable cost to make data objective and useful.
IES comments: The project has just started, with electrification commencing in April 2010. It is too early to make any statement on impact. However, a mechanism to monitor project impact is not in place; hence, the PCR will face issues when it is written. The study reviewed the agreed indicators and finds that these indicators do not address development effectiveness outcomes and impacts of the projects. Exclusion of micro-level economic, environmental and social indicators will create further problem at project completion and later for evaluation to substantiate actual achievements of the project. Reportedly there has been a baseline study conducted for the project but no follow-up actions are proposed during implementation. More specifically, at the local level project envisages impact on poverty, small businesses and replacement of polluting kerosene and fuelwood with renewable hydropower and solar energy. It is not clear how these anticipated achievements could be substantiated.

IES = impact evaluation study, PCR = project completion report, PPAR = project performance audit report, PPTA = project preparatory technical assistance, PVR = PCR validation report, RRP = report and recommendation of the President.

Note: The impact evaluation study refers to the subject of this study.

[a] Since the project is currently under implementation, there is no PCR.

Source: IES findings, PCRs, PVRs, and RRPs.

IMPACT OF RURAL ELECTRIFICATION: EVIDENCE FROM LITERATURE

A. Background

1. Electricity is essential for providing a satisfactory quality of life, as it provides lighting, communication access, refrigeration, and motor applications. Between 1970 and 1990, 800 million people in rural areas of developing countries gained access to electricity, yet 2 billion in these areas were still without access to electricity in 1990.[1] The United Nations Development Programme argues that making modern energy services more available is a necessary, but not sufficient condition for rural development. To be most effective, different forms of energy (i.e., grid-based and off-grid electricity) should be introduced into rural areas only after, or along with, other development inputs or infrastructure components.

2. Although off-grid connections can serve remote communities that may be considered technically and financially nonviable for grid connection, they may not necessarily reach the poor better than grid extension. Sustainability—in terms of operation and maintenance as well as financing—is often a problem. Off-grid systems usually are more expensive in the long term, requiring subsidies to make connections more affordable.

3. Much progress has been made in improving access to electricity worldwide. Current estimates suggest that around three quarters of the world population has access to electricity.[2] The commitment of the World Bank and other international organizations to energy sector has grown tremendously. The Energy Sector Management Assistance Program (ESMAP) is stepping up its assistance to Sub-Saharan Africa through the Africa Electrification Initiative and various partnerships, such as Lighting Africa. Many developed countries have also increased the share of energy expenditure in their national budgets. In the last 30 years, the energy sector has received an extraordinary amount of financing, based on the assumption that electrification can be a potent instrument to eradicate poverty. However, energy infrastructure alone cannot precipitate economic growth and reduce poverty,[3] but the availability of modern energy, together with other growth-inducing factors, can improve the economic welfare of the people. In particular, rural electrification is often considered an equity program for poor countries (footnote 2).

4. The next step is to quantify the benefits emanating from electrification. Since resources are scarce, estimating the benefits of rural electrification would help policy makers and donors in planning future policies. However, the literature on the impact of rural electrification on different outcomes is lacking and has shied away from quantifying direct and indirect benefits. Since infrastructure projects cannot be randomized for several reasons, most impact evaluation studies have used either quasi-experiment or nonexperimental methods to estimate the impact of electricity. The existing literature is heavily skewed to showing association between electricity and development outcomes, and credible studies showing the causality link are still elusive. The causality chain in rural electrification evaluation is hard to establish due to selection bias at the household and community levels—not all households in the electrified villages are connected to the grid due to high connection costs and monthly energy bills. Furthermore, poor countries are often characterized by a shortage of power supplies, thereby resulting in infrequent and fluctuating power supplies to the electrified households. Thus, electricity interventions are unique, and it is difficult to adopt the evaluation methods used in the

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[1] United Nations Development Programme. 2004. *World Energy Assessment.* Paris.

[2] J. Saghir. 2005. Energy and Poverty: Myths, Links, and Policy Issues. *Energy Working Notes No. 4, Energy and mining sector Board, The World Bank Group. No 4.* Washington, DC: World Bank. May 2005

[3] ESMAP. 2000. Reducing the Cost of Grid Extension for Rural Electrification. *ESMAP Report No. 227/00.* Washington, DC: World Bank.

evaluation of microcredit or roads. On outcomes, the literature tends to focus on a diverse set of socioeconomic outcomes, such as income, expenditure, time savings, education, health, business activities, farm productivity, gender empowerment, and deforestation.

B. World Bank Independent Evaluation Group Study

5. A study prepared by the World Bank Independent Evaluation Group (IEG)[4] attempted to measure the benefits of World Bank-funded electrification projects using different methodologies. Ten country case studies across the globe were compiled to capture the variety of experiences in different settings. This was supplemented by (i) an analysis of demographic and health survey data in nine countries to examine the impacts of rural electrification on health and family planning outcomes, and (ii) household income and expenditure surveys in two countries to analyze impacts of rural electrification on rural income generation.

6. The study showed that in terms of connections, residential customers dominate (with a 95% share), while the rest are composed of small industrial or commercial connections and community facilities (e.g., health clinics, schools, streetlights, and water-pumping stations). The basic purpose of rural electrification is to provide more and better lighting at a lower cost than the next available alternative, which is generally kerosene lamps. The next common use is communication and entertainment (e.g., radio and television). A minority of homes, on the other hand, use electricity for cooking and refrigeration, except in Asia, where rice cookers and cold storage are of high importance. Figures A6.1–A6.3 illustrate uses of electricity in this study for domestic, public, and business purposes.

B. Time and Cost Savings

7. In the World Bank IEG study, benefits acquired by rural residents were estimated through fuel savings resulting from the use of electricity for lighting, as valued using willingness to pay and compared with the kilowatt-hour (kWh) costs from a diesel generator as well as the fuel quantity consumed by kerosene lamps. Time savings was likewise estimated and assessed on whether it was used for other productive and income-generating activities.

8. In Latin America, more appliance use (e.g., hot plates, flat irons, and sewing machines) at the household level increases productive hours by at least 20 minutes.[5] Access to electricity leads to more leisure time for men and children, but it also results in longer workdays, especially for women.[6] In South Asia, working hours increase at the household level with electricity and since cooking is delayed to evenings. The productivity of women making handicrafts has grown, as they use electric light at night, and has increased reading time among children and adults (footnote 5).

9. In Southeast Asia, the nonpoor usage pattern indicated high use of home appliances like televisions, refrigerators, sewing machines, and water pumps. While electrification does result in more work hours, it does not generate employment, because capital scarcity, poor product-marketing channels, and inadequate public information hinder business development

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[4] World Bank IEG. 2008. *The Welfare Impact of Rural Electrification: A Reassessment of the Costs and Benefits*. Washington, DC: World Bank.

[5] D. Barnes. 1988. Electric Power for Rural Growth: How Electricity Affects Rural Life in Developing Countries. *Rural Sociology. 54 (1)*: pages 132–135.

[6] A. Valencia et al. 1990. *Electrification and Rural Development—Electrification Project in the Rural Areas of Cusco, Peru.* Helsinki: Finnish International Development Agency.

(footnote 5). Entrepreneurship is limited to the production of popsicles and ice cubes.[7] In Sub-Saharan Africa, most rural electrification projects were in the forms of diesel generators and solar panels, both of which are expensive to maintain. Site selection was thus crucial, and typically included areas where economic activities were easy to stimulate.[8] In cases where solar panels were installed, annual income of at least $2,500 and a down payment of 20% of the connection fees were required. As expected, electricity is mainly used for lighting, and less than 10% of grid-connected customers use it for cooking. None of the solar-powered homes use electricity for lighting and entertainment (i.e., radio), as the voltage is insufficient.

10. In the People's Republic of China, candles and batteries have been replaced as main energy sources, but the cost of electricity is high. There has also been a 47% increase in the use of household electrical appliances for entertainment, communication, and information, despite customer dissatisfaction regarding power reliability and limited time. Fifteen percent of rural electrification beneficiaries use electricity for productive uses, generating additional income of €100–€200 (US$125-US$250). Workloads of men and women have been reduced by almost half, from 11–15 hours to 7–10 hours per day.[9]

11. In Bhutan, time savings has increased. Electricity is cheaper than most other fuel, including kerosene (this includes the opportunity costs of traveling to urban centers and towns to purchase kerosene and other fuel, which often takes half a day or more, and very often suffers from shortages). Less smoke and soot within houses mean that houses do not have to be painted as often as before; further, clothes do not have to be washed as often and thus last longer and cost less to maintain.[10]

12. In addition to fuel and time savings, ESMAP[11] approach was used to measure willingness to pay for the price of lumens[12] and the quantity of energy used. Assuming an electricity tariff of $0.05 per kWh, equivalent to a monthly bill of $0.36 for a 60-watt lightbulb used for 4 hours a day (equal to 7.2 kWh), the price of lumens is estimated at $0.004 per kilolumen-hour (kLh). In contrast, burning a kerosene lamp, which is assumed to have the same monthly cost, will yield $0.06 per kLh. Thus, moving from kerosene to electricity cuts the cost by more than 10-fold (footnote 4).

C. Productive Employment

13. The causal chain for the impact of rural electrification on rural development assumes that access to electricity (i) increases hours that household members put into businesses; (ii) increases use of equipment, tools, and thus productivity; (iii) improves community infrastructure required to bring in economic benefits; and (iv) results in increased profits, thanks to improved community environment, increased productivity, and extended hours of operation.

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[7] T. Meier. 2001. *Mini Hydropower for Rural Development: A New Market-Oriented Approach to Maximize Electrification Benefits—With Special Focus on Indonesia.* Berlin: Lit-Verlag.

[8] G. Foley. 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: Stockholm Environment Institute.

[9] F. Haugwitz. 2006. Renewable Energies in Rural Areas Program. Presented at the 21st European Photovoltaic Solar Energy Conference and Exhibition. Barcelona, 4–8 September.

[10] Asian Development Bank (ADB). 2003. *Performance Audit Report: Rural Electrification Project in Bhutan.* Manila.

[11] Based at the World Bank, Washington, D.C.

[12] A lumen is a measure of light emitted. A candle emits around 12 lumens; a kerosene lamp, 30–80 lumens; and a 60-watt lightbulb, 730 lumens. By using a single 60-watt lightbulb for 4 hours a day for 1 month, a household consumes 88 kLh.

The profits then provide additional capital for local industries that generate additional employment, as increasing personal expenditures that create opportunities for other livelihoods.

14. The World Bank IEG study used a living standard measurement survey to analyze the short-term growth and development impacts of rural electrification on microenterprises. Explanatory variables included were (i) household characteristics (e.g., housing index, education of household head, dependent–adult ratio, and household electricity status); (ii) entrepreneur characteristics (e.g., age, marital status, and education); and (iii) community characteristics (e.g., reservation wage as a proxy for opportunity cost of doing business, price of alternative fuels, and some infrastructure variables like distance to road). The variable used to measure hours devoted to microenterprises was the recorded average hours worked per week by each household member, by industry code.

15. The study showed limited evidence of the direct link between rural electrification and production, except regarding small-scale microenterprises. Electrification has a small but significant impact on the revenue earnings of microenterprises, possibly due to increased numbers of daily work hours by household members and the use of electrical equipment. Yet in cases where productive use is the priority for rural electrification projects, particularly regarding agriculture (e.g., irrigation and rice milling) and livelihood development, and is complemented by different development activities (e.g., hybrid seeds and fertilizer for the Green Revolution in India) as well as government policies (e.g., microfinance and subsidized tariffs), positive agricultural productivity results. For instance, increased crop production in India was partly attributed to rural electrification, because irrigation has been expanded through the use of electric pumps, and is also linked to the promotion of high-yield varieties of crops. In addition, the industrial sector benefits in terms of energy cost savings. Even when industrial electricity charges are three times those of agricultural electricity, they are still much lower compared to diesel. Such lower costs and higher productivity trigger business development in rural areas through additional capital and labor (footnote 5).

16. In Bangladesh, rural communities benefit from employment through direct hiring for rural electrification projects. About 5,800 persons were employed in construction firms and consulting offices working for these projects in 2000.[13] For production, however, the use of electricity has been minimal. Rural factories have opted to continue the use of their own diesel generators, despite being connected to the grid for power supply reliability. Yet the number of home businesses has increased, considering that access to electricity extended the work hours of home production activities as compared to the use of kerosene, diesel generators, and car batteries. The net benefit to rural development brought about by these home businesses, however, may be small, since the impacts were contained at the household level.

17. In Bhutan, there is no difference between electrified and unelectrified households regarding home-based livelihoods. This is because very few households use electricity directly for income-generating purposes; instead, they derive their incomes from the sale of agricultural and livestock products, which is more dependent on market accessibility. Moreover, lending patterns revealed that most farmers would avail of financing support to buy seeds, improve their houses, and purchase agricultural machineries, but not to start or expand a home-based industry. Nonetheless, rural electrification facilitates economic development in the surveyed villages through (i) development of microenterprises using electricity in post-harvest production (e.g., threshing) that extend beyond daytime hours; (ii) longer farm production times, and more

[13] United Nations Development Programme. 2002. *Bangladesh: Socio-Economic Impact of Rural Electrification Briefer.* Available: http://www.bangladeshgov.org

time for weaving, carpentry, and other household chores; (iii) longer operating hours of shops, which earn extra income by entertaining villagers with movies.[14]

18. Other studies showed that in Bhutan, beneficiaries have acquired additional revenue by engaging in income-generating activities at night such as weaving, carpentry, carving, and tailoring. In some instances, income from these activities, especially weaving, has increased by over 50%. Some wealthier households employ poor villagers as weavers on a contract basis, thus providing employment to the needy. In addition, electrically operated rice, flour, and oil mills increase income and employment opportunities. Small shops and bars have sprouted up in these areas and remain open after dark, thereby increasing commercial activities and social interactions. Beneficiaries have also begun using electrically operated grinders to produce chili powder that is marketed in urban centers and towns (footnote 10).

19. In Southeast Asia, rural electrification projects have prioritized those villages that were already relatively well developed and are typically located within a 10-kilometer radius of the district capital. Areas first targeted were near the grid; second, have renewable energy potential; and third, have diesel-generating sets. These projects were also not supported by pro-poor policies; thus, high upfront connection costs, high electricity tariffs, and subsidies for diesel discouraged residents to avail of electricity services. In some areas, solar panels to charge batteries to power lights and radios were installed instead (footnote 5).

20. In Latin America, the aggressive pro-poor programs of various governments have made rural electrification more effective in increasing productivity and augmenting household incomes, especially among cottage, micro, and small-scale industries. First, prioritization of electricity connection was determined through community ranking through cost–benefit analysis. Second, large subsidies were extended for the poor through social tariffs on lifeline customers of less than 30 kWh per month. Third, soft financing or concessionary connection fees were provided to rural cooperatives. Fourth, promotional activities on the benefits of electrification and uses of electrical machines, coupled with access to affordable credit, were extended to small businesses.[15]

21. In Sub-Saharan Africa, the main beneficiaries of rural electrification have been government employees, as the electricity supply is limited and is thus prioritized to support public services.[16] Consequently, no new businesses have emerged after electrification. On the contrary, the number of home business activities is even greater in unelectrified areas. In areas where rural electrification is targeted to promote agricultural development through irrigation and mechanization (e.g., oil pressing, milling, and grinding), on-farm small-scale activities have grown, such as dairy farming, horticulture, and piggery (footnote 4).

22. The implementation of rural electrification projects in Bangladesh has attracted other development partners in initiating complimentary programs. Physical infrastructure has improved, human development programs have been extended, skill trainings (especially on handicraft making) were conducted, and cross-cultural interchanges were facilitated. These dynamics subsequently have reduced migration toward urban areas and relieved rural residents of sluggish public infrastructure and amenities. With more agricultural productivity and

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[14] O. Bhandari. 2006. *Socio-Economic Impacts of Rural Electrification in Bhutan.* Master's thesis. Bangkok: Asian Institute of Technology.

[15] J. A. Shonder and T. J. Wilbanks. 1996. *Final Evaluation of the Central American Rural Electrification Support Project (CARES)*. Washington, DC: United States Agency for International Development.

[16] H. Mariam. 1992. Rural Electrification in Ethiopia. In V. Ranganathan, ed. *Rural Electrification in Africa*. London: Zed Books.

availability of farm-produced food items, health is also improved. One downside, however, is the rapid utilization of natural resources as inputs for production and land conversion for agricultural purposes (footnote 13).

D. Income and Expenditure

23. Rural electrification can lead to increased farm and nonfarm productivity, employment and income opportunities, and availability of wage goods, thereby raising mean income and consumption. However, as the United Nations Development Programme expounded, rural electrification is not a sufficient condition for income growth. Complementary infrastructure such as roads, transport, markets, buildings, equipment, and training and information—often not provided in tandem with electricity—are necessary to achieve economic benefits from electrification.[17] In general, rural electrification does not drive industrial development, but it can spur growth of home businesses and nonfarm activities. Such businesses mostly employ family labor and increase their hours once electricity becomes available. Electrification thus provides a small boost to the incomes of some households. However, the evidence for this point remains meager, as found by the World Bank IEG study.

24. In many developing countries, agricultural output fluctuates due to monsoons, which farmers depend on for irrigation. Rural electrification can boost agricultural output by inducing farmers to use irrigation equipment, tools, and high-yielding farm practices. An evaluation of World Bank-assisted rural electrification projects in Bangladesh and India found that rural electrification enhances the use of irrigation, reducing poverty incidence.[18] Another study,[19] using data from 85 selected districts of 13 states of India to examine the role of rural infrastructure in agricultural investment, found that electricity promotes investment in irrigation infrastructure. It also brought out that the availability of electricity, along with increased agricultural output, stimulates the growth of grain mills. However, the issue of whether electricity increases productivity and profitability through increased hours of operation and use of equipment and tools was not explored.

25. A United States Agency for International Development (USAID) evaluation of rural electrification in Bangladesh found that the average annual income of households with electricity is 64.5% higher than that of households in unelectrified villages, and 126.1% higher than households without electricity in electrified villages.[20] The overall average annual expenditure in the electrified households is more than the corresponding figure for the unelectrified households in electrified villages and for households in unelectrified villages. The study also found a positive impact on irrigation, agricultural production, business turnover, and commercial activities.

26. The World Bank IEG study (footnote 4), focusing on cross-sectional data from Ghana, Peru, Lao People's Democratic Republic, and the Philippines, found that access to electricity increases (i) hours that household members put into businesses; (ii) use of electrical equipment and tools, thereby increasing productivity; and (iii) profit coupled with improved community

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[17] E. Cecelski. 2004. *Rethinking Gender and Energy: Old and New Directions.* Leusden, Netherlands: International Network on Gender and Sustainable Development (ENERGIA).

[18] J. Songco, 2002. Do Rural Infrastructure Investments Benefit the Poor? *World Bank Working Paper No. 2796.* Washington, DC: World Bank.

