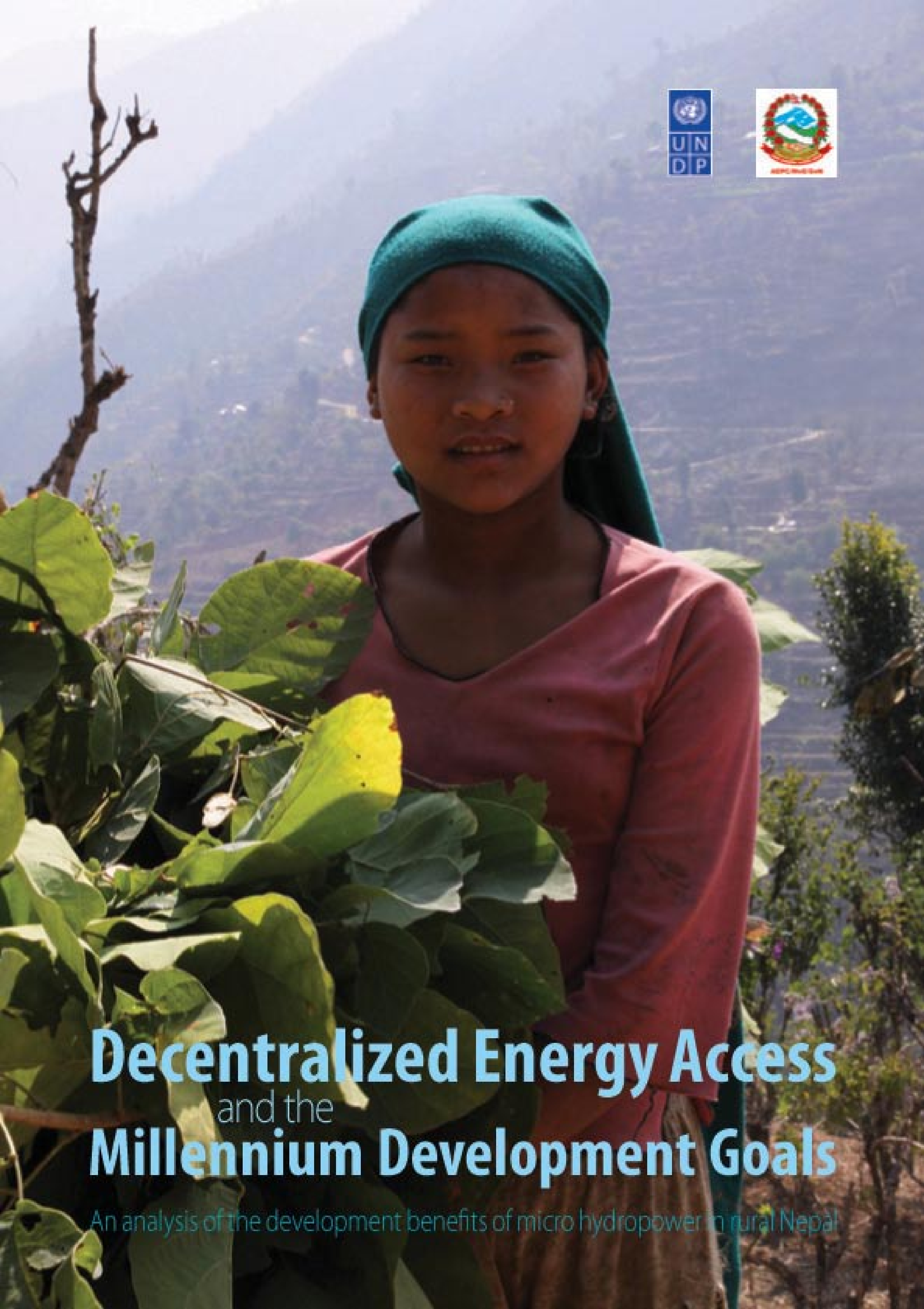

Decentralized Energy Access and the Millennium Development Goals

An analysis of the development benefits of micro hydropower in rural Nepal

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An analysis of the development benefits of micro-hydropower in rural Nepal

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Contents

Figures vii
Tables viii
Boxes x
Forewords xi
Preface xiv
Acknowledgments xv
About the authors xvi
Abbreviations, acronyms and conversion units xvii
Executive summary xviii

1. Introduction 1
    Context and objective of the study 3
    Overview of Nepal's development context 5
        Development 5
        Energy 6
    Rural Energy Development Programme (REDP) 6
        REDP in Nepal 6
        Costs and investments for REDP's MHS programme 8

2. Methodology 11
    Introduction 13
    Selection of sites for the survey 13
    Collection of data 14
    Analysis of data 16
        Review of compiled data and analysis of general trends 16
        Identification of potential association between development indicators and access to electricity 16
        Determination of the extent to which electricity access is associated with observed impacts 16
        Quantification of benefits in monetary terms 17
    Limitations 18
        The with/without methodology 18
        Data quality and reliability 18
        Econometric tools and number of observations 18
        Correlation versus causality 18
        Sample bias 18
        Representativeness of the sample 18

Contents

3. Electricity access accelerates achievement of the MDGs in rural areas 21
MDG 1 23
Increased incomes 24
Productive activities increase 26
Increased agricultural production 28
Energy expenditures are reduced 28
MDG 2 30
More teachers and lower student-to-teacher ratios 31
Children's education improves 32
Households devote more resources to education 34
MDG 3 35
Girls' education improves 36
Women have greater access to communications equipment 37
Women have more time to spend on leisure activities 37
MDGs 4, 5 and 6 38
Cooking and sanitation conditions improve 39
Number of qualified health workers increases 40
People visit health centres more often 41
MDG 7 42
Consumption of batteries and kerosene declines 42
Greenhouse gas emissions are avoided 44
MDG 8 44
Time allocation 44
Reduced time spent on agro-processing activities 45
More time in the day 46
Summary of benefits 46

4. Policy implications and conclusions 49

Annexes 59
Annex 1. Overview of methodologies to quantify benefits 61
Annex 2. Map of Nepal 64
Annex 3. Sample questionnaire – households with electricity access 65
Annex 4. Additional statistics on communities surveyed 74
Annex 5. Data analysis 80
Annex 6. Estimation of consumer surplus 82
Annex 7. Linkages between energy and the MDGs 84
Annex 8. Findings from inferential analysis 86
Annex 9. Findings from regression models analysis 95
Annex 10. Estimation of avoided CO_2 emissions in selected sites 101
Endnotes 102
References 109

Figures

1.	Costs of MHS in selected areas ($/kW)	9
2.	Distribution of annual income in electrified and non-electrified communities	24
3.	Average household income in electrified and non-electrified communities	25
4.	Productive activities created after the installation of MHS in selected areas	27
5.	Annual household production in electrified and non-electrified communities	29
6.	Average household expenditures for energy sources in electrified and non-electrified communities	29
7.	Number of students per teacher	32
8.	Average number of children dropping out of school in 2008	33
9.	Average number of school days missed in 2008	33
10.	Average time spent per children aged 6 to 15 on educational activities	33
11.	Average school enrolment rates in electrified and non-electrified communities	34
12.	Average school expenditures in households with/without electricity access	35
13.	Average number of school days missed by girls in 2008	36
14.	School grade levels of girls living in electrified and non-electrified communities	37
15.	Time spent by women on leisure activities in communities with/without electricity	38
16.	Cooking habits in electrified and non-electrified communities	39
17.	Water supply in electrified and non-electrified communities	40
18.	Toilet facilities in electrified and non-electrified communities	40
19.	Average number of health workers in health posts	41
20.	Average annual number of visits to health centres	41
21.	Average consumption of kerosene and batteries in electrified and non-electrified communities	43
22.	Media facilities in communities with/without electricity access	45
23.	Average annual income by source of revenue (Rs)	76
24.	Distribution of annual income by source of revenue (Rs)	76
25.	Land use in electrified and non-electrified households	77
26.	Distribution of energy expenditures in non-electrified and electrified sample households	78
27.	Average health expenditures per capita (Rs/month)	81
28.	Use of dry-cell batteries	81