[19] H. P. Binswanger et al. 1993. How Infrastructure and Financial Institutions Affect Agricultural Output and Investment in India. *Journal of Development Economics*. *41 (2)*: pages 337–366.

[20] A. Barkat et al. 2002. Economic and Social Impact Evaluation Study of the Rural Electrification Program in Bangladesh. Arlington, VA: Human Development Research Centre and National. Rural Electric Cooperative Association International.

infrastructure. Furthermore, it showed that areas with electricity have more home businesses, which are operated for longer hours and are more profitable. On the other hand, electricity has an insignificant effect on agricultural output and income. Of the 702 farm households surveyed, animal manure as fertilizer appears to be the only factor affecting agricultural production. However, as mentioned before, in other developing countries, electricity does play an important role in improving agricultural output and income.[21]

27. Two other recent World Bank studies, in Bangladesh[22] and Viet Nam,[23] examined the impact of rural electrification on farm income, nonfarm income, total income, and per capita expenditure. Both studies provided credible evidence in support of the positive impacts of rural electrification on income and expenditure. They tackled the issue of causality by employing robust econometric techniques, such as propensity score matching, instrumental variables, and difference-in-differences, to address endogeneity concerns.

28. Using a cross-sectional survey conducted in 2005 of some 20,000 households in rural Bangladesh, the first study (footnote 22) looked at the impact of rural electrification on household welfare. It found that rural electrification has positive impacts on farm income, nonfarm income, total income, and per capita expenditure.[24] Standard propensity score matching showed that electrification increases per capita expenditure and total income by 15.4% and 30.0%, respectively. Further disaggregated analysis found that farm income is increased by 72.9% and nonfarm income is increased by 90.3%. Instrumental variable estimates were qualitatively similar, but the magnitude of impacts was more modest. It showed that total income grows by 12.2%, and farm and nonfarm income by 52.1% and 22.9%, respectively. The study also found heterogeneous effects on rich and poor households, and concluded that physical capital makes a difference in the distribution of electrification benefits since rich households benefit more than poor ones.

29. The other study (footnote 23) evaluated the impacts of rural electrification in Viet Nam using a difference-in-difference design. To date, this is the first study that combined propensity score matching with difference-in-difference to estimate the socioeconomic impacts of rural electrification. Most studies relied on cross-sectional surveys, comparing households with and without electricity, which suffered from selection bias and endogeneity issues. By carrying out panel estimation, this study analyzed the impact of rural electrification on farm income, nonfarm income, total income, and per capita expenditure. It estimated three different models—simple difference-in-differences, difference-in-differences with fixed effect, and finally difference-in-differences with fixed effect and propensity score matching. In the simple difference-in-difference model, a positive and significant impact was found only on total income, but surprisingly, no impact was found on per capita expenditure.[25] A further disaggregated analysis of total income demonstrated an insignificantly negative impact on farm income and a positive

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[21] V. Ranganathan and T. V. Ramanayya. 1998. Long-Term Impact of Rural Electrification: A Study in UP and MP. *Economic and Political Weekly*. *33 (50)*: pages 3, 181–183, 184; and D. F. Barnes and H. P. Binswanger**.** 1986**.** Impact of Rural Electrification and Infrastructure on Agricultural Changes, 1966–1980. *Economic and Political Weekly*. *21 (1)*: pages 26–34.

[22] S. Khandker et al. 2009. Welfare Impacts of Rural Electrification: A Case Study from Bangladesh. *Policy Research Working Paper No. 4859*. Washington, DC: World Bank.

[23] S. Khandker et al. 2009. Welfare Impacts of Rural Electrification: Evidence from Viet Nam. *Policy Research Working Paper No. 5057*. Washington, DC: World Bank.

[24] Economic outcomes used in the paper were in log form.

[25] The study did not discuss the reasons for insignificant effect on per capita expenditure and negative effect on nonfarm income.

impact on nonfarm income.[26] Electrified households have 36.2% higher total income and 70.0% higher nonfarm income than unelectrified households.

30. To improve the simple difference-in-differences, the study estimated a fixed-effect model by extending the difference-in-difference method by adding household- and commune-level covariates as additional dependent variables. Rural electrification impacts from the more rigorous fixed-effect model were different from the simple difference-in-difference impacts. According to this model, farm income increases by 30% and is statistically significant; however, no impacts on nonfarm income are found—in fact, rural electrification has a negative impact on nonfarm income. One possible reason could be the use of electric pumps that may have dramatically improve farm productivity.[27] Total income increases by 25%, and, in contrast to the simple difference-in-difference model, per capita expenditure increases by almost 10% due to electrification.

31. Furthermore, the study improved the fixed-effect model by using a propensity score matching method.[28] First, it matched households with similar characteristics and then used fixed effect with difference-in-difference for samples of matched households. Results from this model were not different from the previous model with difference-in-difference plus fixed effect, suggesting that matching did not improve the model. For electrified households, total income is 25% higher and farm income is higher by 30%. Surprisingly, no significant impacts were found on per capita expenditure and nonfarm income. The study also examined if the welfare impacts differed with respect to length of exposure to electricity. It found that for farm income and per capita expenditure, early connectors gain more than late connectors. There were no differential impact on schooling outcomes, total income, and nonfarm income between the two groups.[29]

32. Taken together, these findings suggested that the economic impacts of rural electrification on income and per capita expenditure are unclear. Only a few studies have demonstrated a positive impact on total income and per capita expenditure, whereas impacts on farm and nonfarm income remain an open research question.

E. Education

33. Rural electrification may affect education by (i) improving the quality of schools, either through the provision of electricity-dependent equipment, or increasing teacher quantity and quality; and (ii) better time allocation at home, with increased study time, though the availability of television may decrease that time (footnote 4).

34. Rural schools in developing countries often lack basic equipment and infrastructure, such as furniture, textbooks, classrooms, toilets, and drinking water, but electricity may not directly affect his. It may indirectly address these constraints if there is an overall development of the electrified village for various reasons, such as social awareness due to media exposure, allocation of more government funds, and effective use of government funds. Further, primary schools in developing countries are characterized by high teacher absenteeism, which may be due to many teachers failing to take up jobs in remote and rural villages, or due to weak teacher

[26] T-statistics for impact of rural electrification on nonfarm income was 1.66.
[27] Viet Nam data showed a much higher level of use of electric pumps by electrified households than by unelectrified households.
[28] The study used double difference with fixed effect on a matched sample created by using propensity score matching.
[29] Heterogeneous impacts were examined for the electrified households only.

incentives.[30] The World Bank IEG study (footnote 4) provided evidence that the availability of electricity makes rural positions more attractive to teachers. Electricity may also have an impact on education through increased study time at home due to high-quality bright light. Children's efficiency and productivity increase when they study under a bright light compared to a dim flickering candle or wick lamp.

35. The World Bank IEG study(footnote 4), based on demographic and health survey data from nine countries, used a Cox proportional hazards model, where the hazard is dropping out of school, to estimate the impact of rural electrification on children's dropout rates. The study reported that rural electrification indirectly improves the propensity of children to stay in school. However, it could not confirm that this effect is mediated through an increase in reading and studying hours due to illumination after dawn.

36. Some evidence suggests that rural electrification leads to an increase in the years of schooling for school-aged children, though the impacts are more pronounced for boys. The World Bank Bangladesh study (footnote 22) studied the impact of rural electrification on years of completed schooling and on study time. Depending on estimation methods, it found that boys' completed years of schooling increase by 0.09–0.27 years. For girls, the study found a positive impact on years of completed schooling, and the estimates varied from 0.12 to 0.36 grades.[31] They also investigated the impact of rural electrification on study time, and results suggested that boys' study time increases by 4.9 to 18.2 minutes per day, whereas girls' study time increases by 8.9 to 17.0 minutes per day, depending on estimation methods. Overall, the impacts on completed years of schooling and study times were positive and highly significant in Bangladesh.

37. The similar study in Viet Nam (footnote 23) investigated the impact of rural electrification on school enrollment and completed years of schooling. It found a significantly positive impact on boys' completed years of schooling but an insignificant effect for girls. The impact on boys' completed years of schooling vary from 0.52 to 0.67 years. Girls' completed years of schooling in electrified households increase by 0.14 to 0.39 years, but these impacts were insignificant. It should be noted that impact on girls' completed years of schooling is similar in Bangladesh and Viet Nam, whereas in the case of boys, the impact in Viet Nam is greater than the impact in Bangladesh. The Viet Nam study also found that school enrollment in electrified households is about 11% and 10% higher for boys and girls, respectively.

38. The ESMAP study found that children in electrified households have almost 2 years more schooling than children in unelectrified households (8.5 versus 6.7 years).[32] However, this estimate was based on single difference and did not control for other individual, household, and community factors. The study also showed that the availability of electricity in a household has no significant effect on adult and children's propensity to read and to study, after controlling for factors such as housing index, education, and age of the head of household. However, once individuals chose to read or study, electricity increases the time that children spend studying by 77 minutes, and the time that adults spent reading by 27 minutes.

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[30] Chaudhury, N.I., J. S. Hammer, M. Kremer, K. Muralidharan, and F.Rogers. *Missing in Action: Teacher and Health Worker Absence in Developing Countries*. Available: http://econ.worldbank.org/external/default/main?theSitePK=477916&contentMDK=20661279&pagePK=64168182&piPK=64168060. The authors found that primary schoolteachers were absent 27% of the time in Uganda, 25% in India, 14% in Ecuador, and 11% in Peru.

[31] The children's sample was 5–18 years old.

[32] ESMAP. 2002. Rural Electrification and Development in the Philippines: Measuring the Social and Economic Benefits. *ESMAP, Report No. 255/02.* Washington, DC: World Bank.

39. The ESMAP study used the Heckman procedure[33] to estimate the effect of rural electrification on children's studying and reading. It found that electricity has a negative effect on children's propensity to read or to study, which, in turn, is presumed to be caused by more time spent watching television and on other forms of entertainment. However, conditional on the decision to study, electricity increases the time spent reading or studying for children and adults by 48 minutes per day and 15 minutes per day, respectively. Finally, the World Bank IEG study found that electricity has a positive impact on education in rural areas, even after controlling for parental and community factors.

40. In general, there is an increase in educational activities after electrification. Study time at school is extended either by providing longer library services or by holding night classes. In Bhutan, for instance, more students are studying for longer durations in electrified villages. Further, nonformal education at night is available to accommodate villagers. The extended evenings, presence of television, and the ability to attend nonformal education facilitate higher literacy and school enrollment rates. In addition, rural electrification shifts some household chores to the nighttime, thus enabling children to attend to school during the daytime (footnote 20). Increased literacy rates in rural Bangladesh, however, are attributed not only to rural electrification but also to an accompanying mass education program. Poor workers are encouraged to attend night school after their regular household chores or farming activities.

F. Health

41. More than 2.6 billion people rely on traditional biomass fuels for cooking and heating purposes (footnote 4), and the burning of solid fuels results in high levels of toxic pollutants in cooking and heating areas. As such, the use of these fuels is considered a major risk factor for lung cancer as well as cardiovascular and respiratory diseases.[34] The available evidence suggests that the indoor air pollution from biomass fuels and traditional cooking stoves may be a serious health threat, particularly to women and young children who spend a considerable amount of time near stoves. Worldwide, 1.3 million premature deaths per year are directly attributed to indoor air pollution from the use of biomass fuels, with more than half of these deaths of children under age 5 years.[35] After contaminated water, solid fuels are the most common environmental cause of disease.[36] Several studies confirmed that exposure to smoke from the burning of traditional solid fuels for cooking and heating increases the risk of diseases, most notably acute respiratory infections, in both children and adults.[37] Further, particulate matters emitted by kerosene lamps is above the 24-hour mean standard of the World Health Organization (WHO) (footnote 4). Since these particles do not disperse, burning a kerosene lamp for 4 hours can result in concentrations several times the WHO standard. The estimates

[33] The Heckman procedure is a two-stage analysis; the first stage is the choice to read, and the second step analyzes the reading levels of a selected sample of readers.

[34] World Health Organization (WHO). Indoor Air Pollution. http://www.who.int/mediacentre/factsheets/fs292/en/index.html

[35] International Energy Agency. 2008. World Energy Outlook. Paris.

[36] N. Bruce et al. 1998. Indoor Biofuel Air Pollution and Respiratory Health: The Role of Confounding Factors among Women in Highland Guatemala. *International Journal of Epidemiology. 27 (3)*: pages 454–458.

[37] K. Smith et al. 2000. Indoor Air Pollution in Developing Countries and Acute Lower Respiratory Infections in Children. *Thorax. 55 (6)*. pages 518–532; WHO. 2002. Addressing the Links between Indoor Air Pollution, Household Energy and Human Health. Based on the WHO–USAID Global Consultation on the Health Impact of Indoor Air Pollution and Household Energy in Developing Countries meeting report. Washington, DC, 3–4 May 2000; and M. Ezzati and D. M. Kammen. 2001. Quantifying the Effects of Exposure to Indoor Air Pollution from Biomass Combustion on Acute Respiratory Infections in Developing Countries. *Environmental Health Perspectives. 109 (5)*: pages 481–488.

show that where rural electrification can help in the replacement of kerosene lamps alone, there is a quantifiable health benefit of $2.50 per day per household.

42. The access to electricity is understood to reverse this health risk through increased use of electrical appliances for cooking and heating purposes. The health benefits from rural electrification operate through a number of health channels: (i) improvements to health clinics; (ii) better health from cleaner indoor air as households reduce the use of polluting fuels for cooking, lighting, and heating;[38] (iii) improved health knowledge though increased access to television; and (iv) better nutrition from improved knowledge, and storage facilities from refrigeration (footnote 4).

43. Using data from a 2000 living standard and measurement survey in Guatemala, one study[39] found that the incidence of respiratory illnesses is higher among households that use fuelwood for cooking and heating purposes. Another study[40] showed that the unadjusted odds of having suffered from acute respiratory infections are almost twice as high among children who live in households using high-pollution biomass fuels than among those living in households using low-pollution natural gas or electricity for cooking.

44. The ESMAP study (footnote 32) reported that electrified households experience fewer incidences of coughing, wheezing, fever, and shortness of breath. The study also examined the impact of electrification on incidences of missing work due to illness, and it found an insignificant relationship between electricity presence in the area and number of sick days reported. Due to complex relations among health, lifestyle, environment, and infrastructure, it is difficult to establish that fewer reported sick days by electrified households is thanks to electricity.

45. In general, however, there has been very little impact on indoor air quality improvement; fuelwood remains the main source for cooking in many rural communities. In Bhutan, it is difficult to isolate the impact of electricity on indoor air quality. First, a stove serves both to cook and to heat. Second, the government initiated pollution reduction programs, such as one that encouraged more fuel-efficient cooking stoves, which improved emissions (footnote 14). In Southeast Asia, although electricity is not used for cooking, rural residents have climbed up the energy ladder from fuelwood to kerosene (footnote 5). As such, indoor air quality has somehow improved, with lesser particulate emissions.

46. For community uses, health clinics can directly benefit from rural electrification by (i) having longer operating hours, and (ii) having equipment that requires electricity. The most claimed benefit is that it helps preserve the cold chain for vaccines. However, the World Bank IEG study revealed that immunization services in general do not differ between electrified and unelectrified health clinics. Thus, while rural electrification can help bring down the cost of providing immunization services, it does not necessarily translate to increased immunization rates in the short term. Nonetheless, in most cases, the number of health clinics has increased over time, all of which are equipped with adequate lighting and cold storage for vaccines.

47. In Bhutan, the electrification of health clinics has resulted in more effective, efficient provision of medical services. Vaccines and medicines are now kept refrigerated and readily

[38] G. Hutton et al. 2006. Evaluation of the Costs and Benefits of Household Energy and Health Interventions at Global and Regional Levels. Geneva: WHO.
[39] K. Ahmed et al. 2005. Environmental Health and Traditional Fuel Use in Guatemala. *Directions in Development Series.* Washington, DC: World Bank.
[40] V. Mishra. 2003. Indoor Air Pollution from Biomass Combustion and Acute Respiratory Illness in Preschool Age Children in Zimbabwe. *International Journal of Epidemiology. 32 (5)*: pages 847–853

available. Residents no longer go to faraway health clinics for vaccinations and basic medical treatment, which saves them time and money on transport and lost wages. Sterilization has improved with the use of electrical apparatus, and the use of electrified suction machines makes labor and delivery safer and more efficient. Outside of health clinics, electricity enables mothers and midwives to deliver babies at home more easily and safely (footnote 14). However, the frequency of hospital visits in both areas does not differ, even though emergency medical services in electrified villages have been extended, even at night.

48. In Sub-Saharan Africa, new and improved health centers now operate on cheaper and more efficient electricity, as compared with diesel generator sets.[41] A decline in the crude death rate has been observed for the past 10 years in the region, but its association with electrification is not well established.[42]

49. Moreover, residents from electrified villages are more aware of major health issues such as HIV/AIDS, child vaccination, and the use of oral rehydration salts thanks to television access. This increased awareness has resulted in changed health behaviors and practices (i.e., sanitation and hygiene), which eventually improved health outcomes. However, the assumption that electrification reduces fertility is not well established. Although access to electricity may prolong waking hours for longer television viewing and radio listening periods, which is believed to provide an alternative to sexual activities, longer waking hours may also increase sexual activities. Yet by taking the total effect based on the combination of the direct impact from the fertility equation and the indirect impact via more knowledge,[43] calculations showed a median impact of a fertility reduction by 0.6 children as a result of electrification.

50. In most cases, the use of electric water pumps has reduced the incidence of waterborne diseases as well as saved time for water collection and treatment. In Bhutan, the staple food in the country requires extensive cooking, while water for drinking needs to be boiled to prevent disease. Also, the hygiene of the beneficiaries has also improved significantly; they find that it is now much easier and requires less time and effort to keep themselves and their homes and clothes cleaner.[44]

51. The use of refrigerated food storage may directly affect nutrition in a positive way, while knowledge acquired from entertainment media may indirectly improve food choices and preparation. Using the height for age z score and weight for age z score for long-run and short-run nutritional status, respectively, the World Bank IEG study showed that refrigerator ownership is significantly positive in Latin America, South Asia, Southeast Asia, as well as Sub-Saharan Africa (footnote 4).

G. Female Employment

52. Rural electrification can have differential effects on labor outcomes. Access to modern fuels and electricity is often argued to have gender-specific effects on labor outcomes. In

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[41] D. Walubengo and A. Onyango. 1992. *Energy Systems in Kenya: Focus on Rural Electrification.* Nairobi: Kengo Regional Wood Energy Programme for Africa.

[42] B. R. Ramasedi. 1992. *Rural Electrification in Botswana.* In V. Ranganathan, ed. *Rural Electrification in Africa*. London: Zed Books.

[43] The indirect impact of electrification from higher knowledge is estimated using 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.