Tables

1.	Development indicators in Nepal versus other regions	4
2.	MHSs selected in Baglung district	13
3.	MHSs selected in Kavre district	13
4.	MDGs and related indicators developed for the study	14
5.	Sample of household survey	15
6.	Size of the interviewed sample per survey questionnaire	16
7.	Statistical and economics approaches applied to selected indicators	18
8.	MDG 1 related indicators’ association with electricity access and difference between households in communities with/without electricity	23
9.	Agro-processing done by different methods and end-use technologies in Nepal	26
10.	Average number of beneficiaries of the productive activities in surveyed areas	26
11.	Productive activities developed in selected areas after MHS installation	27
12.	Average estimated electricity consumption for productive activities (kWh/Year)	30
13.	MDG 2 related indicators’ association with electricity access and difference between households in communities with/without electricity	31
14.	MDG 3 related indicators’ association with electricity access and difference between households in communities with/without electricity	36
15.	MDG 4, 5 and 6 related indicators’ association with electricity access	39
16.	MDG 7 related indicators’ association with electricity access and difference between households in communities with/without electricity	42
17.	MDG 8 related indicators’ association with electricity access	44
18.	Time allocation’s association with electricity access and difference between households in communities with/without electricity	45
19.	Methods of agro-processing technologies in Nepal and average time spent for food processing in surveyed areas	46
20.	Summary of electricity access benefits valued in monetary terms for sample households and beneficiaries	47
21.	Estimated value of potential benefits from scaling up the MHS programme in Nepal	53
22.	Likely impacts of scaling up the REDP MHS project in Nepal	53
23.	Overview of approaches applied to value benefits from electrification	62
24.	Average time spent on activities generating income for men and women	75

25.	Average livestock owned per household at the time of the survey, by surveyed area	75
26.	Electricity access and average energy expenditures by type of energy and area surveyed (Rs/month)	76
27.	Average energy expenditures by type of energy used and area surveyed (Rs/month)	76
28.	Average number of students per school staff by district and types of school	77
29.	Average school enrolment per household for girls and boys aged between 4 and 16	77
30.	Average time spent on educative activities, by gender (hours/week)	77
31.	Average time spent on leisure activities, by gender	78
32.	Electricity access and average time spent on cleaning and cooking, by gender (hours per week)	78
33.	Health centres' statistics	78
34.	Kerosene, fuelwood and dry-cell batteries consumption in areas surveyed	79
35.	Choosing the correct statistical test	81
36.	Linkages between energy and the MDGs	84
37.	Tests of association for indicators related to MDG 1	86
38.	Tests of difference for indicators related to MDG 1	87
39.	Tests of association for indicators related to MDG 2	88
40.	Tests of difference for indicators related to MDG 2	89
41.	Tests of association for indicators related to MDG 3	90
42.	Tests of difference for indicators related to MDG 3	91
43.	Tests of association for indicators related to MDG 4, 5 and 6	91
44.	Tests of association for indicators on energy	92
45.	Tests of difference for indicators on energy consumption	92
46.	Tests of association for indicators on media facilities	93
47.	Tests of association for indicators on allocation of time	93
48.	Tests of difference for indicators on allocation of time	94
49.	Determinant of household income	95
50.	Determinant of household expenses for energy	96
51.	Determinant of the number of students per primary school teachers	96
52.	Determinant of school grade levels for children aged 6 to 16	97
53.	Determinant of household expenses for education	98
54.	Determinant of school grade level for girls aged 6 to 16	98
55.	Determinant of dry-cell batteries consumption levels	99
56.	Determinant of kerosene consumption levels	100
57.	MHS and electricity consumption	101

Boxes

1.	Decentralized energy systems in rural and remote areas	4
2.	Community mobilization in Nepal's national MHS programme	7
3.	Definition of key concepts	15
4.	MDG 1 in Nepal – Reduce poverty and hunger	23
5.	MDG 2 in Nepal – Achieve universal primary education	31
6.	MDG 3 in Nepal – Promote gender equality and empower women	35
7.	MDG 4, 5 and 6 in Nepal – Reduce child mortality, improve maternal health, combat diseases	38
8.	MDG 7 in Nepal – Ensure environmental sustainability	42
9.	MDG 8 in Nepal – Develop a global partnership for development	44
10.	Cost of expanding the MHS programme in Nepal	55
11.	Harnessing people's potential to develop rural energy systems	57

Forewords

The Government of Nepal (GoN) through the Alternative Energy Promotion Centre (AEPC) of the Ministry of Environment (MoEnv) has been giving high priority to the promotion of rural and renewable energy technologies mainly micro-hydro, solar, biogas and improved cook stoves in its development plans and programmes. The promotion of large-renewable energy technologies at large scale in rural Nepal was made possible by the strong and long-term commitment of the Government of Nepal, along with the support of UNDP, the World Bank, DANIDA, Norway, and other development partners. Their joint efforts have enabled Nepal to develop highly effective national energy programmes, successfully scaled up to drastically increase the use of renewable energy technologies, improve livelihoods of the rural populations, protect the environment, and enhance the development of commercially viable alternative energy industries in the country.

Nepal is making notable progress on the Millennium Development Goals (MDGs), yet disparities between ethnic, social and economic groups remain significant, affecting in particular the hard-to-reach poor and those living in remote and inaccessible areas, where delivering services is especially difficult. GoN has accorded importance to tap abundant water resources in Nepal that present immediate opportunities for using decentralized off-grid micro-hydropower development to expand access to modern energy services, in particular electricity. This has a vast potential to improve the lives of Nepalese people in rural remote areas, empowering them to build a better future for themselves and their communities.

The GoN is pleased to collaborate with the United Nations Development Programme (UNDP) on this important study on the development benefits resulting from access to electricity for rural and remote communities in Nepal. This study is based on the successful expansion of the Rural Energy Development Programme executed by the Alternative Energy Promotion Centre. Aimed at increasing access to decentralized energy systems in rural Nepal, the programme has adopted community mobilization as the pillar of its activities.

I am pleased to present an assessment that illustrates the development benefits of rural electrification through micro-hydropower in improving the quality of life of people in rural and remote areas of Nepal. Such benefits of access to electricity have made a profound contribution to multiple aspects of human development, from poverty to health, education, gender equality, access to information and communication and environmental sustainability.

I hope this study will also encourage other developing countries to develop their own rural energy initiatives to help communities break free from poverty and achieve real progress towards the Millennium Development Goals.

Sunil Kumar Manandhar,
Ministry of Environment, Government of Nepal

Nepal's progress toward achieving the MDGs has been remarkable in a number of areas, particularly in terms of poverty reduction. Yet progress has been unequal with significant disparities amongst different geographical regions, urban and rural areas, as well as women and men. Access to electricity, as an essential energy service has a great potential to improve the lives of the poor, particularly in rural and remote communities. Abundant water resources in Nepal present immediate opportunities for decentralized off-grid micro-hydropower development.