[44] ADB. 1995. *Report and Recommendation of the President to the Board of Directors: Proposed Loan and Technical Assistance Grant to Bhutan for the Rural Electrification Project*. Manila.

Becker's[45] canonical model of time use and Willis's[46] model of fertility, home production, and female labor supply, households use time and market goods to produce time- and goods-intensive commodities. The arrival of infrastructure for domestic electricity may be characterized as a positive shock to time productivity.[47] Labor-saving electrification increases the effective amount of labor available for producing commodities; it reduces the need to fetch wood, speeds up cooking time, and allows households to shift activities from daytime into nighttime. This induces income and substitution effect.

53. The net effect on labor supply is determined by the time preference of women, as women may increase their leisure time and prefer to stay with their families rather than join the labor market. Women, who have a high value of marginal product in the home due to child care responsibilities, are less likely to enter the labor market for a given shock to home production technology. Households relying on highly inefficient production technologies experience more labor savings with the advent of electricity than other households; hence, the cost of time in the home falls more dramatically for these women. The work of Becker, Willis, and Gronau[48] indicated that whether electrification leads to increases in short-term labor supply is an empirical question, and one should expect differential effects for different types of households. However, there is a paucity of studies that provide empirical evidence on whether or how electricity affects employment of women engaged in time-intensive home production.

54. Dinkelman[49] investigated the impact of domestic electrification on employment in rural South Africa, where more than 60% of households still rely on wood for basic energy needs. By exploiting community-level variation in project timing, the study found that employment rates are between 0.9 percentage points lower for men and 0.1 percentage point higher for women in electrified communities. Instrumental variable results suggested that female employment rises by a significant 13.5 percentage points (lower bound of 5.0 percentage points, upper bound of 45.0 percentage points) in treated areas, while the change in the male employment rate is not statistically significantly. These positive, significant changes for women are notable, since over the same period, national employment rates fell.

H. Deforestation

55. It has been argued that electrification of rural homes and businesses reduces their wood and biomass fuel use, and that this translates into less deforestation. The evidence on the impact of rural electrification on fuelwood use and deforestation is scant, however. Many rural households continue to use fuelwood due to cultural significance and are reluctant to abandon it in favor of electricity for cooking. Several studies have reported that electrified and unelectrified households both continue to use fuelwood and kerosene for cooking and heating, but the amount of traditional fuels is less in electrified households. A socioeconomic study in Namibia[50] found minor impact of rural electrification on deforestation. The study also found that access to electricity reduces consumption of and demand for other energy sources, but very few households made a complete switch to electricity. For the majority of electrified households,

[45] G. Becker. 1965. A Theory of the Allocation of Time. *Economic Journal. 75 (299)*: pages 493–517.
[46] R. Willis. 1973. A New Approach to the Economic Theory of Fertility Behavior. *Journal of Political Economy. 81 (2)*: pages S14–S64.
[47] R. T. Michael. 1973. Education in Nonmarket Production. *Journal of Political Economy. 81*: pages 306–327.
[48] R. Gronau. 1986. *Handbook of Labor Economics.* Vol. I. Amsterdam: Elsevier Science Publishers.
[49] T. Dinkelman. 2007. *Can Rural Electrification Jumpstart Employment? Evidence from KwaZulu-Natal, South Africa.* Princeton, NJ: Department of Economics, Princeton University.
[50] Norwegian Agency for Development Cooperation (Norad). 2008. Impact Assessment : Norad-Funded Rural Electrification Interventions in Northern Namibia, 1990–2000. Oslo.

fuelwood is still the preferred energy source for cooking (mostly for cultural reasons), and most still use at least some candles, batteries, paraffin, and/or gas as an alternate source of energy.

56. One study in South Africa[51] found that almost a decade after the introduction of electricity, over 90% of households still use fuelwood for thermal purposes, especially cooking, and the mean household consumption rates over an 11-year period had not changed, even with 6 kWh per month of free electricity. The proportion of households purchasing fuelwood increased, probably in response to a number of factors, including (i) increased fuelwood scarcity in the local environment as reflected by increased fuelwood collection times, changes in fuelwood species preferences, and ranking of scarcity by local collectors; and (ii) increases in the price of fuelwood well below that of other fuels and the prevailing inflation rate.

I. Environment and Safety

55. Electricity, aside from bringing comfort and convenience, is also making lives safer and easier in rural communities. In the forest of Sri Lanka or the mountains of Bhutan, electric light offers protection against potential predators, human or animal. Villagers reported that snakes—often venomous—left their homes after electricity was installed.[52]

56. Another benefit is based on the reduction of fire risks and incidence. In Bhutan, rural electrification beneficiaries mentioned instances in the past where their children accidentally drank kerosene. Villagers also cited instances when children unintentionally tumbled on kerosene lamps and burned themselves. Candles or kerosene lamps used for lighting were sometimes left unattended (especially at bedtime) and caused house fires. The frequency of such accidents, however, decreased after electrification (footnote 14).

57. In addition, some rural electrification beneficiaries in Bhutan stated that electricity assists them in protecting their harvest from wild animals. Prior to electrification, villagers said that a few weeks before the harvesting season begins, they would have to stay up all night keeping vigil on their crops and chasing away wild animals from their fields to avoid their crops from being consumed or damaged. Some studies estimated that crop loss due to pests is as high as 40% in certain regions. To protect their crops, most villagers build a small bamboo-matted shelter on stilts in their fields and spend the nights there to ensure that their crop is safe from the animals. With electricity, villagers have begun extending electrical lines outside such shelters and lighting up a bulb or two. This seems to deter pests from coming to their fields (footnote 14).

58. In Latin America, moreover, more streetlights have been installed after electrification, resulting to lower crime incidences, especially at night (footnote 6).

59. In general, rural electrification also contributes to the reduction of carbon dioxide emissions. Both grid-extension and off-grid rural electrification projects displace or reduce the use of polluting fuels, like kerosene, in lighting and charcoal or wood in cooking. Estimating these benefits, however, posed a challenge, given the absence of baseline emissions for the displaced fuels and the rate of reduction over time. Similarly, there is no evidence that forest depletion has been reduced, as most residents in Asia, Latin America, and Sub-Saharan Africa

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[51] M. Madubansi and C. M. Shackleton. 2007. Changes in Fuelwood Use and Selection Following Electrification in Bushbuckridge Lowveld, South Africa. *Journal of Environmental Management. 83 (4)* : pages 416–426.

[52] ADB. 2008. *Powering the Poor: Projects to Increase Access to Clean Energy for All.* Available at: http://www.adb.org/Documents/Books/Powering-the-Poor/Powering-the-Poor.pdf

have resorted to commercial production of fuelwood and other wood-based industries (footnote 15).

J. Institutions

60. Rural electrification in Latin America favors the poor by prioritizing those areas where benefits would be greatest and extending power tariff subsidies in such areas. In Peru, large subsidies, which were more than 20 times less than the real cost, are provided to the poor who use up to 30 kWh per month of electricity (footnote 6). In Costa Rica, rural cooperatives are given concessionary connection fees to those living below the poverty line.[53] To further reach remote areas and promote lower energy costs among them, tapping renewable energy sources are incorporated in the rural electrification plans, while consortiums with the private sector and cooperatives for building hydro and wind power plants have been considered (footnote 53).

61. In South Asia, government policy feels that electricity should be used for agricultural and rural productivity, specifically water pumping for irrigation and powering of rice mills.[54] With the advent of electrification, medical personnel have displayed a higher likelihood of living in communities, which, in turn, reduces absenteeism and increases provision of public services.[55] Most rural electrification projects have been accompanied by public information dissemination to educate rural residents on new ways of using electricity for residential, agricultural, and commercial purposes.[56] The Asian Development Bank (ADB), for instance, typically has corresponding assistance for the strengthening of national electricity utilities or rural electricity cooperatives for effective planning and programming, efficient power tariff structuring and collection, and operational organization.

62. Due to the remoteness of rural electrification project locations, ensuring their sustainability in terms of operation, maintenance, and tariff collection remains a challenge. Thus, most of these projects are complemented with community mobilization and organization to form local cooperatives (i.e., village power associations) composed of household beneficiaries. These cooperatives are then trained in basic engineering and elementary finance.

K. Summary

63. The review of existing literature on the impact of rural electrification suggests that rural electrification has had significantly positive impacts on many economic, social, and health outcomes. The most common economic outcomes measured in the literature were farm income, nonfarm income, total income, and per capita expenditure. Studies found significant and positive impact on income and expenditures, significantly positive impacts on farm income and total income, and surprisingly, no significant impacts on nonfarm income and total expenditure. Studies have also found an impact on opening on new businesses, investment in irrigation, long working hours, and higher profits.

64. The review shows that rural electrification had a positive impact on the incidence of health risks due to burning of solid fuels. Outcomes related to health, respiratory ailments,

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[53] D. Barnes, ed. 2007. *The Challenge of Rural Electrification: Strategies for Developing Countries.* Washington, DC: Resources for the Future.
[54] D. Barnes and H. Binswanger. 1986. Impact of Rural Electrification and Infrastructure on Agricultural Changes, 1966–1980. *Economic and Political Weekly (India). 21 (1)*: pages 26–34.
[55] N. Chaudhury and J. Hammer. 2003. Ghost Doctors: Absenteeism in Bangladeshi Health Facilities. *World Bank Research Working Paper No. 3065.* Washington, DC: World Bank.
[56] World Bank. 2008.

eye irritation, and cough were the most commonly studied. It also showed a positive impact of rural electrification on educational outcomes, which was mediated through better lighting and better health due to reduced smoke and soot. Several studies have found that children's school enrollment and years of completed schooling improved as a result of electrification. The amount of study time at home also was benefited by electrification. The review shows many other outcomes, such as female labor employment, fertility, child mortality, gender empowerment, and general awareness, as being sparse

65. There are several gaps in the literature on the impact of rural electrification on developmental outcomes. Most of the studies have shown the correlations between rural electrification and outcomes. The majority of the impact evaluation of rural electrification has been plagued with econometric challenges, and only a few studies have carefully addressed the issue of endogeneity. More studies are needed to establish the causal link and the mediating factors that help achieve the full benefits of rural electrification.

66. Further, most studies collected subjective information regarding the incidence of health risks. A more objective measure of health benefits is needed, and collecting information on health expenditures could address this issue somewhat.

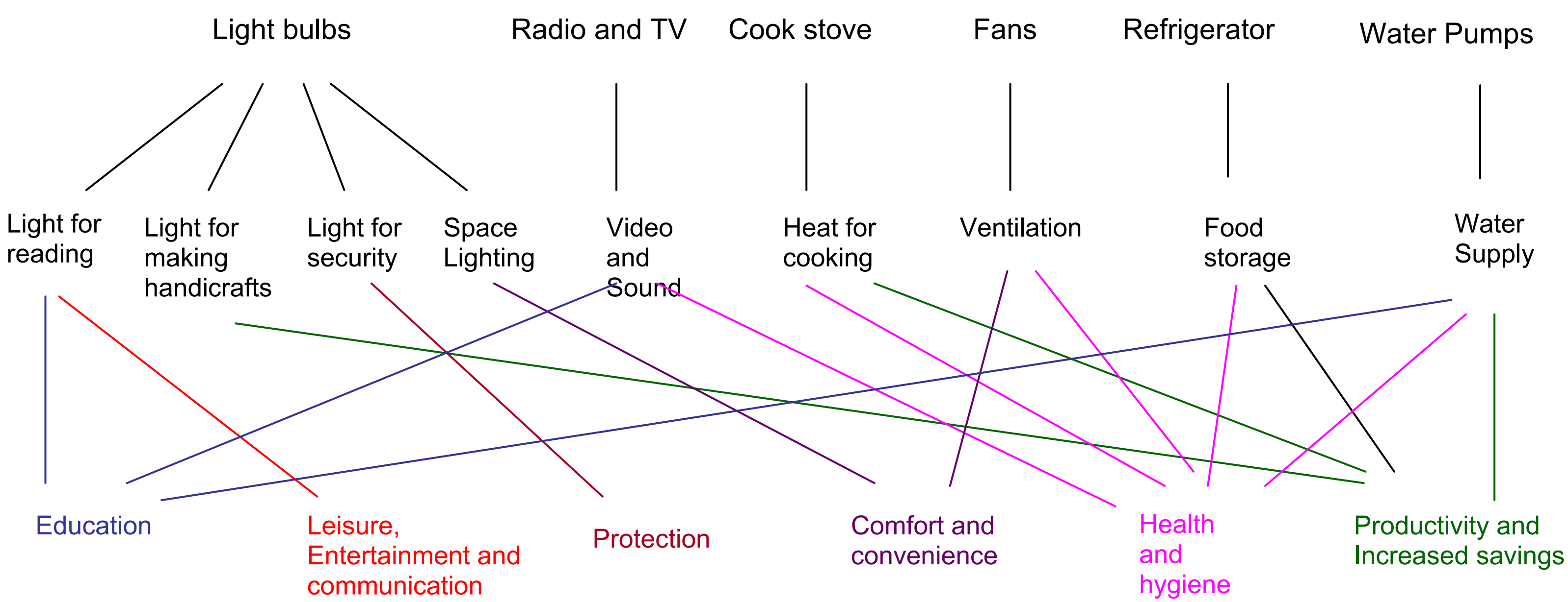
67. Estimating rural electrification benefits on education has likewise been challenging, as other factors such as household income, availability of school facilities, distance between home and school, teacher absentee patterns, and parent education must be included in the equation. While there is no doubt that electrification extends study time, there is no concrete evidence that follows through the causal chain where rural electrification leads to better education and higher educational attainment.

68. Electricity used for the provision of public services in schools, clinics, offices, and street posts benefits both the poor and nonpoor alike. The optimal level of these benefits, on the other hand, is dependent on the availability of the necessary electrical equipment and supplies, as well as the participation of public staff. Benefits accruing from security and safety both on human lives and property, on the other hand, are often left unnoticed and undervalued.

69. Meanwhile, rural electrification projects intended to foster rural development through agricultural productivity have resulted in greater benefits in terms of income generation, employment, and capital formation, as much as they have also generated migration. Electrification projects that are not targeted to the poor and not complemented with rural development strategies and programs have shown little or no impact as compared with electrified communities.

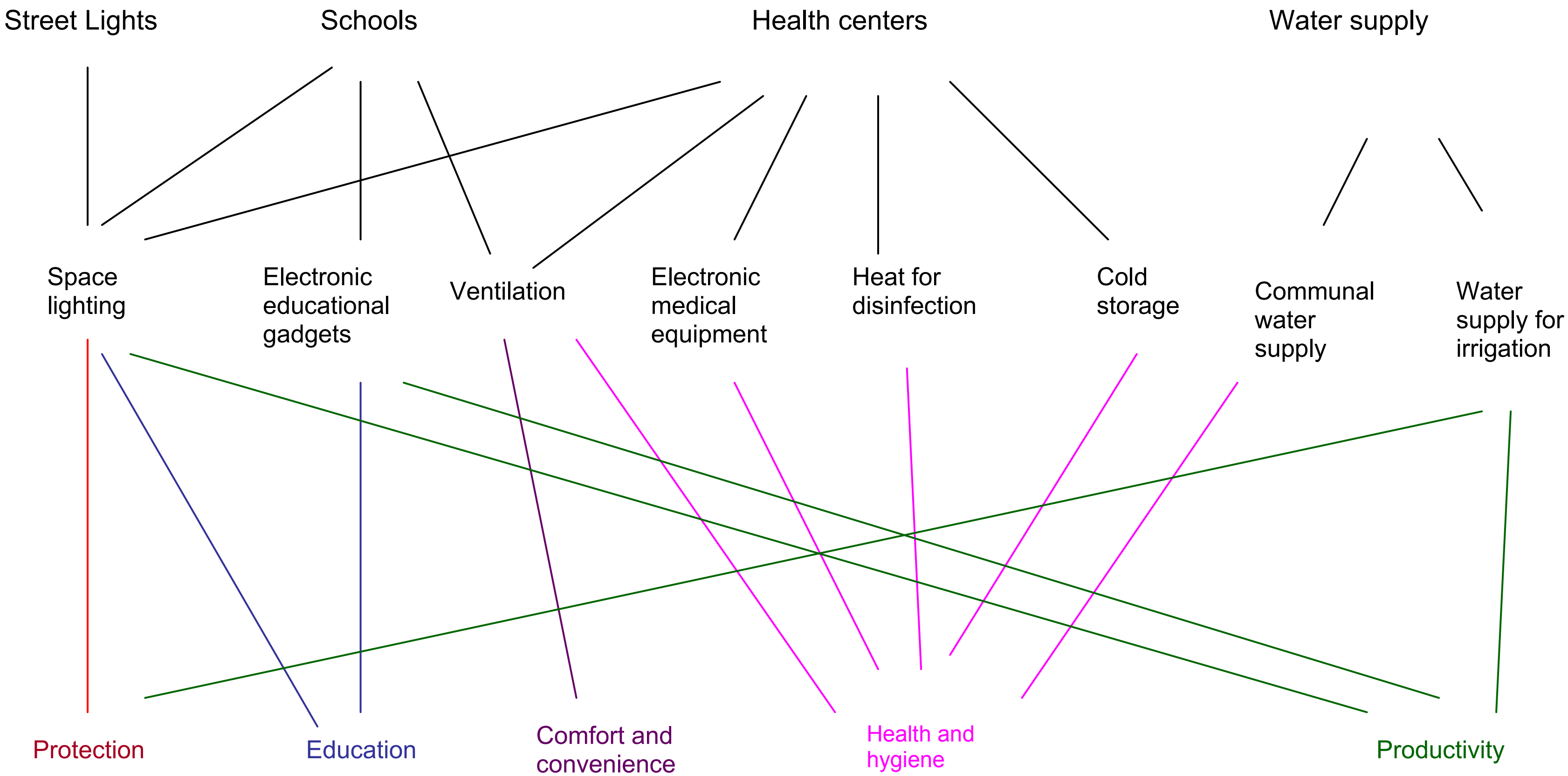
70. Lastly, the methodology for estimating the climate change mitigation benefits of rural electrification has not been fully established. The standard on how carbon reduction emissions from energy substitution will be calculated is yet to be made clear, and the approach on gathering baseline data for each energy source based on usage patterns in rural areas is still to be determined.

Figure A6.1: Electricity Use in Rural Households



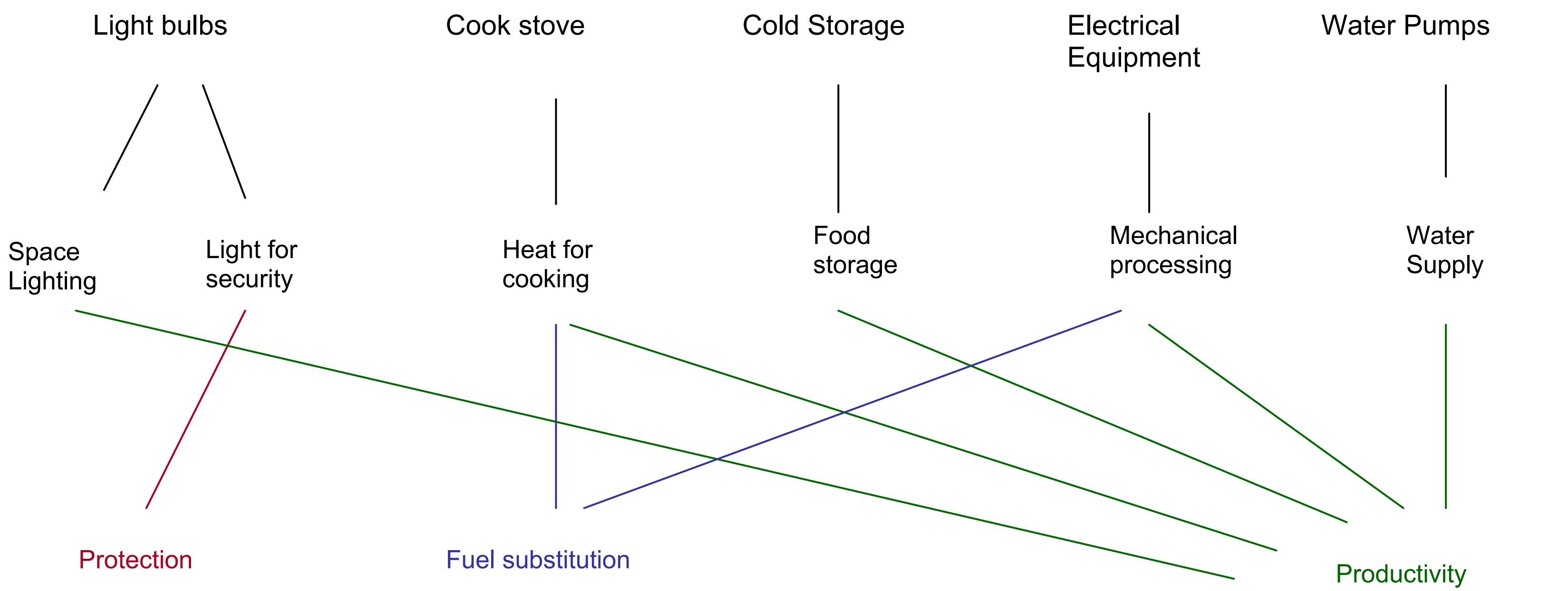
Notes:
Light is also be used for reading entertainment magazines and newspapers (Valencia, 1990)
Light for security provides protection.
Light for making handicrafts increases productivity, especially among women (Barnes, 1988).
Space lighting adds to productivity, since some activities could be done in the evening, thus extending working hours (Barnes, 1988)
Video and audio provide access to information that leads to nonformal education.
Video and audio also build up knowledge about health and hygiene, especially among women.
The use of electric stoves for cooking substitutes the use of fuelwood, thus improving indoor air quality
The use of electric stoves also speeds up food preparation, thus extending working hours (Barnes, 1988)
Food preservation reduces time in food preparation, thus extending working hours (Barnes, 1988)
Water supply enhances health and hygiene, and decreases time for water collection especially among children and women, resulting in better education (i.e., lower absenteeism, longer study time) and productivity.

Figure A6.2: Electricity Use in Public Rural Communities



Notes:
Street lighting led to fewer attacks at night (Valencia, 1990).
Productivity of teachers was enhanced through the used of electronic teaching media while teachers were encouraged to reduce absenteeism (Chaudhury, 2003) and hold night classes with better space lighting (Barnes, 2007)
Productivity of medical staff was improved with the use of electronic medical equipment while working hours were extended with better space lighting (Ramasedi, 1992).
Water channeled to productive uses minimizes the occurrence of flood (Barnes, 2007)

Figure A6.3: Electricity Use in Rural Enterprises



Notes:
Protection includes pest management and animal attacks (ADB Loan 1375, PPAR).
Other studies noted indirect effects like expansion of product range in existing shops to include selling of lightbulbs, electrical wiring, kerosene for cooking (as substitute for fuelwood), and ice cubes (Meier, 2001).
There has been significant growth in small-scale activities such as steel making (Barnes 2007), horticulture, dairy farming, and pig raising with the use of electricity (Ramasedi, 1992)
Setting up of new shops and expansion of production and product range (especially in larger firms) engendered a structural shift in employment to the tertiary sector (Barnes and Binswanger, 1986).
Mechanical processing, like in coffee processing, increased production by 35%–40% (Mariam, 1992).
Diesel motors have been replaced by electric ones, which are cheaper and more efficient (Walubengo and Onyango, 1992).

METHODOLOGY AND STUDY DESIGN

1. The benefits of electricity have been discussed in several studies,[1] and rural electrification is widely considered to be a prerequisite to development. Electricity increases the productivity of farm and nonfarm activities; facilitates household tasks; provides an efficient, clean lighting source; and enables provision of improved social services, such as education and health care.[2] However, despite the expanded efforts of international donors and development agencies in evaluating rural electrification, few studies provide credible estimates of its impact on human welfare. Due to this lack of quality data and tricky identification issues, very little is known about what effects it has at the household level.

2. This impact evaluation study focuses on the impact of rural electrification in three broad areas: (i) economic, (iv) environmental, and (v) social. The model envisages that due to improved income-generating opportunities and reduced use of fuelwood and kerosene, access to electricity results in higher household incomes and lower energy expenditure (i.e., economic impacts). Since rural electrification leads to lower consumption of fuelwood, it also improves indoor air quality and reduces deforestation, (i.e., environmental impacts). Institutional impacts include better consumer satisfaction and better financial position of implementing agencies. Regarding social issues, impacts include health, education, and enhanced safety and security. It can reduce the incidence of respiratory ailments and other health risks associated with use of solid fuels and fuelwood. It can also have an impact on educational outcomes through increased study time at home for children due to better lighting, resulting in the improved school performance and better-quality graduates. Due to better lighting as a result of electrification, lower incidences of crime and reduced damages by wild animals are also expected. Finally, rural electrification may have an impact on gender empowerment by balancing gender roles and control over financial resources.

3. Besides the project input, which is access to electricity, nonproject factors are also considered, such as individual-, household-, and village-level characteristics, which may contribute to realizing the benefits of rural electrification. The main nonproject characteristics included age, gender, education, and wealth. At the village level, the availability of public goods, such as schools, hospitals, and roads; size and population of the village; and distance from the district headquarters are included in the analysis.

4. The fundamental concern with an impact assessment study of rural electrification is causality. Causal models are necessary to link access to electricity with desired outcomes such as improved household health, education, or income. Adequately addressing endogenous

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[1] For details, see Unnayan Shamannay and Development Design Consultants Ltd. 1996. *A Socioeconomic Impact Evaluation of the Rural Electrification Program in Bangladesh*. Final Report to NRECA/Sheladia Associates, Inc. Dhaka; Cabraal, A., and D. Barnes. 2006. Productive Uses of energy for Rural Development. *Annual Review of environment and Resources: Vol. 30 pages 117–144*; Barnes, D., H. Peskin, and K. Fitzgerld. 2003. *The Benefits of Rural Electrification in India: Implications for Education, Household Lighting, and Irrigation*. Draft paper prepared for South Asia Energy and Infrastructure: World Bank, Washington, DC; Kulkarni, V. and D. Barnes. 2004. *The Impact of Electricity School Participation in Rural Nicaragua*. Working Paper, University of Maryland: College Park, MD; Khandker, S. 1996. Education Achievenments and School Efficiency in Rural Bangladesh. *World Bank Discussion Paper No. 319*. Washington, DC; Filmer, D., and L. Pritchett. 1998. *The Effect of Household Wealth on Educational Attainment around the World: Demographic and Health Survey Evidence*. World Bank: Washington, DC; Roddis, S. 2000. *Poverty Reduction and Energy: The Links Between Electricity and Education*. World Bank: Washington, DC (mimeo); World Bank. 2002. Rural Electrification and Development in the Philippines: Measuring the Social and Economic Benefits. *Energy Sector Management Assistance Programme (ESMAP) Report No. 255/02*. World Bank: Washington, DC.

[2] J. Peters. 2009. Evaluating Rural Electrification Projects—Methodological Approaches. *Ruhr Economic Paper No. 136.* Essen, Germany: Rheinisch-Westfälisches Institut für Wirtschaftsforschung.

program placement and selection bias is crucial for credibly estimating the true impacts. Thus, this study adopts the propensity score-matching (PSM) method to address endogeneity and provides empirical evidence on the effects of rural electrification on health, human capital accumulation, income, and other indicators of human welfare.

5. Data collection and analysis are based on the project impacts illustrated in Table A7.1. However, data are not available for improved air quality, financial position of the implementing agency, and quality of graduates; therefore, these outcomes are not analyzed in the study.[3]

Table A7.1: Logic Models to Evaluate the Overall Impact of Rural Electrification in Bhutan

Project Inputs or Activities	Outputs	Outcomes	Impacts
Project Resources	Electrification and availability of clean energy	Improved opportunity for income-generating activities	**A. Economic** (i) Higher household incomes (ii) Improved creditworthiness
		Reduced use of fuelwood, kerosene, and candles	(iii) Lower energy expenditure (cost saving)
Nonproject factors			**B. Environmental**
Household and individual characteristics		Improved ceilings using electrical appliances	(i) Improved indoor air quality
(i) Age, sex, and education of household head		Reduced consumption of fuelwood, and better ventilation	(ii) Reduced use of fuelwood and kerosene
(ii) Socioeconomic status			
(iii)Housing characteristics		Improved response time for repair and maintenance	
		Computerized billing system and improved tariff structure	
			C. Social
Village characteristics			Health
(i) Availability of health facilities		Reduced smoke inside dwellings	(i) Reduced incidence of respiratory ailments
(ii) Availability of education facilities		Improved ventilation and teaching aids	(ii) Reduced incidence of other health problems
(iii) Size and population of the village		Better food storage facilities	Education
(iv) Isolation of the village measured by distance from district headquarters		Longer study time and access to internet	(i) More study time at home for children
		Ease in vigilance	(ii) Better-quality graduates
		Reduced time spent in collecting fuelwood	Security
		More leisure time	(i) Lower incidence of crime
		Improved convenience	(ii) Reduced damage by wild animals
		Reduced time spent on fuelwood collection	Gender Empowerment (i) Balanced gender roles and

3 Due to paucity of data financial resources, air quality and quality of graduates are not measured.

Project Inputs or Activities	Outputs	Outcomes	Impacts
			control over resources (ii) More time for social interaction (iii) Reduction in total fertility

Source: Asian Development Bank (ADB). 2009. *Evaluation Approach Paper for the Impact Evaluation of ADB's Rural Electrification in Bhutan*. Manila.

A. Evaluation Questions

6. The key evaluation objective of the impact evaluation study is to quantify the socioeconomic benefits of rural electrification on electrified households. The ultimate objective is to calculate the social and economic returns from rural electrification. In particular, the study aims to address (i) the direct (i.e., income) and indirect economic benefits (i.e., lower energy expenditure) from rural electrification in Bhutan; (ii) the impact of rural electrification on time use; (iii) the impacts of rural electrification on education, health, and women's empowerment; and (iv) the extent to which rural electrification contributes to the environment (i.e., deforestation) and safety and security.

7. Table A7.1 demonstrates that rural electrification can have a multidimensional impact on beneficiaries' socioeconomic lives. The immediate benefit of electrification comes through improved lighting and increased access to information through radios and televisions; it can also improve household economic activities through increased application of electrical machinery and equipment. Previous studies on impact evaluation of rural electrification programs have discussed the benefits of electrification.[4]

B. Evaluation Methods

8. Impact evaluation is the process of identifying, analyzing, and making explicit the changes and modifications that have been produced in social and economic conditions as a result of a project.[5] A key issue in impact evaluation is to find a counterfactual, that is, to be able to know what would have happened to electrified households in the absence of electricity.

9. Of the various evaluation methodologies, experimental or randomized control trials are generally considered to be the most robust, because they guard against selection bias, a problem pervasive in project evaluation literature. In such trials, any detected effects can be attributed to the project, because any confounding effects are nullified by random assignment.

10. However, randomized control trials often have issues of internal and external validity. Critics argue that the results from randomized experiments are difficult to extrapolate to a larger population and in different locations (i.e., external validity). Internal validity can also be

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[4] A. Cabraal and D. Barnes. 2006. Productive Uses of Energy for Rural Development. *Annual Review of Environment and Resources. (30)*: pages 117–144; D. Barnes et al. 2003. The Benefits of Rural Electrification in India: Implications for Education, Household Lighting, and Irrigation. Draft paper prepared for South Asia Energy and Infrastructure, World Bank, Washington, DC; V. Kulkarni and D. Barnes. 2004. The Impact of Electrification on School Participation in Rural Nicaragua. *University of Maryland Working Paper.* College Park, MD: University of Maryland; D. Filmer and L. Pritchett. 1998. The Effect of Household Wealth on Educational Attainment around the World: Demographic and Health Survey Evidence. Washington, DC: World Bank; and S. Roddis. 2000. Poverty Reduction and Energy: The Links between Electricity and Education. Washington, DC: World Bank. Unpublished.

[5] J. C. Cockburn. 2005. Social Impact Evaluation Project: Fund For the Promotion of Micro-Hydro Power Stations. Lima: Intermediate Technology Development Group.

questionable when there is selective compliance with the theoretical randomized assignment. Spillover effects are an important source of internal validity.[6]

11. Besides the theoretical limitations of this randomized method, randomizations of infrastructure projects are practically infeasible due to the very high fixed and sunk costs associated with them. It is nearly impossible to implement randomization for most infrastructure projects such as electrification, road construction, railways, and piped water, which makes it difficult to assess their impacts using experimental methods.

12. Despite the concerns with this method, it is still a perfect evaluation method in theory. Thus, when a treatment cannot be randomized, the next best thing to do is to try to mimic randomization, that is, to try to have an observational analogous of a randomized experiment. However, each method varies by its underlying assumption of how to resolve selection bias in estimating the project treatment effect, and has its own limitations. Therefore, when a project cannot be implemented randomly across a sample of observations, a quasi-experimental method can be relied upon to obtain a credible impact of interventions on the beneficiaries.

13. Quasi-experimental methods can be used when it is not possible to randomize either for ethical or for practical reasons. Instead of randomly placing subjects into treatment and control groups, quasi-experimental methods rely either on matching or on discontinuity to construct the control groups. Regression discontinuity design (RDD), difference-in-difference (DID) method, and propensity score matching are some of the most popular quasi-experimental design used to evaluate program effects.

14. The basic idea behind RDD is that assignment to the treatment is determined, either completely or partly, by the value of a predictor (the covariate X_i) being on either side of a fixed threshold or cut-off.[7] The fixed threshold or discontinuity arises from administrative decisions and subjects just below the cut-off who did not participate in the control group. The main advantage of RDD is that it delivers marginal gains from the project around the eligibility cut-off point, which is important for program expansion. However, this method could not be used for this study, as there is no cut-off or threshold for receiving an electricity connection.

15. Another popular approach to estimate project effect is the DID method. It is based on comparison of the changes that occurred over time for the target group and for a similar group that is not eligible for the treatment. Essentially, it compares the changes between the treatment and control groups before and after the project. The validity of DID estimator rests on the identifying assumption that the selection bias is time invariant. In other words, the absence of treatment changes in the outcomes in the treated group and control group would have been the same (i.e., a parallel trend assumption). In practice, it is hard to test this assumption. The DID method also requires data on treatment and control groups at two time points: before the intervention and after the intervention. Unfortunately, this approach could also not be used for this study, as baseline data does not exist for the target and control villages.

16. Direct matching or PSM[8] techniques are used to identify the counterfactual based on observed characteristics of treated (electrified) and comparison (unelectrified) households. The basic idea is to match electrified households with one or more unelectrified households with

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[6] M. Ravallion. 2008. *Evaluating Anti-Poverty Programs.* Washington, DC: World Bank.
[7] G. Imbens and T. Lemieux. 2007. Regression Discontinuity Designs: A Guide to Practice. *Journal of Econometrics. 142 (2)*: pages 615–635.
[8] E. Duflo and M. Kremer. 2008. Use of Randomization in the Evaluation of Developmental Effectiveness. *Massachusetts Institute of Technology (MIT) Working Paper.* Cambridge, MA: MIT.

similar observed characteristics. The PSM method calculates for both treated and comparison samples, the probability of treatment or electrification as a function of household or village characteristics, from either a logit or a probit model.[9] This probability of adopting electricity, calculated for households both with and without electricity, is called the propensity score. The mean outcomes of households with electricity are then compared with those of unelectrified households to estimate the effects of rural electrification.[10] The biggest advantage of this method is it requires neither randomization nor baseline (pre-intervention) data. However, it rests on a very strong identifying assumption of no unobserved heterogeneity. It should be noted that matching addresses only observable selection bias and not unobservable selection bias.

17. Several recent studies have compared the performance of matching by comparing experimental estimates with nonexperimental estimates using matching, mostly using data from voluntary employment and job training programs in the United States. Comparing experimental estimates to matching estimates using nonexperimental data from the Job Training Partnership Act Program, Heckman et al. provided evidence that PSM methods perform well relative to experimental estimators.[11] They showed that such methods provide reliable, low-bias estimates of project impact, provided that (i) the same data source is used for treatment and comparison households, (ii) treatment and comparison households have access to the same markets, and (iii) the data include meaningful explanatory variables capable of identifying project participation. A more recent paper by Diaz and Handa[12] provided evidence on the performance of matching estimators using non-United States data. Comparing experimental and nonexperimental estimates of the impact of a voluntary anti-poverty program in Mexico, the authors found that the program performed well when the outcomes of interest are measured comparably across treated and untreated groups, and a rich set of covariates is available.

18. This impact evaluation study was designed to fulfill these requirements of PSM. A comprehensive household survey was designed to capture information about several conditioning variables that potentially affect the outcomes and participation, which help reduce a potentially significant source of bias in PSM estimators. Secondly, the same survey questionnaire was administered in electrified and unelectrified villages, as a result of which outcomes are measured identically. Since for every electrified village, an unelectrified village was selected in the same *gewog* (group of villages), households in these villages are likely to face the same economic and ecological situations.

19. In addition, the Bhutan Power Corporation adopted a radial approach to implement rural electrification. First, villages falling in close vicinity of the power substations were electrified, followed by villages farther away from the substations. Given that the radial approach was

[9] H. Smith. 1997. Matching with Multiple Controls to Estimate Treatment Effects in Observational Studies. *Sociological Methodology. 27 (1)*: pages 325–353.