Clean, reliable and affordable energy services are indispensable for achievement of the MDGs. In this context, the Alternative Energy Promotion Centre (AEPC) of the Ministry of Environment, Government of Nepal and the United Nations Development Programme (UNDP) are pleased to have collaborated on this important study on the development benefits resulting from access to electricity for rural and remote communities in Nepal.

The development of micro-hydropower in rural Nepal was made possible by the vision and hard work of many dedicated Nepalese, as well as long-term commitments and support from the Government of Nepal, and development partners, including UNDP, the World Bank, DANIDA, and Norway. Their joint efforts have enabled Nepal to develop highly effective national energy programmes, successfully scaled up to bring electricity, mechanical power and modern fuels to rural communities throughout the country.

This study is based on the successful expansion of the Rural Energy Development Programme executed by the Alternative Energy Promotion Centre. Aimed at increasing access to decentralized energy systems in rural Nepal, the programme has provided a sustainable approach to improving living conditions and increasing economic development for thousands of rural people. One of the programme's key achievements has been the expansion of micro-hydropower systems that provide electricity to some 250,000 people living in rural and remote areas. This achievement makes it possible to assess development benefits from electrification as an entry point for human development, and its contribution to achieving the MDGs, from poverty to education, gender equality, health, access to information and communication and as well as environmental benefits.

It is now our privilege to present a detailed assessment of the development benefits that, allowed by multiparty efforts, provide a sustainable approach to improving the quality of life of people in rural and remote areas of Nepal. Access to electricity allows better lighting and equipment at home, but also better facilities in schools and health centres. It can also provide access to mechanical power to grow and process more food, as well as energy for communication and productive income-generating activities. We hope the data and information presented in this report will encourage other developing countries to set the path for their own rural energy initiatives and achieve real progress towards the Millennium Development Goals.

Shoko Noda,
Country Director, UNDP Nepal

Clean, reliable and affordable modern energy services are prerequisites for achievement of the Millennium Development Goals (MDGs). In this context, the Government of Nepal (GoN) has been placing high priority on the promotion of renewable energy technologies – mainly micro-hydro, solar, biogas and improved cook stoves – in Nepal. The on-going Three Year Plan (2010/11–2012/13) has a target to provide electricity access to rural people by producing an additional 15 MW capacity from micro-hydro schemes.

Various bilateral and multilateral donor agencies are providing financial and technical assistance to GoN for planning, capacity building and implementation of rural energy system development programmes and projects. The development of micro-hydropower in rural Nepal became possible as a result of the hard work of Nepalese people, as well as long-term commitments of GoN and generous support from UNDP, the World Bank, DANIDA, Norway, and other development partners.

The GoN, through Alternative Energy Promotion Centre (AEPC), is pleased to work in collaboration with UNDP on this important study entitled *Decentralized Energy Access and the Millennium Development Goals: An analysis of the development benefits of micro-hydropower in rural Nepal*. This study is based on the experience of the Rural Energy Development Programme (REDP) executed by the AEPC. Aimed at increasing access to energy services in rural Nepal, the programme has been successful in developing a model of community managed rural energy systems. One of the key achievements of REDP is the expansion of micro-hydropower systems to provide electricity services to some 250,000 rural people.

We are pleased to present a detailed assessment of the development benefits of micro-hydropower services in terms of improving the quality of life of people in rural and remote areas of Nepal. Such benefits of access to electricity include lights at school, energy to run equipment at health centres, more education for girls, mechanical power to grow and process more food and spur more productive income-generating activities. In short, it can be noted that electricity has resulted in profound contributions on multiple aspects of human development, from poverty to health, education, and gender equality, access to information and communication, and climate change.

We hope this study will encourage developing countries to plan and budget for their own rural energy initiatives, help rural communities alleviate poverty and achieve real progress towards the Millennium Development Goals.

Dinesh Chandra Devkota, Ph.D,
Acting Vice Chairman, National Planning Commission

Preface

In April 2010, the Secretary-General's Advisory Group on Energy and Climate Change called upon the United Nations system and its member states to commit themselves to ensuring universal energy access to modern energy services by 2030. Rapid implementation of this commitment is essential for boosting pro-poor economic growth in the poorest countries and achieving the Millennium Development Goals relating to poverty reduction, health, education, gender equality and environmental sustainability.

The UN General Assembly also emphasized the need to improve access to reliable, affordable, and environmentally sound energy for development in adopting a December 2010 Resolution recommending that 2012 be designated as the 'International Year for Sustainable Energy for All.'

Lack of energy access is a widespread problem that diminishes the prospects and hopes of people throughout the world, especially in Africa and Asia. Close to 1.4 billion people in developing countries currently live without electricity, and about 3 billion rely on inefficient and polluting fires for cooking and household needs (IEA et al., 2010; UNDP and WHO, 2009). Without new policies, and investments, in energy technologies and infrastructure, little progress will be made in bringing these numbers down by 2030.

This report from Nepal assesses the economic, environmental and social benefits that micro-hydropower electricity generators bring to people in remote communities beyond the reach of the national grid, and demonstrates the cost-effectiveness of an off-grid electrification programme using locally available resources. Scaling up this micro-hydropower programme to reach an additional 6 million people would enable Nepal to achieve its national plans for universal access to energy, and for poverty reduction, in an affordable manner.

While the upfront investments required to bring off-grid electrification to rural areas may be substantial, the development benefits rapidly and emphatically outweigh the costs. A comparison of similar communities in Nepal with and without electricity shows substantial and quantifiable increases in household incomes, school attendance, health care visits and girls' education attributable to the installation of village micro-hydropower systems. Even more important, access to electricity creates time and opportunities for new productive activities for village men and women, such as agro-processing mills, livestock farming, and sewing businesses.

UNDP and the Government of Nepal are pleased to present this study as a resource and encouragement for other countries undertaking the challenges of providing electricity to rural communities. Community mobilization is critical to ensure active participation and sustainable self-governance towards achieving development objectives. Electrification programmes can be seen as an `entry point' for the poor in rural development. Nepal's experience shows that developing capacities to scale-up energy access initiatives and promoting income-generating activities using newly available electricity are critical for boosting economic growth and reducing poverty in remote rural areas. In this respect, we look forward to continued dialogue with governments and other development partners as we join forces to make universal access to modern energy services for poor men and women a global reality.

Veerle Vandeweerd,
Director, Environment and Energy Group, Bureau for Development Policy, United Nations Development Programme

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This study was jointly initiated by the Sustainable Energy Programme, part of the Environment and Energy Group of the UNDP Bureau for Development Policy (UNDP BDP) in New York, UNDP Nepal, and the Alternative Energy Promotion Centre (AEPC), an autonomous organization within the Ministry of Environment of the Government of Nepal. It benefited from the valuable contributions and collaborative efforts of many people, including staff from the Rural Energy Development Programme in Nepal as well as peer reviewers both internal and external to UNDP. AEPC and UNDP facilitated consultations with national stakeholders in Nepal throughout the study.