[10] Rosenbaum and Rubin showed that, under specific assumptions, the propensity score matching method achieves the properties of direct matching (i.e., matching on observables). P. R. Rosenbaum and D. B. Rubin. 1983. The Central Role of the Propensity Score in Observational Studies for Causal Effects. *Biometrika. 70 (1)*: pages 41–55.

[11] J. Heckman et al. 1997. Matching as an Econometric Evaluation Estimator: Evidence from Evaluating a Job Training Program. *Review of Economic Studies. 64 (4)*: pages 605–654; J. Heckman et al. 1998a. Matching as an Econometric Evaluation Estimator. *Review of Economic Studies. 65 (2)*: pages 261–294; and J. Heckman et al. 1998b. Characterizing Selection Bias Using Experimental Data. *National Bureau of Economic Research (NBER) Working Paper No. 6699.* New York: NBER. Provided the following set of conditions are met: (i) the presence of a rich set of conditioning variables, (ii) use of the same survey instruments for participants and nonparticipants, and (iii) participants and nonparticipants face the same economic conditions.

[12] J. J. Diaz and S. Handa. 2006. An Assessment of Propensity Score Matching as a Nonexperimental Impact Estimator: Evidence from Mexico's PROGRESA Program. *Journal of Human Resources. 41 (2)*: pages 319–345.

adopted and that Bhutan had its first census in 2005, the probability of villages being electrified based on some observable variables are quite minimal. Furthermore, selectivity bias at the household level is also minimized, as all households in electrified villages are considered electrified.[13] Based on the above facts, it is reasonable to argue that matching estimates provide reliable impact estimates.

C. Propensity Score Matching

20. Rosenbaum and Rubin (footnote 10) proposed statistical matching using a propensity score, the predicted probability that an individual receives the treatment of interest (e.g., roads, electricity, financial services) to make comparisons between households with and without a treatment. Methodological issues are discussed in detail by other studies.[14]

21. For this impact evaluation study, the propensity score was the conditional probability of receiving electricity and was based on a pretreatment household or village characteristics (X).

$$P(X) = Pr\{D=1|X\} = E\{D|X\} \quad (1)$$

22. Where D= {0, 1} is the binary variable, 1 denoting treatment, 0 denoting control, and X is the vector of pre-treatment characteristics or time invariant or relatively stable household characteristics. It can be shown that if exposure to electricity is random within cells defined by X, it is also random within cells defined by the values of the propensity score *p(X*) (footnote 11).

23. The average effect of electrification (also known as average effect of treatment on the treated, or ATT) can be estimated in the same way as

$$\begin{aligned} ATT &= E\{Y_{1i} - Y_{0i}|D_i = 1\} \\ &= E\{E\{Y_{1i} - Y_{0i}|D_i = 1, p(X_i)\}\} \\ &= E\{E\{Y_{1i}|D_i = 1, p(X_i)\} - E\{Y_{0i}|D_i = 0, p(X_i)\}|Di = 1\} \quad (2) \end{aligned}$$

24. Where the outer expectation is over the distribution of (p (X_i |D_i = 1), and Y_{1i} and Y_{0i} are the potential outcomes in the two counterfactual situations (i.e., with access to electricity and without). Rather than matching all of the Xs, a scalar propensity score can also be used for matching (footnote 11). Since the propensity score is a continuous variable, there are four different methods that are proposed in the literature for matching: nearest neighbor matching, radius matching, kernel matching, and stratification matching (footnote 12).

D. Assumptions

25. Rosenbaum and Rubin established the following conditions to estimate the ATT effect based on the propensity score. Formally, the following two properties are needed to estimate ATT given the propensity score *p*(*X)*.

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[13] This is unlike other countries, where in addition to selectivity bias at the village level, there is selection at household level as households decide whether to connect to the grid, thereby resulting in severe selection bias. Typically, electrified villages have both off- and on-grid households.

[14] S. Becker and A. Ichino. 2002. Estimation of Average Treatment Effects Based on Propensity Scores. *The Stata Journal. 2 (4)*: pages 358–377; R. H. Dehejia and S. Wahba. 2002. Propensity Score-Matching Methods for Nonexperimental Causal Studies. *Review of Economics and Statistics. 84 (1)*: pages 151–161; and J. A. Smith and P. E. Todd. 2005. Does Matching Overcome LaLonde's Critique of Nonexperimental Estimators? *Journal of Econometrics. 125 (1–2)*: pages 305–353.

Lemma 1 is the balancing of pre-treatment variables given the propensity score.
If *p*(*X)* is the propensity score, then

(3) $D \perp X \mid p(X)$

Lemma 2 is the conditional independence assumption (CIA).

(4) (Unconfoundedness) $Y_1, Y_0 \perp D \mid p(X)$

26. Balancing properties of Lemma 1 means that for observations with the same propensity score, the distribution of pre-treatment characteristics (i.e., observable and unobservable) must be the same across matched treated and comparison groups. In other words, for a given propensity score, exposure to treatment is random. The CIA implies that selection is solely based on observable characteristics and that all variables that influence treatment assignment and potential outcomes are observed simultaneously.[15]

E. Balancing Test

27. Lemma 1 checks if a matched comparison group can be considered to represent a plausible counterfactual. To satisfy a balance hypothesis, balancing properties are checked for all of the variables that are used to estimate the propensity score. Individual mean t-tests between the matched treated and comparison households for each variable are performed to check the balance. If significant differences remain after matching, then either the propensity score model should be estimated using a different approach (i.e., fine-tuning the specification of the propensity score), or a different matching approach should be used, or both. Some statisticians suggest a process of recycling between checking for balance on the covariates and reformulating the propensity score. For example, when large mean differences in an important covariate are found to exist between the treatment and comparison groups, even after its inclusion in the model, then the square of the variable and interactions with other variables can be tried.

28. This impact evaluation study uses individual mean t-tests between the matched treated and comparison households to ensure that there are no statistically significant differences between the means of matched electrified and unelectrified households.[16]

F. Overlap and Common Support

28. A further requirement besides independence is the common support or overlap condition. It rules out the phenomenon of perfect predictability of *D* given *X*:

(5) (Overlap) $0 < P(D = 1 \mid X) < 1$

This ensures that persons with the same *X* values have a positive probability of being both participants and nonparticipants.[17] The common support is the region where the propensity score has positive density for both treatment and comparison households. No matches can be

[15] It is important to distinguish the CIA from balancing property of propensity scores. One does not imply the other. For example, it is possible to obtain balance for samples of data where the CIA is valid or where it does not hold.

[16] The pstest command in stata was used to check the balance between matched treated and comparison households.

[17] J. Heckman et al. 1999. The Economics and Econometrics of Active Labor Market Programs. In O. Ashenfelter and D. Card, eds. *Handbook of Labor Economics.* Vol. III. Amsterdam: Elsevier.

formed to estimate the treatment effect when there is no overlap between the treatment and comparison households. Several methods are suggested in the literature, and the most straightforward one is a visual analysis of the density distribution of the propensity score in both groups. One[18] argued that given that the support problem can be spotted by inspecting the propensity score distribution, there is no need to implement a complicated formal estimator.

29. The most common approach to identify the region of common support is the minima and maxima comparison. Its basic criterion is to delete all observations whose propensity score is lower than the minimum and larger than the maximum in the opposite group. Observations that lie outside of the common region are discarded from analysis.[19] Since observations falling outside of the region of common support are dropped nonrandomly, it may make the sample biased and unrepresentative. Bryson, Dorsett, and Purdon noted that when the proportion of lost individuals is small, this poses few problems. However, if the number is too large, there may be concerns whether the estimated effect on the remaining individuals can be viewed as representative.[20]

30. This impact evaluation study uses the minima and maxima criterion for identifying the region of common support. Given that the CIA holds, and assuming that there is sufficient overlap between both groups, the PSM estimator for ATT can be written as

$$ATT = \{E[Y(1) \mid D = 1, P(X)] - E[Y(0) \mid D = 0, P(X)]\} \quad (6)$$

The PSM estimator is simply the mean difference in outcomes over the common support, appropriately weighted by the propensity score distribution of participants.

G. Estimation Strategy

31. The impacts of rural electrification on different outcomes are estimated by three methods. First, simple difference-in-means impacts are estimated by comparing households in electrified villages to households in unelectrified villages without applying matching. The simple difference-in-means can be stated as[21]

$$\Delta\overline{H} = 1/T \sum_{j=1}^{T} (H_{j1}) - 1/C \sum_{i=1}^{C} (H_{i0}) \quad (7)$$

Where

$\Delta\overline{H}$ = Difference in mean outcome H

H_{j1} = Outcome H for treated households

H_{i0} = Outcome H for comparison households

T = Number of treated households

C = Number of treated households

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[18] M. Lechner. 2000. A Note on the Common Support Problem in Applied Evaluation Studies. University of St. Gallen Economics Discussion Paper No. 2001-01. Available at: http://ssrn.com/abstract=259239 or doi:10.2139/ssrn.

[19] To give an example, assume that the propensity score lies within the interval [0:07; 0:94] in the treatment group and within [0:04; 0:89] in the control group. Hence, with the minima and maxima criterion, the common support is given by [0:07; 0:89]. Also, see M. Caliendo and S. Kopeinig. 2005. Some Practical Guidance for the Implementation of Propensity Score Matching. Institute for the Study of Labor (IZA) Discussion Paper No. 1588. Bonn: IZA.

[20] A. Bryson et al. 2002. The Use of Propensity Score Matching in the Evaluation of Active Labor Market Policies. *Department for Work and Pensions Working Paper No. 4.* London: Department for Work and Pensions.

[21] The simple difference-in-means method assumes that the other variables affecting the outcomes are identical for the treatment and comparison households. If this is not true, then the estimated impacts would be biased.

32. The unadjusted difference-in-means method, however, does not control for individual-, household-, and village-level characteristics that may affect the outcomes of interest. In addition, mean differences only show an association between two variables and do not imply causation, whereas the objective of this study is to estimate the impact of rural electrification in a causal framework. Nonetheless, unadjusted mean differences are calculated largely to serve as a comparison to the regression and matching-based estimates.

33. The multivariate regression method can overcome some of the problems present in the mean-difference analysis. The advantage of this method is that other variables that may potentially affect the outcomes can be included in the analysis. The multivariate regression approach is superior to the simple difference-in-means approach due to its ability to control for observed characteristics. Whether the impacts are causal depends on the exogeneity of the explanatory variables. The regression model can be stated in as

$$Y_{ij} = \alpha + \beta_1 {}^{*} T_{ij} + \beta_2 {}^{*} X_{ij} + €_{ij} \qquad (8)$$

Where
Y = Outcome variable
T = Treatment status (T=1 if electrified, 0 otherwise)
α = Intercept
β_i = Coefficient
X = Individual-, household-, and village-level variables
€ = Unobserved random error term.

34. The parameter β_2 can be interpreted as the causal impact of treatment on outcome Y when treatment T is random and there is no omitted variables bias. This equation is estimated by the ordinary least squares (OLS) method for continuous dependent variables, such as income or years of completed schooling. However, some of the outcomes analyzed in the study are dichotomous. For these dichotomous variables, a nonlinear model, such as probit, is used.

35. As stated, the challenge in most impact evaluation studies is to overcome the possible selection bias, which is more severe in the evaluations of infrastructure projects. Compared to other infrastructure projects, electrification suffers from two sources of bias: endogeneity of project placement and household adoption of electricity. Furthermore, frequent power outages make evaluation more problematic. When the selection criteria are observable, then a regression-based approach overcomes selection bias. In the case of electrification, selection is very clearly based on observables, most notably income and location.[22] Since electrification rollout in Bhutan was phased in and the implementing agency adopted the radial approach, selection bias is less of an issue, and regression estimates can address the causality issues if observables are adequately controlled.

36. A popular alternative to the regression-based approach in evaluation literature is matching methods. To supplement the regression analysis, matching was used because of its ability to reduce sensitivity to parametric assumptions and its use of common support, reducing

[22] World Bank Independent Evaluation Group. Methodology. http://web.worldbank.org/WBSITE/EXTERNAL/EXTOED/EXTRURELECT/0,,contentMDK:21610847~menuPK:4563117~pagePK:64829573~piPK:64829550~theSitePK:4489015,00.html. Income may be regarded as endogenous with respect to electrification, creating problems 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, can be used.

the impact of outliers, thus minimizing bias in the results.[23] The following equation is estimated using PSM:

$$\text{(9)} \qquad ATT = \{E[Y(1) \mid D = 1, P(X)] - E[Y(0) \mid D = 0, P(X)]\}$$

37. Propensity scores are estimated for electrified households by a logit model that potentially affect the outcomes of interest.[24] Household-level fixed characteristics, such as age, gender, marital status, religion, education of the household head, land ownership, household size, household size, ownership of livestock, type of house, and main source of drinking water, were used as the control variables in the logistic model. In addition, a few village-level variables, such as distance to district headquarters (measuring isolation of the village), area and population of the village, travel time to the nearest road from the village, and availability of educational infrastructure, were also used for estimation of the propensity score.[25] A variety of methods for matching exist, such as nearest neighbor, stratification, and kernel matching, which all use PSM.

38. This impact evaluation study used kernel PSM. The advantage of kernel is the reduction in variance in the matching estimate achieved by the introduction of data from all control households in the matching process. Relative to other matching methods, it is more efficient since it uses more untreated units.[26] Kernel-weighted matching methods match a treated unit with the weighted average score of all untreated units within a certain distance, referred to as the bandwidth. The weight is inversely proportionate to the distance between treated observations *i* and the matched untreated observation *j,* and depends on the weighting function that is used. This is in contrast to traditional pair-wise matching methods, which place equal weight to matched units. However, kernel matching may also increase bias if the sample size is small by giving consideration to scores that are far from the treated score that is being matched (Heckman and Smith 1999).[27] All the three approaches, difference-in-means, OLS, and PSM, were implemented to estimate and compare the impacts and also to check the robustness and sensitivity of the results.

39. It is important to note that matching is done on the basis of observable characteristics. When multiple rounds of data are available, a difference-in-differences PSM estimator can be used. In recent years, many studies have extended PSM to a longitudinal setup and have used difference-in-differences matching method (a combination of PSM and difference-in-differences) to estimate the causal effect of projects.[28] The idea behind using difference-in-differences matching is to overcome the weakness of the PSM method. The PSM method matches treatment and comparison households only by using observed characteristics, whereas the difference-in-difference method is used to deal with selection by unobserved characteristics. Difference-in-differences matching is thought to be superior to simple cross-sectional matching

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[23] Matching only deals with selection on observables, while instrumental variable estimation can address problems of selection on unobservable.

[24] A logistic model is estimated because the outcome variable (whether household has electricity or not) is a discreet choice and is coded as one (T) or zero (C).

[25] These variables are included in estimating propensity score.

[26] However, while the use of most (or all) untreated units reduces the variance of the matching estimates due to more matches, it can increase the bias due to worse matches.

[27] Heckman, J., Smith, J. 1999. The pre-programme earnings dip and the determinants of participation in a social programme: Implications for simple programme evaluation strategies. *Economic Journal 109(457)*, pages 313–348.

[28] S. K. Pattnayak et al. 2007. Informing the Water and Sanitation Sector Policy: Case Study of an Impact Evaluation Study of Water, Sanitation, and Hygiene Interventions in Maharashtra, India. *Research Triangle Institute Working Paper 06_04.* Research Triangle Park, NC: Research Triangle Institute; and S. Galiani et al. 2005. Water for Life: The Impact of Privatization of Water Services on Child Mortality. *Journal of Political Economy. 113*: pages 83–120.

techniques because it eliminates important time-invariant sources of bias, such as local environment and systematic measurement error. The data requirements for doing a double-difference are huge and require at least two data points for both the treatment and comparison households.

40. With the single round of data available for this impact evaluation study, the difference-in-differences approach is not feasible. Instead, the study uses a single-difference estimation method and matches electrified with unelectrified households using time-invariant characteristics. The approach relies on a stronger assumption that unobservable and observable had the same distribution.

41. Another crucial consideration in the matching method is whether pre- or post-intervention characteristics should be used for matching. In the presence of baseline data, matching using baseline characteristics is considered superior, but it is a luxury that not all studies have. While doing ex-post matching, matching should not be done using endogenous variables (i.e., variables that change due to a treatment), and only time-invariant characteristics should be used for post-treatment matching purposes. In the absence of the baseline survey, this study resorts to matching based on post-treatment variables. It uses household- and village-level fixed characteristics for matching electrified with unelectrified households (footnote 27).

42. Furthermore, there is also an issue regarding the level of matching, whether matching should be done at the village or household level. Since heterogeneity exists within the village, most studies prefer matching at the household level.[29] This study uses both household- and village-level variables to match the households.

H. Description of Outcome Variables

43. The impact evaluation study estimates the impact of rural electrification in Bhutan on human welfare through equations (7), (8), and (9) for outcomes in three broad categories discussed in the logic model (Table A7.1). The most common welfare impact is increased household income and lower energy expenditure. By improving opportunity for income-generating activities, for example, small and medium-sized enterprises and home businesses, electrification may increase household income. Likewise, due to reduced use of fuelwood, kerosene, and candles, electrification may lower expenditure incurred on pollutant fuels.

44. For the analysis of economic outcomes, the main outcomes variables used in the study are total income, farm income, and nonfarm income.[30] All of the economic outcomes variables are continuous variables expressed in ngultrum. As a robustness check, income measures expressed in log form are also included.[31] To assess the impact of electrification on the use of pollutant fuels, the study uses the amount of fuelwood and kerosene consumed per year as the outcome variables. Energy expenditures are not used, as the majority of the households collect fuelwood from the forest and do not buy it from the market.

45. For health benefits, the outcomes used are the incidence of various health risks and whether these health risks are caused by indoor air pollution. Four types of health risks are

[29] Many studies are constrained to using village-level data to estimate the propensity score due to lack of household-level data. However, Jalan and Ravallion used both village and household matching to compare the results. J. Jalan and M. Ravallion. 2003. Does Piped Water Reduce Diarrhea for Children in Rural India? *Journal of Econometrics. 112 (1)*: pages 153–173.

[30] Total income is sum of income earned from farm activities, unskilled or casual labor, businesses, and rent.

[31] Variables expressed in log form are normally distributed.

analyzed: cough, respiratory ailment, eye irritation, and headache.[32] In addition to these outcomes, responses to whether these health risks occurred due to indoor air pollution (e.g., smoke) are included as separate outcomes. For working adults, the number of workdays missed due to illness in the last 12 months is also included. All variables, except the number of workdays missed, are dichotomous variables. Table A7.2 shows the summary of sampling frame for electrified and unelectrified households and also for the whole sample.

Table A7.2: Sampling Frame for Impact Evaluation in the Study Area

		Number of Villages			Number of Households		
Region	**Dzonkhag**	**Electrified**	**Unelectrified**	**Total**	**Electrified**	**Unelectrified**	**Total**
Central	Bumthang	4	8	12	86	67	153
Western	Chukha	12	20	32	325	344	669
Central	Dagana	4	9	13	116	207	323
Eastern	Lhuntse	33	66	99	1,019	1,058	2,077
Western	Punakha	22	14	36	545	205	750
Southern	Samtse	41	55	96	1,242	1,087	2,329
Southern	Sarpang	17	27	44	492	1,087	1,579
Eastern	Trashigang	57	45	102	2,222	746	2,968
Central	Trongsa	1	6	7	17	105	122
Western	Wangdue	7	27	34	252	468	720
Total		198	277	475	6,316	5,374	11,690

Source: Derived from data provided by the Bhutan Power Corporation.

I. Sampling Design

46. A mix of purposive and probability sampling approaches were undertaken to design the sampling frame. Villages and households that were electrified under SREP and RENEP constituted the sample for treatment,[33] and villages that are going to electrified under Green Power Development Project and through assistance from the Japan International Cooperation Agency (JICA) constituted the control sample. Green Power Development Project and JICA projects were slated to start in April 2010.

47. Out of the 20 *dzonkhags* (districts) in Bhutan, Asian Development Bank (ADB) assistance for rural electrification has been in 15, of which 10 were selected to achieve a geographically disparate and diverse study sample.[34] Three dzonkhags (Chukha, Punakha, and Wangdue Phodrung) were selected from western Bhutan, three (Bumthang, Dagana, and Trongsa) were selected from central Bhutan, two (Lhuntse and Trashigang) were selected from eastern Bhutan, and two (Samtse and Sarpang) were selected from southern Bhutan for the study. In the next step, the sampling frame consisted of 198 electrified and 277 unelectrified villages. There were 11,690 households in total, out of which 6,316 were in electrified villages and 5,374 in unelectrified villages.

[32] The survey asked respondents whether members of household suffered from any of these four health risks in the last 3 years.
[33] Had data been available for the first ADB rural electrification project villages, they could have also been included in the treatment sample. Neither the Department of Energy nor Bhutan Power Corporation could provide the list of villages electrified under this project.
[34] Out of 20 dzonkhags, five did not have any villages electrified under ADB projects, so they were removed from the sampling frame. Four also would not be electrified under the current ADB or the JICA program known as Rural Electrification IV.

48. Furthermore, the number of sampled villages in each dzonkhag is in proportion to their share in the total number of electrified and unelectrified villages. In dzonkhags that have a large number electrified villages, more villages were surveyed; conversely, a smaller number of villages were surveyed in dzonkhags that have fewer electrified villages. To save resources and time, villages that comprise less than 15 households were dropped from the sample. However, in such cases, villages that had nine or more households were selected. Finally, households in each village were sampled for the study based on their share in the total number of households (Table A7.3).

Table A7.3: Sampling Distribution for Impact Evaluation of Rural Electrification

		Number of Villages			Number of Households		
Region	**Dzonkhag**	**Electrified**	**Unelectrified**	**Total**	**Electrified**	**Unelectrified**	**Total**
Central	Bumthang	5	4	9	51	27	78
Western	Chukha	4	4	8	70	81	151
Central	Dagana	2	2	4	36	44	80
Eastern	Lhuntse	9	10	19	200	168	368
Western	Punakha	9	2	11	160	34	194
Southern	Samtse	12	8	20	235	151	386
Southern	Sarpang	5	4	9	101	102	203
Eastern	Trashigang	22	6	28	348	122	470
Central	Trongsa	2	4	6	68	73	141
Western	Wangdue	1	1	2	7	20	27
Total		71	45	116	1,276	822	2,098

Source: Derived from data provided by the Bhutan Power Corporation.

J. Data

49. The study collected quantitative and qualitative data. Quantitative data were collected by administering two surveys: village and household. The study team designed the survey instruments, and these were pre-tested and piloted in one electrified and one unelectrified village in Trongsa. Based on household responses and feedback during the pre-testing phase, survey instruments were modified before the actual survey. The household questionnaire collected information on various indicators pertaining to benefits of electricity. All questionnaires were in English, but the investigators were proficient in English and region-specific local languages.

50. The household questionnaires had 22 sections: (i) household roster; (ii) employment and occupation; (iii) household characteristics; (iv) land holding, irrigation, and livestock; (v) income-generating activities; (vi) information on microenterprises; (vii) sources of energy used and costs; (viii) electric appliance ownership; (ix) attitudes and perceptions; (x) child education; (xi) indoor air quality and health; (xii) time use pattern; (xiii) gender empowerment; (xiv) environment; (xv) fuelwood collection; (xvi) information networks; (xvii) credit access; (xviii) electricity and consumer satisfaction; (xix) safety and security; (xx) willingness to pay for electricity; (xxi) social and political capital; and (xxii) food security. A village questionnaire was also administered to the gup, which collected information on (i) general characteristics of the village, (ii) water and sanitary conditions in the village, (iii) education and health infrastructure, (iv) availability of energy, and (v) economic activity in the village.

51. In addition to the collection of quantitative data, qualitative data were collected by conducting focused group interviews in each dzonkhag. A national consultant with expertise in conducting household surveys with the assistance of field supervisors and enumerators

conducted the village and household surveys. The study team held a 3-day training session for the enumerators. The session introduced the survey and discussed the survey questions in details and emphasized the role of interviewers and supervisors in the data collection process. Around 20 enumerators were involved in collecting data from 2 January to 20 March 2010. Data were entered by the survey team in Thimphu. To ensure high-quality data, they were entered twice and were matched later for comparison.

K. Focus Group Discussions

52. As part of the study, a series of focus group discussions were conducted in 10 dzonkhags with rural electrification to supplement the overall evaluation findings. The discussions were held at (i) Ganjo in Wangdue Phodrang (with 18 participants), (ii) Botokha (with 17 participants) in Punakha, (iii) Dorji Goenpa in Trongsa (with 15 participants), (iv) Chumey in Bumthang (with 19 participants), (v) Berpa in Lhuntse (with 17 participants), (vi) Momnangkhola in Trashigang (with 19 participants), (vii) Jubrey in Sarpang (with 21 participants), (viii) Hanggay in Samtse (with 20 participants), (ix) Baleygang in Dagana (with 18 participants), and Gurungdara in Chukha (with 18 participants). The discussions also served as a follow-up to the household surveys conducted in the same dzonkhags. In all, 182 participants (90 male and 92 female) took part in the discussions. Participants were randomly selected by the gup.

53. The discussions were held outdoors since most village houses could not accommodate the number of participants. Moreover, the bright, pleasant winter days were conducive for holding outdoor discussions where the participants felt more relaxed, setting the tone for free, frank discussions. Discussions lasted about 2 hours each, beginning with the study team giving a short introduction on rural electrification and outlining the objectives of the discussions. Focus group questions were initially open-ended and then moved from the general to the specific. The participants addressed a series of issues related to the impacts of rural electrification in five areas: economic, social, environment, gender empowerment, and institutional. Specifically, the discussions concentrated on (i) gathering opinions, beliefs, perceptions, benefits, and impacts of rural electrification; (ii) testing existing assumptions on the impacts of rural electrification, (iii) encouraging discussions the topics mentioned above; and (iv) providing an opportunity to learn about impacts directly from the rural beneficiaries.

CHARACTERISTICS OF OUTCOME AND DETERMINANT VARIABLES

Table A8.1: Characteristics of Survey Households

Characteristics	Electrified Households	Unelectrified Households	All Households
Household size (no. of persons)	4.35	4.39	4.36
Literacy rate (%)	37.50	31.00	34.90
Average years of schooling (all members)	4.43	4.02	4.29
Average years of schooling (household head)	4.01	3.43	3.84
Religion of household head (%)			
Buddhist	72.45	66.29	70.12
Hindu	24.33	32.83	27.54
Other	3.22	0.88	2.34
Ethnic composition (%)			
Sharchop	30.83	18.51	26.17
Lhotshampa	28.91	33.75	30.74
Ngalong	18.25	8.44	14.54
Kurtoep	15.72	22.42	18.26
Other	6.29	16.88	10.29
Households with cultivable land (%)	94.71	97.73	95.85
Average cultivable land holding size	3.33	3.88	3.54
Less than 0.5 acres of land owned (%)	84.20	93.70	87.80

Source: Independent Evaluation Department estimation.

Table A8.2: Physical Attributes of Survey Households
(%)

Characteristics	Electrified Households	Unelectrified Households	All Households
Type of housing			
Mud-bonded brick or stone house	66.10	60.58	64.01
Cement-bonded brick or stone house	6.83	2.39	5.15
Concrete	2.07	1.13	1.72
Mud	3.99	6.68	5.00
Wood, bamboo, branches	20.55	28.84	23.69
Other	0.46	0.38	0.43
Main source of drinking water			
Tap inside the house	3.83	2.52	3.34
Tap outside the house (private)	52.53	53.40	52.86
Tap outside the house (shared)	28.76	27.46	28.27
River, spring, pond	10.28	12.34	11.06
Other	4.60	4.28	4.48
Households with private toilet	97.01	97.86	97.33
Type of toilet			
Pit latrine	82.52	93.58	86.70
Indian latrine	16.49	5.04	12.15
Other	0.99	1.38	1.15
Main source of lighting			
Electricity	100	0.50	62.35
Wicked lamp	0.00	84.63	32.03
Other	0.00	15.87	5.62
Main source of cooking fuel			
LPG gas	2.53	3.78	3.00
Electricity	76.99	0.76	48.14
Kerosene	0.00	0.63	0.24
Fuelwood	20.32	94.58	48.43
Other	0.16	0.25	0.19

LPG = liquefied petroleum gas.
Source: Independent Evaluation Department estimation.

Table A8.3: Asset Ownership in Survey Households
(%)

Type of Appliance	Electrified	Unelectrified	All
Motor vehicles, including two-wheelers	9.28	7.43	8.58
Traditional stoves (without chimney)	79.06	89.55	83.03
Smokeless stoves (with chimney)	3.68	3.15	3.48
Bukhari[a]	21.93	18.51	20.64
Sewing machine	4.22	2.77	3.67
Tape recorder	34.51	17.51	28.07
Mobile phone	72.32	57.93	66.87
Radio or transistor	55.29	64.99	58.96
Television	33.59	1.64	21.50
Electric fan	15.41	0.25	9.68
Refrigerator	13.34	0.13	8.34
Electric water boiler	48.01	0.13	29.89
Electric stove for cooking	4.68	0.13	2.96
Rice cooker	86.35	1.13	54.10
Electric heater	4.75	0.13	3.00
Oil column heater	0.38	0.13	0.29
Iron	3.3	0.63	2.29

[a] Bukhari is a fuelwood based house or space heating system with smoke exhaust through chimney.

Source: Independent Evaluation Department estimation.

Table A8.4: Descriptive Statistics for Outcome Variables

Variables	Electrified Households (1)	Unelectrified Households (2)	All Households (3)
A. Economic Outcomes			
Yearly total income (Nu)	26,123.91	21,044.25	24,201.49
Standard deviation	50,469.18	45,257.08	48,613.98
Yearly farm income (Nu)	11,172.30	9,454.927	10,522.35
Standard deviation	30,111.42	21,641.35	27,224.87
Yearly nonfarm income (Nu)	7,520.33	4,361.48	6,324.85
Standard deviation	30,644.79	24,504.17	28,512.11
B. Health Outcomes			
Cough incidence	0.93	0.95	0.93
Standard deviation	0.26	0.23	0.25
Respiratory ailment	0.33	0.37	0.35
Standard deviation	0.47	0.48	0.48
Eye irritation	0.40	0.53	0.45
Standard deviation	0.49	0.50	0.50
Headache	0.85	0.88	0.86
Standard deviation	0.36	0.32	0.34
No. of workdays missed in last 12 months	6.36	7.07	6.62
Standard deviation	7.46	10.46	8.66
Cough due to smoke	0.17	0.28	0.21
Standard deviation	0.37	0.45	0.41
Respiratory ailment due to smoke	0.30	0.32	0.30
Standard deviation	0.46	0.47	0.46
Eye irritation due to smoke	0.47	0.60	0.53
Standard deviation	0.50	0.49	0.50
Headache due to smoke	0.10	0.18	0.13
Standard deviation	0.29	0.39	0.34
C. Use of Pollutant Fuel			
Yearly use of fuelwood (kilograms)	2,211.86	2,867.64	2,469.91
Standard deviation	2,071.11	2,306.61	2,189.82
Yearly use of kerosene (liters)	16.18	53.39	37.68
Standard deviation	20.75	43.67	40.26
D. Educational Outcomes			
Boys' literacy rate	0.79	0.71	0.76
Standard deviation	0.41	0.45	0.43
Girls' literacy rate	0.79	0.70	0.76
Standard deviation	0.41	0.46	0.43
Boys' completed schooling years	2.93	2.30	2.70
Standard deviation	2.73	2.42	2.64
Girls' completed schooling years	3.14	2.25	2.82
Standard deviation	2.86	2.50	2.76
Study time (minutes per day)	75.75	65.32	72.57
Standard deviation	46.9	41.87	45.66
E. Other Outcomes			
Yearly consumption of trees for fuelwood	1.40	1.62	1.49
Standard deviation	1.00	1.15	1.06
Yearly consumption of trees for other purposes	0.52	0.68	0.58
Standard deviation	1.95	2.18	2.04
Time spent on fuelwood collection by males	1.93	2.14	2.01
Standard deviation	1.37	1.41	1.39
Time spent on fuelwood collection by females	1.41	1.63	1.49
Standard deviation	1.31	1.43	1.36

Source: Independent Evaluation Department estimation.

Table A8.5: Difference in Mean Estimates

Outcomes	Electrified	Unelectrified	Difference	t-Statistics
A. Economic Outcomes				
Farm income	11,172.3	9,454.927	1,717.37	1.51
Nonfarm income	7,520.33	4,361.48	3,158.85	2.6[c]
Total income	26,123.91	21,044.25	5,079.66	2.39[b]
B. Health Outcomes				
Cough incidence	0.93	0.95	(0.02)	1.8[a]
Respiratory ailment	0.33	0.37	(0.04)	1.82[a]
Eye irritation	0.40	0.53	(0.13)	5.62[c]
Headache	0.85	0.88	(0.03)	2.28[b]
Cough due to smoke	0.17	0.28	(0.11)	5.71[c]
Respiratory problem due to smoke	0.30	0.32	(0.02)	0.68
Eye irritation due to smoke	0.47	0.60	(0.14)	4.21[c]
Headache due to smoke	0.10	0.18	(0.09)	5.24[c]
No. of workdays missed	6.36	7.07	(0.71)	1.5
C. Environmental Outcomes				
Yearly consumption of fuelwood (kilograms)	2,211.86	2,867.64	(655.77)	6.36[c]
Yearly consumption of kerosene (liters)	16.18	53.39	(37.22)	20.47[c]
Trees cut for fuelwood (no. per year)	1.40	1.62	(0.22)	4.41[c]
Trees cut for other purposes (no. per year)	0.52	0.68	(0.17)	1.76[a]
D. Educational Outcomes				
Boys' literacy rate (age 7–18 years)	0.89	0.80	0.09	3.51[c]
Girls' literacy rate (age 7–18 years)	0.87	0.80	0.07	2.9[c]
Boys' years of completed schooling	3.40	2.66	0.74	4.5[c]
Girls' years of completed schooling	3.55	2.62	0.93	5.61[c]
Study time at home (minutes per day)	75.75	65.32	10.44	3.33[c]
E. Time Use and Women's Status				
Time spent on fuelwood collection (female)	1.41	1.63	(0.22)	3.61[c]
Time spent on fuelwood collection (male)	1.93	2.14	(0.21)	3.41[c]
Women's empowerment (education and health decisions)	0.80	0.74	0.07	4.47[c]
Women's empowerment (financial decisions)	0.78	0.75	0.02	1.57
F. Ownership of Appliances				
Television	33.59	1.64	31.95	23.09[c]
Radio	55.29	64.99	(9.70)	4.41[c]
Rice cooker	86.35	1.13	85.22	83.32[c]

() = negative.

Notes: Differences in means are unadjusted.

[a] $p < 0.1$ indicates that the coefficient is statistically significant at 10% level.

[b] $p < 0.05$ indicates that the coefficient is statistically significant at 5% level.

[c] $p < 0.01$ indicates that the coefficient is statistically significant at 1% level.

Source: Independent Evaluation Department estimation.

IMPACT EVALUATION FULL ESTIMATION RESULTS

Table A9.1: Impact on Income
(full model estimation)

	Yearly Total Income (Nu) (1)	Yearly Farm Income (Nu) (2)	Yearly Nonfarm Income (Nu) (3)
Treatment	4,033[a]	3,062[b]	1,977
Robust standard error	2,373	1,464	1,252
Household size	(1,615)	(1,731)	(1,686)
Robust standard error	2,604	1,793	1,264
Square of household size	331.40	362.20[a]	76.63
Robust standard error	246.40	196.40	91.14
Gender of head of household	(3,519)[a]	(2,706)[b]	(1,298)
Robust standard error	2,112	1,165	1,240
Age of head of household	424.0[c]	283.4[b]	84.41
Robust standard error	160.20	113.90	85.44
Square of age of head of household	(4.484)[c]	(2.668)[b]	(0.737)
Robust standard error	1.653	1.203	0.843
Marital status of head of household	7,791[c]	3,147[c]	3,688[c]
Robust standard error	2,086	1,125	1,202
Literacy status of head of household	12,787[c]	3,835[b]	5,852[c]
Robust standard error	3,489	1,947	1,993
Total number of literate persons in the family	1,423.0	(399.4)	828.0
Robust standard error	1,064.0	646.9	635.0
Amount of agricultural land	1,766.0[b]	1,529.0[b]	216.1
Robust standard error	743.2	695.9	148.5
Square of amount of agricultural land	(2.800)[a]	(2.331)[a]	(0.482)
Robust standard error	1.486	1.393	0.294
Main source of drinking water (1 = tap water)	4,915[b]	3,363[c]	1,077
Robust standard error	1,913	1,030	1,172
Type of house (1 = brick)	8,312.0[c]	4,144.0[c]	927.5
Robust standard error	2,700	1,506	1,661
Religion (1 = Buddhist)	59.99	(5,375.00)[c]	3,049.00[a]
Robust standard error	3,045	1,713	1,822
Own cow (1 = yes)	(2,720)	1,971	(2,091)
Robust standard error	2,836	1,243	1,854
Own bull (1 = yes)	(3,574)	1,106	(3,278)[b]
Robust standard error	2,628	1,791	1,451
Own horse (1 = yes)	2,508	454.4	(2,129)[a]
Robust standard error	2,592	1,383	1,245
Own poultry (1 = yes)	95.94	(1,912)	512.0
Robust standard error	2,160	1,267	1,292
Population of village	1.630	(2.548)[b]	1.587
Robust standard error	2.746	1.255	1.482
Distance to district headquarters	(14.62)	24.65	(10.73)
Robust standard error	25.18	20.08	11.03
Constant	(6,542)	(7,032)	3,556
Robust standard error	8,178	6,178	4,081
Observations	2,040	2,040	2,040
R-squared	0.075	0.122	0.030

() = negative.
Notes: [a] $p < 0.1$ indicates that the coefficient is statistically significant at 10% level.
[b] $p < 0.05$ indicates that the coefficient is statistically significant at 5% level.
[c] $p < 0.01$ indicates that the coefficient is statistically significant at 1% level.
Source: Independent Evaluation Department estimation.