UNDP and AEPC wish to thank the lead authors, Gwénaëlle Legros (UNDP consultant) and Kamal Rijal and Bahareh Seyedi of the UNDP Sustainable Energy Programme, Environment and Energy Group, BDP. Special thanks are extended to all the contributors, Kiran Man Singh (Rural Energy Development Programme, REDP, Nepal), Bhuvan Keshar Sharma (REDP consultant), Laurent Mathieu (Professor, University of Versailles, France), Edgar Blaustein (consultant), Bhim Adhikari (Professor, University of Michigan, USA), Trilok Singh Papola (Professor, Institute for Studies in Industrial Development, New Delhi, India), Gail Karlsson (consultant), and Ines Havet (consultant). They worked together to develop an appropriate methodology, design and implement the survey, and consolidate and analyse data to assess the development benefits of micro-hydropower systems in rural Nepal. This publication is founded on their expertise in the fields of energy for sustainable development, socioeconomic surveys and data analysis as well as their in-depth understanding of Nepal's rural areas. In addition, credit is due to Kamal Rijal for his lead role in directing the development of the paper, to Gwénaëlle Legros for her meticulous analysis of extensive data and for presenting this data in a policy-relevant fashion, and to Bahareh Seyedi for overall coordination of the process from analysis to finalization and production of the publication.

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About the authors

Gwénaëlle Legros is consultant with the Sustainable Energy Programme within UNDP's Environment and Energy Group in New York, for which she prepares advocacy and communication materials, conducts analytical and technical assessments as well as data analysis on key issues relevant to the sustainable energy programme. She holds a PhD. in Energy and Development Economics and a Master in Environmental Economics from the University of Versailles Saint-Quentin-en-Yvelines (France). She has been working over the last ten years in the fields of energy and sustainable development conducting research, statistical and analytical work or implementing renewable energy projects in developing countries. She lived and worked in Burundi as survey coordinator, in China as adviser for sustainable development projects, and in Pacific islands (Palau, the Marshall Islands and the Federated States of Micronesia) as renewable energy expert. She also took part in the development of several decentralized energy projects in China, Morocco, Madagascar and Laos.

Kamal Rijal is a Policy Adviser with the Sustainable Energy Programme within UNDP's Environment and Energy Group in New York. He is mainly involved in the development of knowledge products for advocacy, advice and policy dialogue to advance energy poverty agenda and provides policy advisory services to UNDP offices on energy and development issues. Prior to joining UNDP, he served as an Energy Specialist with the International Centre for Integrated Mountain Development, Kathmandu and as a Senior Advisor with the Government of Nepal's National Planning Commission. Kamal holds a PhD in Energy Economics and Planning from the Indian Institute of Technology in Delhi and Masters in Energy Technology from Asian Institute of Technology in Bangkok. He brings more than 25 years of experience, has more than 30 publications in international journals, and has edited and co-authored more than 15 publications on energy, water, gender, and development.

Bahareh Seyedi is an Energy Policy Specialist with the Sustainable Energy Programme within the Environment and Energy Group of UNDP in New York. She holds a Master of Science from De Montfort University (United Kingdom) with a concentration on Climate Change and Sustainable Development policy issues, and a bachelor in Electrical Engineering from McGill University (Canada). Prior to joining UNDP Headquarters in New York, she was posted at UNDP in Burkina Faso where she managed multiple projects in the area of energy and environment. She has also worked with civil society organizations, leading several international development projects in Central America and South East Asia, in addition to conducting research in academic institutions, and working as an analyst in the private sector and engineering firms.

Abbreviations, acronyms and conversion units

AEPC	Alternative Energy Promotion Centre
DDC	District Development Committee
DHS	Demographic Health Survey
CER	Certified Emission Reduction
CO_2	Carbon dioxide
ESMAP	Energy Sector Management Assistance Program (World Bank)
GDP	Gross Domestic Product
GHG	greenhouse gas
GTZ	Gesellschaft für Technische Zusammenarbeit
HH	household
IEA	International Energy Agency
IEG	Independent Evaluation Group (World Bank)
LPG	liquefied petroleum gas
MDGs	Millennium Development Goals
MHP	Micro-hydropower
MHS	Micro-hydropower system
NLSS	Nepal Living Standards Survey
REDP	Rural Energy Development Programme
UNDP	United Nations Development Programme
VDC	Village Development Committee
WHO	World Health Organization

Conversion units

1 ropani = 0.05 hectare

1 muri = 72 kg

1 dharni = 2.5 kg

1 bhari = 8 kg

US$ 1 = Rs75 (Average exchange rate in September/October 2008)

The currency used is United States dollars unless otherwise specified.

Executive summary

Expanded access to electricity is a common development priority for many governments because it delivers substantial benefits to households and communities, especially in terms of improved income generation, healthcare and education. Yet about 3 billion people still depend on solid fuels for cooking and heating, and 1.4 billion people have no access to electricity, which seriously limits their economic and development prospects (IEA et al., 2010; UNDP and WHO, 2009). Practical, effective and large-scale actions are needed to accelerate progress towards universal energy access.

In Nepal, around 93 per cent of rural households and 40 per cent of urban households rely on biomass fuels for cooking and heating (Ministry of Health and Population, 2007). While 90 per cent of the urban population is connected to the grid, it is estimated that only 34 per cent of rural households have access to electricity (IEA/OECD, 2009).

This study assesses the development benefits of investments in decentralized micro-hydropower systems in remote mountain areas of Nepal (in the districts of Baglung and Kavre) in terms of reducing poverty and achieving the Millennium Development Goals (MDGs). Evaluation of the impacts of energy initiatives provides a basis for understanding the relative merits of policy options, and for prioritizing programmes. This is especially important with respect to decentralized/off-grid energy initiatives due to their (perceived) relatively high costs. Yet, to date, analysis of the impacts of decentralized/off-grid electrification initiatives has been scarce. This study aims to help fill that knowledge gap.

Methodology

The analysis is based on a field survey covering 571 households, as well as schools, health centres, and businesses in rural communities of Nepal. Information was collected from communities with micro-hydropower systems installed by Nepal's Rural Energy Development Programme (REDP), which is an initiative of Nepal's Alternative Energy Promotion Centre supported by UNDP, the World Bank and other partners. For comparison purposes, information from nearby communities without electricity access was also gathered and analysed.

The study used statistical techniques to analyse the differences observed between communities with and without electricity. The objective was to evaluate the strength of the correlation between electricity access and the improvements in MDG-related indicators. In order to determine the extent to which development benefits could be attributed specifically to electricity access, regression analysis was also conducted, which produced estimates of the development benefits gained by households with electricity, such as income, expenditures and time allocation.

Main findings

The cumulative development benefits far outweigh the investment costs of a micro-hydropower system. The study estimates that the total benefits attributable to electricity access amount to about $150 per year for a rural household. Assuming the average household size of 6.5 people and a 15-year lifespan for a micro-hydro system in Nepal, the total over-the-lifespan development benefits would be $345 per beneficiary, significantly larger than the average one-time installation cost of a micro-hydropower system of $85 per beneficiary. In addition to such quantifiable benefits, significant development benefits were observed in terms of education, gender equality and health.

Promotion of new productive applications of energy services can enormously enhance rural development benefits. This study estimates that starting a new productive activity using newly available electricity can produce an additional $912 for a household. Clearly, decentralized off-grid programmes need to emphasize skills enhancement to support the development of income-generating activities that make productive use of the newly available electricity, and thereby boost economic growth in remote rural areas.

Investing in a countrywide scaling up of the micro-hydropower programme in Nepal would yield significant economic returns, accelerating progress towards reaching the MDGs. An earlier UNDP and AEPC study (2010) estimated that the full capacity for micro-hydropower in Nepal is about 150 MW, and that scaling up to that level would reach roughly an additional 6.3 million rural people (about 1.2 million households) for a relatively small overall investment of about $435 million.

This study estimates that the potential cumulative quantifiable benefits of expanding installed micro-hydropower capacity to 150 MW could amount to about $217 million per year – and considerably more as new productive activities are undertaken and economic development takes hold in communities with a reliable supply of electricity. At the same time, people gain from additional social and environmental benefits that this study could not monetize, such as improved education, better sanitation and health services, and decreased pollution. Taken all together, they can make greater progress towards achievement of the Millennium Development Goals.

Estimated value of potential benefits from scaling up the MHS programme in Nepal

Benefit category	Benefit value for 1.2 million households ($ million/year)
Additional income	145
New productive activity (3.4 per cent of households)	37.2
Reduced energy expenditures	30
Avoided GHG emissions[1]	4.8
Total	217

Note: 1. Sale of CERs at $10 per ton of CO_2

Specific impacts of off-grid electricity access on MDGs

MDG 1: Eradicate extreme poverty and hunger

The introduction of electricity is strongly associated with higher revenues for rural households due to the use of new equipment for improved productivity in existing agro-processing activities, longer working hours made possible by electric lights, better access to market information and weather forecasts, and new income-generating activities. The programme implemented by REDP has enabled the benefits of electricity access to reach even the poorest households, as opposed to the elite and already privileged families within the community.

- The study estimates that the average increase in household income attributable to electricity access is around $121 annually. This represents about 8 per cent of the average annual income of electrified households. The average yearly household income in the newly electrified communities surveyed in Nepal was $1,530, which was $317 higher than the average of $1,213 in similar communities without electricity. Thus, the income increase attributable to electricity access explains about 30 per cent of the difference between the households with and without electricity access. Other factors such as the geographical location of farmland, the number of livestock owned or education levels of household members, can also account for some of the differences in average incomes.

- In the communities surveyed, there were 40 new businesses created after a micro-hydropower system was installed, compared with only 4 established prior to electricity access. The new businesses involve activities that rely on the use of electricity. The average annual net profits from new productive enterprises ranged from $32 for sewing or knitting to $2,667 for poultry raising or pig farming, with an overall estimated average of $912. However, very few of the households surveyed (only 3.4 per cent) created a new income-generating activity after electrification. This reflects the fact that, currently, a number of barriers, such as poor market access, lack of available capital, and low skill levels can constrain the development of new income-generating activities.

- Training for the development of entrepreneurial capacities is important. Three times as many businesses were developed in Kavre district, where the programme offered more training on undertaking productive activities, than in the Baglung district where similar training was not provided.

- In communities with electricity, households are able to meet some of their energy needs with high-quality services at less than half the price. Households in non-electrified communities spend an average of $41 annually to buy kerosene and dry-cell batteries, while those in communities with electricity spend an average of $19 to meet their needs – about $11 for electricity and $8 for kerosene and batteries. The average decrease attributable to electricity access amounts to almost 60 per cent of energy expenditures for non-electrified households.

- Use of electricity enables large reductions in energy costs for enterprises and productive activities. Switching from diesel to micro-hydropower electricity saves about 1,500 litres of diesel per mill per year, worth about $1,200. The price paid for electricity for the same activity is approximately $650, i.e. 45 per cent lower. In 2007, 1.75 per cent of the GDP, or an estimated $180 million was allocated to fuel subsidies (IMF, 2008). Savings that the government could make from reducing fossil fuel subsidies could be invested into micro-hydropower programmes or other clean energy services.

MDG 2: Achieve universal primary education

The study found that electricity access is associated with many education-related indicators, including the number of students per primary school teacher, the average enrolment rates in secondary schools, and the percentage of girls dropping out of school.

Access to electricity contributes to a better student-to-teacher ratio. Communities with electricity are better able to attract and retain teachers due to better living and working facilities. The survey found that primary schools with electricity have an average of 17 fewer students per teacher than those in areas without electricity. The study estimates that 70 per cent of the difference in the student-to-teacher ratio is attributable to electrification.

Children in communities with electricity are also more likely to attend school. The study estimates that children living in electrified communities are 1.7 times more likely to be in grade 4 or 5, 4.2 times more likely to be in grade 6 or 7, and 5.2 times more likely to be in grade 8 or higher.

The survey results showed that households with electricity spent twice as much on education – an average of $160 for registration fees, school supplies, clothes and other expenses – compared with $80 for households in communities without electricity. The study estimates that the average increase attributable to electricity is about 26 per cent of electrified households' average school expenditures.

MDG 3: Promote gender equality and empower women

The study found that electricity access is correlated with various indicators related to the MDG 3, including women's access to education and information.

With relieved household burdens for women, girls' educational attainment is also higher in communities with electricity. The survey data showed that girls living in electrified communities reach higher school levels and have better school attendance than girls living in communities without electricity access. The survey data indicated that girls living in electrified communities missed an average of 0.25 days, compared to 0.7 days for girls living in non-electrified communities. The study estimates that girls living in electrified communities are 2.2 times more likely to be in grades 4 or 5; are 7 times more likely to be in grades 6 or 7; and are 15 times more likely to be in grade 8 or higher.

Access to electricity for motorized equipment reduces the amount of time women have to spend grinding grains, hulling rice and pressing oils by hand. The surveys showed that significantly more women than men were beneficiaries/consumers of new productive activities (234 women compared with 145 men). They also showed that about 75 per cent of agricultural production consists of crops such as rice, maize and wheat that require processing, and women contribute 65 per cent of the time spent on agro-processing activities. It is estimated that the use of electrical mills instead of manual agro-processing would save about 155 hours per year for women and 85 hours for men. If the time saved is used for additional income-generating activities, the annual increase in earnings could reach $19 for women and $18 for men, an average of about $37 per household.

The survey data showed that in communities with electricity, women have greater access to television and communications equipment (78 televisions in electrified communities versus 1 in the non-electrified ones). Thus, women can become more informed about news and events (including weather and market information), more educated about important matters such as local and national politics and health issues, and more exposed to examples of women taking active roles in business and public affairs. This increased access to information can be critical for improving women's participation in community development activities and entrepreneurial activities.

MDG 4, 5 and 6: Reduce child mortality, improve maternal health and combat HIV/AIDs and other diseases

This study found several correlations between electricity access and development indicators related to child mortality and maternal health. For example, the number of health visits per person per year is greater in health centres with electricity. Health centre records show that there are almost twice as many visits to electrified health facilities than to those without electricity. The number of health workers per unit of population is also much greater in communities with electricity than in those without electricity, i.e. it averages 11 health workers per 10,000 people in electrified areas, compared with only two in non-electrified health posts in non-electrified areas. Like teachers, health workers are more likely to live in remote communities if they have access to electricity at home and at work.

MDG 7: Ensure environmental sustainability

Generating electricity using micro-hydropower systems avoids the greenhouse gas emissions associated with electricity production based on fossil fuels, including the diesel generators commonly used in remote, rural areas.

Based on information in the Rural Energy Development Programme's application for registration as a small scale project under the Kyoto Protocol's Clean Development Mechanism, the study estimates that providing electricity with micro-hydropower instead of diesel avoids the emission of an estimated 4 tons of CO2 per kilowatt installed per year, or 517 tons of CO2 per year for the six MHSs in the communities surveyed. Assuming that 1 ton of CO2 is worth $10, the sale of certified emission reductions (CERs) would yield about $5,175 per annum for the six MHSs selected, or about $3.80 per household per annum.

Having electricity also reduces by more than 80 per cent the likelihood of using dry-cell batteries or kerosene, therefore limiting environmental damage related to disposal of used batteries, and air pollution and greenhouse gas emissions associated with burning kerosene.