Table A9.2: Impact on Log-Income
(full model estimation)

	Yearly Total Income (Nu) (1)	Yearly Farm Income (Nu) (2)	Yearly Nonfarm Income (Nu) (3)
Treatment	0.131	0.204	0.495[c]
Robust standard error	0.173	0.180	0.179
Household size	(0.1690)	0.0632	(0.9030)[c]
Robust standard error	0.143	0.160	0.179
Square of household size	0.0282[b]	0.0169	0.0577[c]
Robust standard error	0.0118	0.0140	0.0165
Gender of head of household	(0.490)[b]	(0.666)[c]	(0.339)
Robust standard error	0.201	0.230	0.232
Age of head of household	0.0167	0.0558[c]	(0.0194)
Robust standard error	0.0182	0.0210	0.0200
Square of age of head of household	(0.000162)	(0.000466)[b]	0.000389[a]
Robust standard error	0.000187	0.00021	0.000209
Marital status of head of household	0.1720	(0.0411)	0.4210[a]
Robust standard error	0.208	0.230	0.232
Literacy status of head of household	0.407[a]	0.387	0.412[a]
Robust standard error	0.220	0.250	0.242
Total number of literate persons in the family	0.1220	0.0418	0.1800[b]
Robust standard error	0.0765	0.0870	0.0815
Amount of agricultural land	0.0630[b]	0.1100[c]	0.0315
Robust standard error	0.0314	0.0300	0.0263
Square of amount of agricultural land	(0.000107)[a]	(0.000194)[c]	(7.53e-05)
Robust standard error	6.23e-05	6.05e-0	5.24e-05
Main source of drinking water (1 = tap water)	0.131	(0.111)	0.228
Robust standard error	0.163	0.182	0.175
Type of house (1 = brick)	0.3390	0.1120	(0.0130)
Robust standard error	0.2090	0.2180	0.2110
Religion (1= Buddhist)	1.316[c]	(0.203)	1.312[c]
Robust standard error	0.221	0.231	0.215
Own cow (1 = yes)	0.591[c]	1.098[c]	0.385
Robust standard error	0.224	0.240	0.235
Own bull (1 = yes)	0.479[c]	1.490[c]	(0.311)
Robust standard error	0.181	0.211	0.201
Own horse (1 = yes)	0.220	(0.0438)	(0.161)
Robust standard error	0.210	0.256	0.247
Own poultry (1 = yes)	0.0720	0.1620	0.1510
Robust standard error	0.171	0.197	0.189
Population of the village	(0.000241)	(0.000194)	0.000351
Robust standard error	0.000231	0.000299	0.000314
Distance to district headquarters	0.00515[b]	0.00875[c]	0.01090[c]
Robust standard error	0.00209	0.00243	0.00252
Constant	5.009[c]	1.265[a]	3.405[c]
Robust standard error	0.633	0.694	0.691
Observations	2,040	2,040	2,040
R-squared	0.072	0.123	0.076

() = negative.

Notes: [a] $p < 0.1$ indicates that the coefficient is statistically significant at 10% level.
[b] $p < 0.05$ indicates that the coefficient is statistically significant at 5% level.
[c] $p < 0.01$ indicates that the coefficient is statistically significant at 1% level.

Source: Independent Evaluation Department estimation.

Table A9.3: Impact on Health
(full model estimation)

	Cough	Respiratory Ailment	Eye Irritation	Headache	No. of Workdays Missed
	(1)	(2)	(3)	(4)	(5)
Treatment	(0.0214)[b]	(0.0537)[b]	(0.1340)[c]	(0.0382)[b]	(0.9520)[b]
Robust standard error	0.00988	0.02330	0.02380	0.01550	0.48300
Household size	0.00652	(0.03470)[a]	(0.01880)	0.02150	(0.00891)
Robust standard error	0.00875	0.02080	0.02200	0.01440	0.44800
Square of household size	0.000180	0.003370[a]	0.001430	(0.001090)	0.008200
Robust standard error	0.000808	0.00184	0.00197	0.00135	0.04420
Gender of head of household	(0.0123)	(0.0504)[a]	(0.0700)[b]	(0.0485)[b]	(1.6030)[c]
Robust standard error	0.0109	0.0300	0.0303	0.0191	0.6180
Age of head of household	0.000495	(0.004250)[a]	(0.005840)[b]	0.003410[b]	0.020200
Robust standard error	0.00097	0.00247	0.00257	0.00153	0.03820
Square of age of head of household	(5.59e-06)	6.19e-05[b]	8.66e-05[c]	(3.06e-05)[a]	0.000449
Robust standard error	9.93e-06	2.57e-05	2.71e-05	1.64e-05	0.000448
Marital status of head of household	0.00551	0.04470	0.04530	(0.01490)	0.34600
Robust standard error	0.0123	0.0293	0.0308	0.0208	0.6030
Literacy status of head of household	0.00344	(0.02910)	0.02580	0.00840	0.55900
Robust standard error	0.0115	0.0297	0.0313	0.0200	0.4840
Total no. of literate persons in family	(0.00773)	(0.00640)	(0.00547)	0.00262	(0.368)[a]
Robust standard error	0.00512	0.01060	0.01110	0.00743	0.20100
Amount of agricultural land	(0.00149)	(0.00944)[b]	0.00187	0.00293	(0.09550)[a]
Robust standard error	0.00220	0.00424	0.00323	0.00287	0.05710
Square of amount of agricultural land	9.44e-05	1.56e-05[a]	(7.17e-06)	(4.01e-06)	0.000196[a]
Robust standard error	0.000112	8.28e-06	6.53e-06	5.67e-06	0.000113
Main source of drinking water (1 = tap water)	0.0144	(0.0238)	(0.0192)	0.0232	0.1700
Robust standard error	0.0101	0.0221	0.0231	0.0155	0.3900
Type of house (1 = brick)	0.01530	0.00977	0.00489	(0.01150)	0.72100[a]
Robust standard error	0.0120	0.0266	0.0278	0.0180	0.3740
Religion (1= Buddhist)	(0.028000)[b]	(0.264000)[c]	(0.000251)	0.081400[c]	1.945000[c]
Robust standard error	0.0125	0.0286	0.0288	0.0215	0.4380
Own cow (1 = yes)	0.011900	0.041900	0.003760	(0.039200)[b]	(0.000923)
Robust standard error	0.0121	0.0282	0.0303	0.0176	0.4830
Own bull (1 = yes)	(0.01050)	0.00215	0.07480[c]	0.01780	1.32500[c]
Robust standard error	0.0102	0.0253	0.0260	0.0174	0.4980
Own horse (1 = yes)	(0.00185)	(0.01400)	0.02050	(0.00730)	0.69200
Robust standard error	0.0120	0.0308	0.0319	0.0229	0.7820
Own poultry (1 = yes)	(3.19e-05)	(0.0621)[b]	0.0531[b]	0.0356[b]	(0.4580)
Robust standard error	0.00915	0.02440	0.02490	0.01710	0.49500
Population of village	1.93e-06	(6.66e-05)	(3.64e-05)	(1.72e-05)	(0.00110)[a]
Robust standard error	1.30e-05	4.56e-05	4.07e-05	2.50e-05	0.000568
Distance to district headquarters	(0.000593)[c]	(0.001150)[c]	0.000347	(0.000787)[c]	(0.010200)[a]
Robust standard error	0.000208	0.000318	0.000323	0.000193	0.005520
Constant					4.817[c]
					1.372
Observations	2,040	2,031	2,037	2,040	1,709
R-squared					0.057

() = negative.

Notes: [a] p < 0.1 indicates that the coefficient is statistically significant at 10% level.
[b] p < 0.05 indicates that the coefficient is statistically significant at 5% level.
[c] p < 0.01 indicates that the coefficient is statistically significant at 1% level.

Source: Independent Evaluation Department estimation.

Table A9.4: Impact on Health due to Smoke
(full model estimation)

	Cough (1)	Respiratory Ailment (2)	Eye Irritation (3)	Headache (4)
Treatment	(0.0214)[b]	(0.0537)[b]	(0.1340)[c]	(0.0382)[b]
Robust standard error	0.00988	0.02330	0.02380	0.01550
Household size	0.00652	(0.03407)[a]	(0.01880)	0.02150
Robust standard error	0.00875	0.02080	0.02200	0.01440
Square of household size	0.000180	0.003370a	0.001430	(0.001090)
Robust standard error	0.000808	0.001840	0.001970	0.001350
Gender of head of household	(0.0123)	(0.0504)[a]	(0.0700)[b]	(0.0485)[b]
Robust standard error	(0.0109)	0.0300	0.0303	0.0191
Age of head of household	0.000495	(0.004250)[a]	(0.005840)[b]	0.003410[b]
Robust standard error	0.00097	0.00247	0.00257	0.00153
Square of age of head of household	(5.59e-06)	6.19e-05[b]	8.66e-05[c]	(3.06e-05)[a]
Robust standard error	9.93e-06	2.57e-05	2.71e-05	1.64e-05
Marital status of head of household	0.00551	0.04470	0.04530	(0.01490)
Robust standard error	0.0123	0.0293	0.0308	0.0208
Literacy status of head of household	0.00344	(0.02910)	0.02580	0.00840
Robust standard error	0.0115	0.0297	0.0313	0.0200
Total no. of literate persons in family	(0.00773)	(0.00640)	(0.00547)	0.00262
Robust standard error	0.00512	0.01060	0.01110	0.00743
Amount of agricultural land	(0.00149)	(0.00944)[b]	0.00187	0.00293
Robust standard error	0.00220	0.00424	0.00323	0.00287
Square of amount of agricultural land	9.44e-05	1.56e-05a	(7.17e-06)	(4.01e-06)
Robust standard error	0.000112	8.28e-06	6.53e-06	5.67e-06
Main source of drinking water (1 = tap water)	0.0144	(0.0238)	(0.0192)	0.0232
Robust standard error	0.0101	0.0221	0.0231	0.0155
Type of house (1 = brick)	0.01530	0.00977	0.00489	(0.01150)
Robust standard error	0.01200	0.02660	0.02780	0.0180
Religion (1= Buddhist)	(0.028000)[b]	(0.264000)[c]	(0.000251)	(0.081400)[c]
Robust standard error	0.0125	0.0286	0.0288	0.0215
Own cow (1 = yes)	0.01190	0.04190	0.00376	(0.03920)[b]
Robust standard error	0.0121	0.0282	0.0303	0.0176
Own bull (1 = yes)	(0.01050)	0.00215	0.07480c	0.01780
Robust standard error	0.0102	0.0253	0.0260	0.0174
Own horse (1 = yes)	(0.00185)	(0.01400)	0.02050	(0.00730)
Robust standard error	0.0120	0.0308	0.0319	0.0229
Own poultry (1 = yes)	(3.19e-05)	(0.0621)[b]	0.0531[b]	0.0356[b]
Robust standard error	0.00915	0.02440	0.02490	0.01710
Population of village	1.93e-06	(6.66e-05)	(3.64e-05)	(1.72e-05)
Robust standard error	1.30e-05	4.56e-05	4.07e-05	2.50e-05
Distance to district headquarters	(0.000593)[c]	(0.001150)[c]	0.000347	(0.000787)[c]
	0.000208	0.000318	0.000323	0.000193
Observations	1,899	712	917	1,746

() = negative.
Notes: [a] $p < 0.1$ indicates that the coefficient is statistically significant at 10% level.
[b] $p < 0.05$ indicates that the coefficient is statistically significant at 5% level.
[c] $p < 0.01$ indicates that the coefficient is statistically significant at 1% level.
Source: Independent Evaluation Department estimation.

Table A9.5: Impact on Appliance Ownership
(full model estimation)

	Television (1)	Radio (2)	Rice Cooker (3)	Refrigerator (4)
Treatment	0.2490[c]	(0.1240)[c]	0.8650[c]	0.0988[c]
Robust standard error	0.04380	0.02370	0.01070	0.00968
Own television	0.035500[b]	0.011900	0.072000[b]	0.000999
Robust standard error	0.01400	0.02150	0.03060	0.00404
Household size	(0.002760)[b]	(0.000323)	(0.006740)[b]	8.27e-05
Robust standard error	0.00128	0.00203	0.00281	0.00036
Square of household size	(0.00466)	0.03480	(0.04800)	(0.00389)
Robust standard error	0.01660	0.03070	0.04870	0.00656
Age of head of household	(0.000699)	0.000962	(0.001590)	(0.000377)
Robust standard error	0.001340	0.002600	0.004120	0.000481
Square of age of head of household	3.94e-06	(1.13e-05)	9.00e-06	3.40e-06
Robust standard error	1.42e-05	2.73e-05	4.14e-05	5.02e-06
Marital status of head of household	(0.00190)	0.03220	0.03790	0.00444
Robust standard error	0.01710	0.03120	0.04850	0.00562
Literacy status of head of household	0.0915[c]	0.0275	0.0602	0.0245[a]
Robust standard error	0.0244	0.0279	0.0439	0.0128
Amount of agricultural land	0.008230[c]	0.011400[b]	0.011200[c]	(0.000122)
Robust standard error	0.002580	0.005490	0.004150	0.000776
Square of amount of agricultural land	(0.000274)[a]	(0.000268)	(2.01e-05)[b]	8.08e-07
Robust standard error	0.000144	0.000178	8.63e-06	1.59e-06
Income	6.58e-07[c]	8.95e-07[c]	9.84e-07[b]	2.50e-07[b]
Robust standard error	1.81e-07	2.87e-07	4.08e-07	1.01e-07
Main source of drinking water (1 = tap water)	0.01420	0.03970[a]	0.02620	(0.00625)
Robust standard error	0.01260	0.02320	0.03460	0.00484
Type of house (1 = brick)	(0.00314)	0.00437	0.13400[c]	(0.00761)
Robust standard error	0.01520	0.02790	0.03990	0.00639
Religion (1= Buddhist)	(0.0213)	0.1790[c]	0.1620[c]	0.0135[b]
Robust standard error	0.01740	0.02870	0.04150	0.00627
Own cow (1 = yes)	(0.0256)	0.0573[a]	0.0782[a]	(0.0111)
Robust standard error	0.01810	0.03030	0.04350	0.00698
Own bull (1 = yes)	(0.0206)	0.0587[b]	(0.0166)	(0.0137)
Robust standard error	0.01490	0.02640	0.04010	0.00865
Own horse (1 = yes)	0.006240	0.041600	(0.000374)	(0.000194)
Robust standard error	0.01760	0.03260	0.04660	0.00588
Own poultry (1 = yes)	0.01290	(0.00971)	(0.02160)	0.00556
Robust standard error	0.01370	0.02530	0.03750	0.00513
Population of village	(3.35e-05)[a]	5.01e-06	1.72e-05	(1.75e-05)
Robust standard error	1.95e-05	3.96e-05	5.43e-05	1.44e-05
Distance to district headquarters	(0.000576)[b]	(0.000539)[a]	(0.000984)[a]	(0.000292)[a]
Robust standard error	0.000274	0.000318	0.000547	0.000151
Observations	2,040	2,040	2,040	2,040

() = negative.
Notes: [a] $p < 0.1$ indicates that the coefficient is statistically significant at 10% level.
[b] $p < 0.05$ indicates that the coefficient is statistically significant at 5% level.
[c] $p < 0.01$ indicates that the coefficient is statistically significant at 1% level.
Source: Independent Evaluation Department estimation.

Table A9.6: Impact on Total Fertility
(full model estimation)

	Number of Children Born		Children Born (Yes=1)	
	5 Years before Survey	3 Years before Survey	5 Years before Survey	3 Years before Survey
	(1)	(2)	(3)	(4)
Treatment	(0.0510)[a]	(0.0350)	(0.0526)[b]	(0.0351)[b]
Robust standard error	0.0272	0.0219	0.0224	0.0173
Household size	0.139[c]	0.103[c]	0.267[c]	0.176[c]
Robust standard error	0.0293	0.0215	0.0216	0.0166
Square of household size	0.002630	(0.000800)	(0.013900)[c]	(0.009740)[c]
Robust standard error	0.00326	0.00237	0.00187	0.00145
Age of head of household	(0.01950)[c]	(0.01050)[c]	(0.01570)[c]	(0.00544)[c]
Robust standard error	0.00343	0.00306	0.00272	0.00181
Marital status of head of household	(0.0950)[c]	(0.0610)[b]	(0.0494)[a]	(0.0430)[a]
Robust standard error	0.0331	0.0250	0.0278	0.0223
Square of age of head of household	0.000125[c]	7.04e-05[b]	9.72e-05[c]	2.65e-05
Robust standard error	3.47e-05	2.97e-05	2.78e-05	1.93e-05
Literacy status of head of household	(0.01470)	0.01290	(0.00592)	0.01600
Robust standard error	0.0306	0.0251	0.0247	0.0196
Amount of agricultural land	2.16e-07	0.001500	(0.001030)	(0.000614)
Robust standard error	0.00398	0.00367	0.00305	0.00236
Square of amount of agricultural land	(1.51e-06)	(3.99e-06)	(6.06e-07)	(6.19e-07)
Robust standard error	7.93e-06	7.31e-06	6.06e-06	4.67e-06
Main source of drinking water (1 = tap water)	(0.008720)	0.010400	(0.023800)	0.000736
Robust standard error	0.0261	0.0203	0.0213	0.0162
Type of house (1 = brick)	(0.0223)	(0.0300)	(0.0258)	(0.0317)
Robust standard error	0.0318	0.0254	0.0261	0.0203
Religion (1 = Buddhist)	0.1120[c]	0.0350	0.0851[c]	0.0222
Robust standard error	0.0333	0.0268	0.0246	0.0196
Own cow (1 = yes)	(0.0540)[a]	(0.0511)[b]	(0.0399)	(0.0443)a
Robust standard error	0.0319	0.0251	0.0295	0.0242
Own bull (1 = yes)	(0.05140)[a]	(0.00835)	(0.04160)[a]	(0.00148)
Robust standard error	0.0292	0.0232	0.0246	0.0191
Own horse (1 = yes)	(0.05690)	(0.02530)	(0.03340)	(0.00929)
Robust standard error	0.0363	0.0278	0.0275	0.0216
Own poultry (1 = yes)	0.0489[a]	0.0226	0.0316	0.0169
Robust standard error	0.0270	0.0218	0.0230	0.0176
Population of the village	1.30e-05	(1.54e-05)	1.62e-05	(1.37e-05)
Robust standard error	3.61e-05	2.40e-05	3.79e-05	3.05e-05
Distance to district headquarters	(2.88e-06)	8.55e-06	(7.68e-05)	(0.000164)
Robust standard error	0.000304	0.000243	0.000317	0.000242
Constant	0.452c	0.226b		
	0.1080	0.0913		
Observations	2,040	2,040	2,040	2,040
R-squared	0.294	0.179		

() = negative.
Notes: [a] $p < 0.1$ indicates that the coefficient is statistically significant at 10% level. .
[b] $p < 0.05$ indicates that the coefficient is statistically significant at 5% level.
[c] $p < 0.01$ indicates that the coefficient is statistically significant at 1% level.
Source: Independent Evaluation Department estimation.