Policy implications and conclusions

This study provides, along with other available literatures on Nepal's decentralized energy programmes, important information for politicians, policy makers, development practitioners and local organizations on the benefits of investing in expanding energy services to enhance economic growth in rural communities, including acceleration of progress in meeting MDG targets.

- Decentralized energy policy frameworks play a significant role in facilitating the development and scale-up of energy access programmes such as rural electrification schemes in areas where there is a great need to bring vast socio-economic opportunities for the poor. In Nepal, rural electrification is one of government's priority programmes as it is reflected in its national development plan and poverty reduction strategy. This has played a catalytic role in developing innovative and sustainable policies that bring together various actors including the private sector to further facilitate scaling-up rural electrification programmes.
- Integration of renewable energy sources such as hydro, solar, and biomass in energy policy frameworks and programmes as a fuel option to expand access to energy services to the poor yields double dividends in terms of achievement of the MDGs and the fight against climate change. Harnessing and utilization of renewable sources of energy is an integral part of government's strategy to meet the population's energy needs in Nepal. The country's rich renewable energy resources offers an opportunity for the government to minimize its dependence on fossil-fuel based technologies while reducing impacts on climate change, increasing the use of renewable energy mix for decentralized systems that are more appropriate and efficient, particularly in the provision of electricity in remote and rural areas.
- Documentation and quantitative estimation of the development benefits of off-grid decentralized rural electrification schemes provide a basis for evaluating the long-term cost-effectiveness of these investments. As with any other development intervention, illustration of the social, economic, and environmental benefits and impacts of rural electrification programmes presents the much-needed evidence and justification for further financing and investment to scale-up of such programmes.
- Capacity development is critical to successful scaling up of decentralized rural electrification schemes. REDP's experience demonstrates that rural electrification schemes and adoption of off-grid energy technologies, particularly in dispersed and geographically challenging environments, requires substantial assistance to provide guidance to national governments, local authorities, private entities, as well as communities and civil society organizations. Capacity development in areas such as developing policy and regulatory frameworks, mobilizing financing, enhancing institutional structures and performance, communications and community mobilization, planning, management, and oversight of the programme are critical parts of energy service delivery to the poor and must be reflected in rural electrification plans and budgets accordingly.
- Scaling-up successful decentralized rural electrification schemes is financially feasible but requires great participation from both the public and private sector. As shown in the other analysis by UNDP and AEPC (2010), public investment is dominant at the beginning of the programme to build local and national capacities. However, with increasing capacity of local and national level actors, these public investments can attract substantial financing from private sectors, which gradually take over a greater portion of the overall investments.
- Promoting income-generating activities using newly available electricity must be a clear priority for boosting economic growth in remote rural areas. The example of micro-hydro schemes in Nepal shows that promoting productive uses of electricity not only boosts rural economies by raising people's incomes, but it also encourages greater participation from the private sector, including microfinance and other sources such as carbon financing.

- Local people have the ability to implement and manage rural energy systems for productive applications with appropriate guidance and capacity development, and community mobilization in all areas of organizational development, skills enhancement, capital formation, technology promotion, environment management and vulnerable community empowerment. Unlike many electrification schemes, the programme implemented by REDP has enabled the benefits of electricity access to reach even the poorest households, increasing the development benefits for the whole community.

This assessment confirms that the cumulative development benefits of decentralized electrification can significantly outweigh the investment costs. Efforts should be strengthened at the national, local, and community level in a collaborative manner between the public, private, and civil society organizations to scale up rural off-grid decentralized electrification as part of the poverty reduction strategies of Nepal and other developing countries with populations without access to electricity in remote rural areas.

UNDP/Nepal

Night schools for adults and children are possible with electricity access.

1 Introduction

- Context and objective of the study
- Overview of Nepal's development context
  - Development
  - Energy
- Rural energy development programme (REDP)
  - REDP in Nepal
  - Costs and investments for REDP's MHS programme

Introduction

The aim of this study is to quantify the development benefits of electricity access and to assess how electricity access contributes to the achievement of the millennium development goals using Nepal as a case study. Nepal is one of the poorest and least developed countries, with marked disparities between rural and urban areas; it is also emerging from a period of internal unrest. Access to electricity remains very low, especially in rural areas, where only 34 per cent of the population has access to electricity. To boost development in rural areas, the Government of Nepal is emphasizing the provision of decentralized energy systems such as micro-hydropower, solar PV home systems or improved cooking stoves. Its Rural Energy Development Programme (REDP) operates not only in the provision of hardware but also in wider development activities through community mobilization.

Context and objective of the study

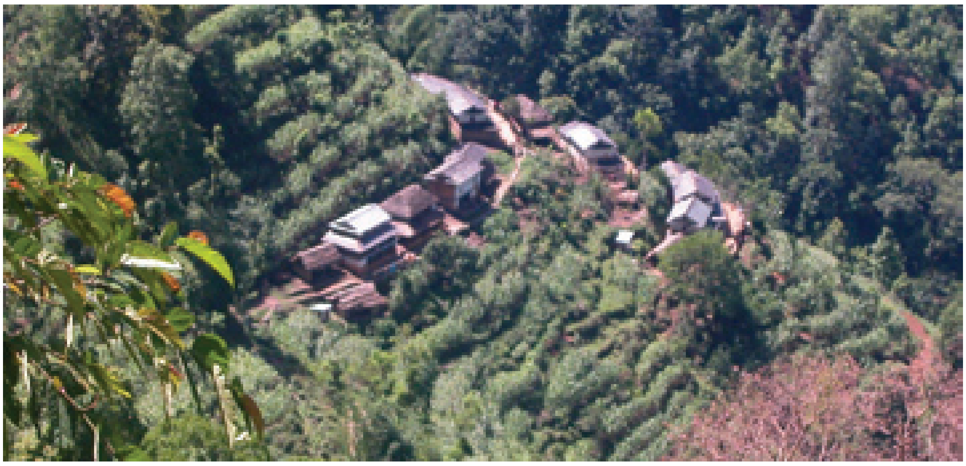
Access to modern energy services is essential for poverty reduction and sustainable development. Living without modern energy services significantly compromises progress towards the MDGs, including those relating to poverty reduction, child and maternal survival, education, gender equity and environmental sustainability. Yet 2.7 billion people still depend on traditional biomass for cooking and heating, and 1.4 billion people have no access to electricity (IEA, UNDP, UNIDO, 2010).

Access to modern energy services to meet the basic development needs of poor people must be a top priority on the international development agenda. Those needs include:

- modern fuels and devices for cooking;
- electricity for health clinics, schools and public lighting;
- mechanical power for basic agricultural and food processing, and water pumping;
- energy for cottage- and micro-enterprises; and
- household electricity for illumination and communication.

Such services can drastically expand poor people's opportunities and choices for development. They also help to develop social, economic and environmental capital, which are essential for people faced with adapting to the increased risks from climate change.

Recognizing the fundamental role of energy for sustainable development, a recent report issued by the United Nations Secretary General's Advisory Group on Energy and Climate Change (AGECC) has called on the United Nations system and its Member States to commit themselves to ensuring universal access to modern energy services by 2030 (AGECC, 2010).



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Conventional approaches to electrification, through a centralized power plant and power line distribution, cannot reach poor people who live in dispersed rural communities.

Box 1. Decentralized energy systems in rural and remote areas

Conventional approaches to electrification, through a centralized power plant and power line distribution, cannot reach poor people who live in dispersed rural communities, where levels of demand are low and limited, and the cost of providing energy is high.

The best option for improving access to a modern, sustainable energy service in rural areas is the promotion of decentralized and integrated rural energy systems that are cheaper, more environmentally friendly and easy for local people to operate and manage.

Source: *Neupane M., Sharma B., 2006*

Table 1. Development indicators in Nepal versus other regions

Field	Selected indicator	Nepal[1]	LDCs	DCs	World
Poverty	Population living below $1.25 (2005 PPP) per day in 2005 (%)	55.1	53.4	26.6	-
	Malnutrition prevalence, weight for age in 2007 (% of children under 5)	39	31	26	23
	Population below minimum level of dietary energy consumption in 2008 (% of total population)	15	34	17	14
	GNI per capita in 2008 (current $)	400	585	-	8,613
Education	Primary completion rate, total in 2006 (% of relevant age group)	76	-	-	86
	Net enrolment ratio in primary education in 2007[1]	76.5	76.0	88.1	89.0
Gender	Ratios of girls to boys in secondary education	0.91	0.81	0.94	0.95
	Proportion of seats held by women in national parliament in 2009	33.2	18.8	17.2	18.5
Health	Under-five mortality rate in 2007 (per 1000 live births)	55	-	74	67
	Maternal mortality ratio in 2005 (per 100,000 live births)	830	870	450	400
	Births attended by skilled health staff around 2007 (% of total)	19	38	61	64
Energy and environment	Proportion of land area covered by forest in 2005 (%)	25.4	27.4	-	30.3
	Electric power consumption in 2006 (kWh per capita)	80	129	-	2,750
	Energy use in 2006 (kg of oil equivalent per capita)	340	308	-	1,818
	CO_2 emissions in 2006 (metric tons per capita)	0.1	0.2	2.6	4.4
New technologies	Internet users in 2007 (per 100 population)	1.4	1.5	12.7	20.6
	Mobile cellular subscriptions in 2007 (per 100 population)	12	14.5	38.6	50.3
	Access to electricity in 2008	43.6	21.1	72.4	78.2

LDC – Least Developed Countries. DC – Developing Countries.
Note: 1. Data for Nepal refer to the closest year available.
Source: World Development Indicators and MDGs indicators databases, UNDP, WHO, 2009 for data on access to electricity.

In order to ensure that new investments in energy access programmes are cost effective and actually provide the expected development benefits, it is critical for policy makers and practitioners to understand what works and what does not work, and where their efforts should best be concentrated. Evaluation of the impacts of energy initiatives allows for comparisons between different approaches in terms of delivery of results, and provides a more solid basis for prioritizing programmes and developing successful policies.

It is particularly important to document the development benefits of decentralized off-grid electrification systems, because the relatively high up-front costs have often deterred governments from investing in these systems (Box 1). To date, analysis of the impacts of decentralized off-grid electrification models has been scarce and there is a knowledge gap in terms of exactly what levels of development benefits they deliver to communities.

This study aims to fill the knowledge gap on the development benefits of off-grid electrification systems by providing an assessment of impacts from such programmes, and showing that the benefits from investing public and private funding in this area far outweigh the costs.

The main objectives of this study of the Nepal national micro-hydropower programme are to:

- quantify the benefits of access to off-grid electricity in remote rural villages. The study assesses the development benefits of electricity from Nepal's national micro-hydropower programme (popularly known as the Rural Energy Development Programme), which is executed by the Alternative Energy Promotion Centre of the Government of Nepal with support from UNDP, the World Bank and other partners. It also examines the benefits of expanding access to electricity using micro-hydropower systems as an entry point for rural development.[1]
- demonstrate the linkages between electricity access and the MDGs. The study seeks a better understanding of the various MDG-related development benefits of expanding access to electricity based on decentralized off-grid models. A previous report produced by Winrock International Nepal (2007) assessed the development impacts of the Rural Energy Development Programme, which provides a wide variety of energy systems (e.g. solar household systems, improved cooking stoves, and biogas), with regard to MDG-specific indicators; however, it did not quantify the development benefits derived specifically from expanding access to electricity.
- highlight lessons learned and provide recommendations to policy makers. The study provides important information and recommendations for policy makers and development practitioners seeking to expand energy services to enhance economic growth in rural communities and accelerate progress in meeting MDG targets.

Overview of Nepal's development context

Development

Nepal is among the world's poorest and least developed countries. The Human Development Index 2007 ranks Nepal 144th out of 182 countries (Table 1; UNDP, 2009).

Rural-urban disparities are still large in Nepal. Urban poverty stands at around 10 per cent, compared to about 35 per cent in rural areas, where 85 per cent of the people live.[2] While 80 per cent of households are involved in agriculture, the sector contributes only 35 per cent of Gross Domestic Product (GDP) and has high under-employment rates and low productivity. Expansion of rural electrification is one of the five key elements

Practical Action Nepal

▲ Expansion of rural electrification is one of the five key elements under the Agriculture Perspective Plan to improve the agricultural sector.

outlined by the national Agriculture Perspective Plan to improve the agricultural sector (IMF, 2007).

Nepal is currently in a transitional period following internal conflict. The government proposed a three-year Interim Development Plan to address challenges during the transition.[3] The Plan's main objective is to reduce poverty and unemployment, and to establish sustainable peace. The main strategies identified are broad-based economic prosperity, good governance in development activities and service delivery, and inclusive development (ADB, 2007).[4] The primary challenge is to alleviate poverty and reduce the increasing gap between rich and poor (Government of Nepal National Planning Commission, 2007b).

Energy

The primary source of energy in Nepal is traditional biomass.[5] Biomass accounts for about 86 per cent of total energy consumption. Firewood alone meets nearly 77 per cent of total energy consumption.[6] Around 93 per cent of rural households and 40 per cent of urban households rely on biomass fuels for cooking and heating (Ministry of Health and Population, 2007).

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Constructing the route for the micro-hydro penstock, which carries water down to the turbine. MHSs are installed by community members.

Electricity, meanwhile, accounts for just 2 per cent of the total energy consumption in Nepal; more than 99 per cent of electricity is generated by hydropower.[7]

Access to electricity remains very low, especially in rural areas, where only 34 per cent of the population has access to electricity, compared with 90 per cent in urban areas (IEA/OECD, 2009). In 2007, just over half of Nepal's Village Development Committees (VDCs, the lowest local administrative units) had electricity access (Government of Nepal National Planning Commission, 2007a).

New and renewable energies are already well developed in Nepal. This is a result of the strong support of the national executing agency for rural energy programmes, the Alternative Energy Promotion Centre. By July 2009, renewable and alternative energy systems had benefited about nine per cent of the population nationally. The installed systems include biogas plants (214,000), micro-hydropower (13.5 MW), improved cooking stoves (300,000), solar PV home systems (18,000), solar *tuki* sets[8] (59,120), and improved water mills (5,500) (AEPC, 2010).

The government recognizes that the expansion of electricity services to rural areas will improve the standard of living of the rural population and promote social justice. Under its Interim Development Plan, electrification in remote rural areas will be promoted by developing alternative energy systems and, more specifically, through the development of small and micro-hydropower projects. These are considered the foundation for overall economic development, by providing quality energy services at low cost (Government of Nepal National Planning Commission, 2007b).