Table A9.7: Impact on Fertility
(full model estimation)

	Number of Children Born		Children Born (Yes=1)	
	5 Years before Survey (1)	3 Years before Survey (2)	5 Years before Survey (3)	3 Years before Survey (4)
Treatment	(0.0220)	(0.0175)	(0.0357)	(0.0256)
Robust standard error	0.0292	0.0236	0.0239	0.0186
Own television	(0.0929)[c]	(0.0559)[b]	(0.0492)[a]	(0.0270)
Robust standard error	0.0337	0.0267	0.0257	0.0198
Household size	0.143[c]	0.105[c]	0.268[c]	0.177[c]
Robust standard error	0.0292	0.0215	0.0217	0.0166
Square of household size	0.002360	(0.000961)	(0.014000)[c]	(0.009770)[c]
Robust standard error	0.00325	0.00236	0.00188	0.00145
Age of head of household	(0.01950)[c]	(0.01050)[c]	(0.01570)[c]	(0.00546)[c]
Robust standard error	0.00341	0.00305	0.00271	0.00180
Marital status of head of household	(0.0949)[c]	(0.0609)[b]	(0.0494)[a]	(0.0429)[a]
Robust standard error	0.0330	0.0250	0.0278	0.0223
Square of age of head of household	0.000125[c]	7.03e-05[b]	9.73e-05[c]	2.66e-05
Robust standard error	3.46e-05	2.96e-05	2.77e-05	1.93e-05
Literacy status of head of household	(0.001780)	0.020700	0.000567	0.019700
Robust standard error	0.0312	0.0255	0.0253	0.0200
Amount of agricultural land	0.000563	0.001840	(0.000766)	(0.000508)
Robust standard error	0.00394	0.00365	0.00305	0.00235
Square of amount of agricultural land	(2.81e-06)	(4.77e-06)	(1.25e-06)	(9.10e-07)
Robust standard error	7.86e-06	7.29e-06	6.06e-06	4.67e-06
Main source of drinking water (1 = tap water)	(0.00621)	0.01190	(0.02170)	0.00202
Robust standard error	0.0260	0.0203	0.0214	0.0162
Type of house (1 = brick)	(0.0216)	(0.0296)	(0.0250)	(0.0313)
Robust standard error	0.0317	0.0253	0.0262	0.0203
Religion (1 = Buddhist)	0.1090[c]	0.0332	0.0831[c]	0.0210
Robust standard error	0.0333	0.0268	0.0247	0.0197
Own cow (1 = yes)	(0.0576)[a]	(0.0533)[b]	(0.0418)	(0.0454)[a]
Robust standard error	0.0318	0.0251	0.0295	0.0242
Own bull (1 = yes)	(0.05510)[a]	(0.01060)	(0.04440)[a]	(0.00283)
Robust standard error	0.0291	0.0232	0.0246	0.0192
Own horse (1 = yes)	(0.05590)	(0.02470)	(0.03250)	(0.00895)
Robust standard error	0.0362	0.0278	0.0276	0.0216
Own poultry (1 = yes)	0.0510[a]	0.0239	0.0325	0.0170
Robust standard error	0.0270	0.0217	0.0230	0.0176
Population of village	6.60e-06	(1.92e-05)	1.26e-05	(1.52e-05)
Robust standard error	3.63e-05	2.42e-05	3.78e-05	3.02e-05
Distance to district headquarters	(7.00e-05)	(3.18e-05)	(0.000114)	(0.000188)
Robust standard error	0.000303	0.000242	0.000319	0.000243
Constant	0.449[c]	0.224[b]		
Robust standard error	0.1080	0.0911		
Observations	2,040	2,040	2,040	2,040
R-squared	0.294	0.179		

() = negative.
Notes: [a] $p < 0.1$ indicates that the coefficient is statistically significant at 10% level.
[b] $p < 0.05$ indicates that the coefficient is statistically significant at 5% level.
[c] $p < 0.01$ indicates that the coefficient is statistically significant at 1% level.
Source: Independent Evaluation Department estimation.

Table A9.8: Impact on Migration and Food Security
(full model estimation)

	Migration in Last 5 Years (1 = yes) (1)	**Number of Migrants** (2)	**Debtedness** (1= yes) (3)	**Food Security** (1=yes) (4)
Treatment	0.0300	0.0785	0.0295[b]	0.0422[c]
Robust standard error	0.0228	0.0621	(0.0149)	0.0153
Income	…	…	…	3.06e-07[c]
Robust standard error	…	…	…	9.09e-08
Household size	(0.0249)	(0.275)[c]	0.0358[b]	(0.0358)[c]
Robust standard error	0.0217	0.0697	0.0142	0.0134
Square of household size	0.00178	0.02160[c]	(0.00261)[a]	0.00235[b]
Robust standard error	0.00197	0.00634	0.00137	0.00118
Gender of head of household	0.107000[c]	0.282000[c]	0.033400[a]	0.000795
Robust standard error	0.0280	0.0772	0.0201	0.0184
Age of head of household	0.000304	(0.017800)[a]	(0.000310)	(0.001840)
Robust standard error	0.00247	0.00915	0.00180	0.00164
Square of age of head of household	7.25e-06	0.000206[b]	(5.34e-06)	1.25e-05
			1.87e-05	1.72e-05
Robust standard error	2.60e-05	9.12e-05		
Marital status of head of household	(0.0583)[b]	(0.0303)	(0.0118)	0.0301
Robust standard error	0.0292	0.0796	0.0196	0.0192
Literacy status of head of household	(0.0262)	(0.0240)	(0.0311)	0.0342[a]
Robust standard error	0.0292	0.0840	0.0212	0.0180
Total number of literate persons in family	0.00535	0.00514	0.02160[c]	0.00666
Robust standard error	0.01030	0.02980	0.00781	0.00697
Amount of agricultural land	(0.000785)	0.003810	(0.000415)	0.005560[b]
Robust standard error	0.00290	0.00866	0.00258	0.00259
Square of amount of agricultural land	4.32e-07	(9.75e-06)	3.43e-07	(1.13e-05)[b]
Robust standard error	5.76e-06	1.72e-05	5.11e-06	5.12e-06
Main source of drinking water (1 = tap water)	(0.01560)	(0.02010)	0.00495	(0.00210)
Robust standard error	0.0220	0.0626	0.0154	0.0143
Type of house (brick=yes)	0.04940[a]	0.22200[c]	0.00962	0.07410[c]
Robust standard error	0.0258	0.0707	0.0170	0.0189
Religion (1= Buddhist)	0.149000[c]	0.348000[c]	0.056100[c]	0.000945
Robust standard error	0.0264	0.0701	0.0181	0.0189
Own cow (1 = yes)	0.01490	0.10600	(0.02220)	0.00439
Robust standard error	0.0292	0.0809	0.0193	0.0197
Own bull (1 = yes)	0.0127	(0.0449)	0.0207	0.0276
Robust standard error	0.0253	0.0718	0.0169	0.0170
Own horse (1 = yes)	0.00425	0.05060	0.00181	0.05030[c]
Robust standard error	0.03100	0.09140	0.02270	0.0175
Own poultry (1 = yes)	0.00204	0.01030	(0.01180)	(0.01810)
Robust standard error	0.0242	0.0678	0.0173	0.0147
Population of the village	(3.06e-05)	(5.32e-06)	1.63e-05	3.98e-05[b]
Robust standard error	3.94e-05	0.000114	2.89e-05	1.86e-05
Distance to district headquarters	(0.000190)	(0.001590)[a]	(0.000599)[c]	0.000799[c]
Robust standard error	0.000319	0.000863	0.000188	0.000193
Constant	0.23600[c]	1.26400[c]	(0.00331)	0.83300[c]
	0.0845	0.2970	0.0554	0.0560
Observations	2,040	2,040	2,036	2,040
R-squared	0.038	0.051	0.038	0.048

() = negative, ... = data not available.

Notes: [a] $p < 0.1$ indicates that the coefficient is statistically significant at 10% level.
[b] $p < 0.05$ indicates that the coefficient is statistically significant at 5% level.
[c] $p < 0.01$ indicates that the coefficient is statistically significant at 1% level.

Source: Independent Evaluation Department estimation.

MANAGEMENT RESPONSE TO THE IMPACT EVALUATION STUDY ON ADB'S ASSISTANCE FOR RURAL ELECTRIFICATION IN BHUTAN – DOES ELECTRIFICATION IMPROVE THE QUALITY OF RURAL LIFE?

On 18 October 2010, the Director General, Independent Evaluation Department, received the following response from the Managing Director General on behalf of Management:

I. General Comments

1. We appreciate this comprehensive study of ADB's assistance for the two Bhutan rural electrification projects completed in 2006. We commend IED's in-depth analysis and identification of the benefits from ADB-supported rural electrification projects and the potential areas for our future assistance.

2. The overall performance of the two ADB-funded rural electrification projects has been rated "successful", and twelve of the thirteen loan and technical assistance projects related to rural electrification during 1989-2009 were evaluated "successful" or "highly successful". The report notes ADB's significant contribution to expanding access to electricity and improving operations; ADB support is estimated to have been responsible for one-third of the rural households electrified between 1995 and 2010. The study indicates quantifiable, visible, and positive outcomes of rural electrification that are improving quality of life, while the flow of benefits is slowly emerging with the gradual increase in electricity consumption. Rural electrification has served as an important pillar for poverty reduction, and benefits will also spread over time from programmatic interventions in other sectors such as rural roads, financial and social services.

II. Comments on Specific Recommendations

3. **Recommendation 1: Building on success so far, stimulate and manage household and community demand for electricity.** We agree. We highlight the importance of linking rural electrification with income generating activities to achieve poverty reduction. The proposed 2010 Japan Fund for Poverty Reduction grant project (i.e., *Improving Gender-Inclusive Access to Clean and Renewable Energy in Bhutan, Nepal, and Sri Lanka)* includes training on energy-related income generating activities for beneficiaries under the next proposed investment project, i.e., the *Rural Renewable Energy Development Project* (planned for Board consideration in late October 2010). The combination of this training with the physical investments will contribute to improving income levels and living standards. The training programs will include raising consumers' awareness of energy efficiency and safety issues.

4. **Recommendation 2: Ensure the sustainability of project benefits.** We agree. Sustainability of rural electrification projects in Bhutan will depend on continuous cross-subsidization, which is sourced from energy royalty, where (i) 15% of total generation is supplied at discount rates (mainly for residential customers), and (ii) subsidy levels are based on affordability for each consumer bracket. The sector's efficiency and sustainability have been demonstrated through the utility's financial health and the government's policy initiatives. For

example, in August 2010, the Bhutan Electricity Authority, the independent regulator, announced multi-year tariffs for the next three years, thereby bringing transparency to cost base tariff and subsidy requirements. In the Economic Development Policy 2010, the Government has stated that the 15% cap for the royalty energy will continue until 2020. These regulatory and policy frameworks will ensure reasonable tariff mechanisms and the operational and financial sustainability of rural electrification. Linked to the draft Renewable Energy Policy, the proposed 2010 investment project (referred to in para. 3 above) will further widen access to clean energy and improve overall energy efficiency in rural areas through grid extension and a mix of renewable energy resources (e.g., biogas from animal dung for cooking and solar home systems for isolated and remote rural areas).

5. **Recommendation 3: Encourage monitoring of project outcome and impacts over time.** We agree. For monitoring, the proposed 2010 investment project includes socioeconomic and environmental indicators in the design and monitoring framework. The proposed 2010 Japan Fund for Poverty Reduction grant project will also determine baseline data and monitor specific socioeconomic indicators related to rural electrification.

DEVELOPMENT EFFECTIVENESS COMMITTEE OF THE BOARD (DEC)

Chair's Summary of the Committee's Discussion on 19 October 2010

I. Impact Evaluation Study of Asian Development Bank's Assistance for Rural Electrification in Bhutan—Does Electrification Improve the Quality of Rural Life? (DOC.IN.211-10)

Discussion highlights

1. Director General, IED highlighted that the impact evaluation study (IES) was part of the Independent Evaluation Department's (IED) efforts to promote impact evaluation studies in ADB and mainstream IES in regional departments. In the future, up to two IESs would be completed by IED every year . This IES provided empirical evidence that electrification improves quality of rural life. The same conclusion had been also reached in a similar study by the Independent Evaluation Group (IEG) in 2008. Management agreed to the recommendations of the study.

2. DEC members were concerned about the lagged impact of rural electrification, and they noted that four years into the implementation of the projects maybe a short period to measure all the lifestyle or technological changes. Staff, IED noted that measuring impact could be difficult due to lack of data. Staff, IED also stated that lack of valid baseline data was a major constraint in conducting impact evaluation in ADB.

3. DEC members noted the (i) economic benefits of electrification in terms of increase in income, (ii) environmental benefit such as reduction in use of fuel wood and kerosene, and (iii) social benefits like better lights for children's study and better indoor air quality. They also noted that some factors, like savings from storage facilities due to increased refrigeration, were not taken into account. . Members emphasized that provision of rural electricity should accelerate economic activities, and improve education facilities.

4. DEC members were concerned about environmental sustainability of rural electrification projects, and concurred on the need to explore alternative sources of energy, including off-grid options. However, off-grid connections may pose maintenance and financing problems, and may require subsidies to make the connections more affordable. Director General, SARD mentioned that there are ongoing efforts to explore solar energy technologies; a renewable energy project would soon be submitted for the Board's approval. Similarly, on the thrust for "energy for all", he explained that ADB's approach is on selectivity, where assistance could be considered for projects that have internal rates of return at permissible level. Otherwise, off-grid solutions would be explored. Staff, SAEN added that for that purpose, there were plans to explore mixes of alternative renewable energy sources (e.g. biogas for cooking, and solar energy for lighting).

Conclusions

5. DEC welcomed the study, which was the first study to present a rigorous quantification of the economic, environmental and social impact of rural electrification in ADB.

6. The study confirmed that access to electricity for rural households contributed to increased household income; reduced expenditure on traditional energy sources such as kerosene; improved in-door air quality, thereby contributing to better health; and enabled

children to use better lighting for their studies. DEC members hoped that through time, the impact of rural electrification on the connected households will become even stronger.

7. DEC members noted that there was need for impact evaluation studies, and given the external benefits of such evaluation studies, there was merit in the cost being shared by stakeholders, apart from the country where the study is done. Furthermore, these impact evaluation studies should be used to draw lessons about how to do such projects or programs even better to increase their beneficial impact.

II. 2010 Annual Evaluation Review (DOC.IN.235-10)

Discussion highlights

8. Director General, IED emphasized that the annual evaluation review (AER) is a collection of IED's findings in 2009, and does not present any new recommendations. DEC hoped that the report would be simultaneously disseminated to stakeholders who would benefit from the richness of the report.

9. DEC noted IED's finding that the Bank should engage more in real-time studies, particularly on evaluative aspects of the reviews as different from normal reviews. DEC found it reasonable for IED to delineate its role in real-time evaluation that does not unduly overlap with the responsibilities of either the regional departments or the executing agencies. Such approach would avoid conflicts of interest. IED would do real-time evaluation of ongoing operations only when requested by the Board or Management. Deputy Director General, SPD explained that midterm reviews are a normal practice in ADB which involves a full review of project designs, with emphasis on inputs. There is a working group looking at strengthening the midterm reviews that could also address issues of implementation delays, and cost overruns, among others. Principal Director, COSO added that project administration instructions required staff to carry out comprehensive midterm reviews. IED staff stated that according to evaluation findings only a small proportion of mid-term reviews were comprehensive.

10. DEC members, while noting the importance of evaluating the results of governments' commitments to ADB's assistance, agreed that there should be adequate involvement of the governments in the inclusive evaluation process. Director General, IED explained that evaluations are based on adequate consultations with governments. For major evaluations, there were workshops and consultations in the field, while for project-level evaluations, drafts were sent to governments for their comments. There were also no particular recommendations to governments, but some follow-on actions for regional departments (RDs) could require follow-up with governments.

11. DEC noted ongoing efforts by Management to address issues in ADB's assistance to justice reforms, resettlement, water supply and sanitation, and technical assistance (TA) operations, including the quality of consulting services. On justice reforms, Principal Director, COSO explained that law and policy reforms were considered in the context of Strategy 2020 and resource availability. On TA operations, he acknowledged difficulties faced in delegating TA administration to executing agencies, and noted that very few countries were receptive to the delegation, partly due to anticipated difficulties in managing consultants. On the same note, he emphasized that compensation for consultants were market-based, and remuneration may not be a factor for low quality of consulting services. It may be worthwhile to look at the terms of reference, supervision of consultants, and capacity of executing agencies.

12. Director General, SPD mentioned ADB's efforts to address resettlement issues, including creating new safeguards policy statement, strengthening safeguards activities, with more emphasis on addressing safeguards issues during projects implementation, and hiring more safeguards experts. He also assured that there were ongoing efforts to integrate water supply with sanitation.

13. DEC members and some Board members noted the declining success rates of portfolio. One Board member suggested disaggregating the analyses to get a better picture of the quality of consulting services engaged by ADB, particularly for urban development, and to get insights into how procurement processes contributed to implementation delays.

Conclusions

14. DEC noted that the 2010 AER provided an opportunity for an annual stocktaking of lessons learned from IED's activities in the past year. DEC welcomed the increased volume of work done by IED in terms of project completion report validation, high level evaluation of priority topics to ADB, and new knowledge products.

15. DEC noted the decline in the projects' success rate, which could have been partly due to the increased volume. Nevertheless, DEC emphasized the importance of improving the success rate of loans, particularly, program loans.

16. DEC welcomed the Management Action Record System (MARS) introduced in the year, and some members emphasized that apart from explicit recommendations given by IED, it was for consideration whether more could be distilled from the reports. Some members suggested that the title of the tables on detailed performance indicators in Appendix 2 could be changed from "ADB and Borrower Performance" to "ADB and Executive Agency Performance". DEC welcome the inclusive nature of the IED reports where many stakeholders were consulted.

17. DEC members reiterated the need for improving the quality of consultancy inputs in ADB work. DEC also requested IED to consider whether there was merit in doing further analysis regarding the deterioration in rating of ADB Group B countries' projects approved in 2001-2007, including in particular, projects in the Pacific DMCs.

(signed)
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