Rural energy development programme (REDP)

REDP in Nepal

The Rural Energy Development Programme aims to expand access to energy services in rural areas. The programme is executed by the Government of Nepal's Alternative Energy Promotion Centre, with support from UNDP, the World Bank and other partners.[9] It focuses on decentralized, off-grid approaches, particularly efficient in reaching the poor in remote and rural areas (Box 1). By December 2009, REDP had installed 267 micro-hydropower systems (equivalent to 4,453 kW) in addition to 5,440 toilet-attached biogas plants, 2,410 solar PV home systems and 11,757 improved cooking stoves.

REDP applies a holistic development approach that adopts community mobilization as a vehicle for ensuring

Box 2. Community mobilization in Nepal's national MHS programme

Nepal's micro-hydropower system programme places a strong emphasis on community mobilization. It works to ensure that MHSs are installed by community members, in close cooperation with District Development Committees and Village Development Committees. Local NGOs are engaged to act as support organizations and carry out the process of community mobilization.

Within the MHS programme, the process of community mobilization is guided by six basic principles (the *'Mul Mantras'*). These principles include organizational development, skills enhancement, capital formation, technology promotion, environmental management, and empowerment of vulnerable groups and communities. The support organizations work with villagers to establish community organizations, and to ensure that at least one male and one female from each household are members of a community organization.

Multiple community organizations form a wide range of functional groups based on common interests. The groups may focus on interests such as micro-hydropower, income generation, forestry, biogas, and poultry farming. The functional groups consist of representatives from all community organizations, ensuring representation from men, women and vulnerable groups.

The micro-hydropower functional group is the key body at the village level for establishment, operation and management of MHSs. Once the community-managed MHS has been running successfully for at least six months, the community groups are encouraged to convert the micro-hydropower functional group into a legal entity, such as a cooperative, to encourage long-term sustainability.

Source: *UNDP, AEPC, 2010*

sustainable active participation and self-governance (see Box 2).

Access to electricity is used as an 'entry point' for REDP programmes, but other activities are also implemented to enhance sustainable development in remote villages. In Baglung, for example, the programme has held awareness campaigns on health and sanitation and has promoted the installation of toilet-attached biogas plants and improved cooking stoves. It has also conducted training on income generation activities using agricultural products. In Kavre, REDP has conducted environmental management classes in the community and encourages parents to send their children to school. It has provided training on off-season vegetable farming, and on productive activities such as poultry farming, sewing/knitting, saw mills, agricultural processing, or incense stick making. Programme activities are mainly demand driven and based on an assessment of needs. Depending on demand and available resources, some programme managers decide to focus on different training activities. For example, in Baglung, more training was given on issues related to health and the environment, whereas in Kavre the focus was on productive activities.[10]

Practical Action/Lucy Stevens

▲ This small pond is the top reservoir for a pico-hydro plant.

Bamboo scaffolding enables community members to cut into rock, during the construction of the micro-hydropower installation.

Water catchment systems, which are needed for hydropower electricity generating systems, can also be used to manage water for drinking, irrigation or other applications.

Costs and investments for REDP's MHS Programme

Between 1996 and 2006, micro-hydropower systems installed by REDP have reached more than 130,000 people at an average cost of about $110 per beneficiary (in 2005 constant dollars). A recent study from UNDP and AEPC (2010) estimated that between 1996 and 2006, REDP's MHS programme installed systems producing 2500kW and benefiting more than 130,000 people. The total cost of this programme over that period was about $14.3 million, of which 56 per cent was spent on capacity development activities.[11] The study showed, however, that per-unit programme costs declined by 73 per cent between 1996 and 2006, mainly driven by the decline in capacity development costs. Funding from public sources was dominant at the outset (well over 90 per cent), but community contributions increased over time to reach almost 40 per cent of investments in 2006.

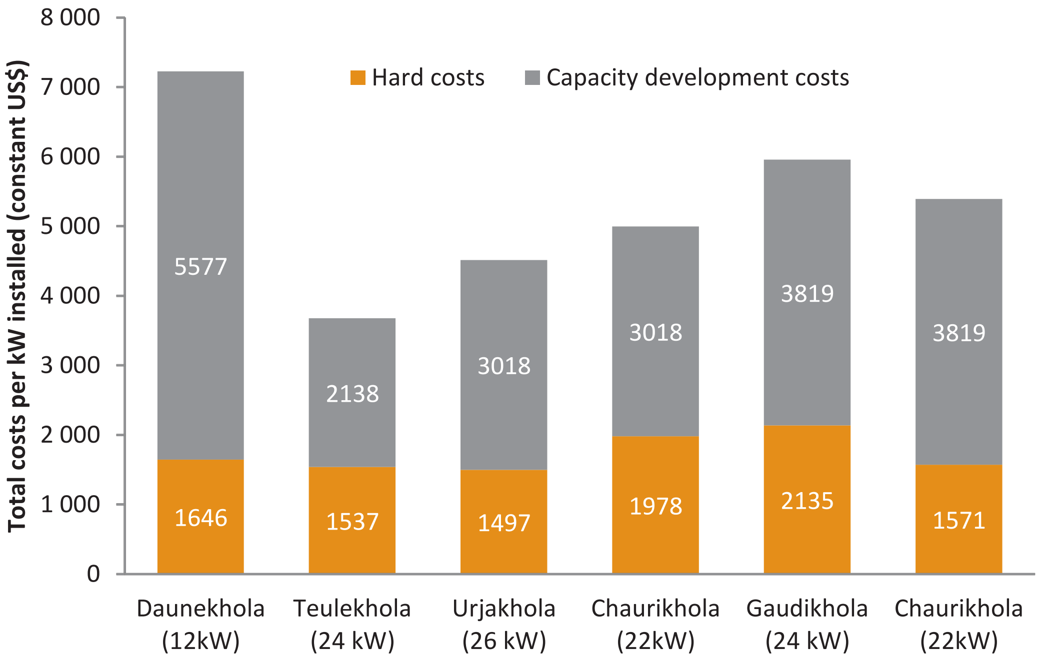


Figure 1. Costs of MHS in selected areas ($/kW)

The MHSs selected for the current study were installed between 1998 and 2002 at an average cost of $85 per beneficiary,[12] and benefit about 7,000 people. The hard costs[13] and capacity development costs[14] vary between sites, but capacity development costs make up the largest share of the programme costs (Figure 1).

Practical Action Nepal

The REDP programme includes training in income-generating activities.

2

Methodology

- Selection of sites for the survey
- Collection of data
- Analysis of data
  - Review of compiled data and analysis of general trends
  - Identification of potential association between development indicators and access to electricity
  - Determination of the extent to which electricity access is associated with observed impacts
  - Quantification of benefits in monetary terms
- Limitations
  - The with/without methodology
  - Data quality and reliability
  - Econometric tools and number of observations
  - Correlation versus causality
  - Sample bias
  - Representativeness of the sample

Methodology

The analysis of the development benefits of the decentralized off-grid electrification programme presented in this study is based on a field survey conducted in rural communities of Nepal. Information was collected from communities that have been beneficiaries of the REDP micro-hydropower programme, as well as nearby communities without electricity access, and it was analysed to determine linkages between electricity access and MDG-related indicators. Where possible, the contributions of electricity in improving economic, social and environmental conditions of electrified communities were quantified. This chapter describes the selection criteria for the communities and the 570 households that participated in the survey, how the data were collected and analysed, and the limitations of the method.

Introduction

In order to evaluate the development benefits from access to electricity in a specific context, it is necessary to compare the actual observed benefits with a hypothetical situation in which there is no electricity.

For this study we chose to compare communities `with' and `without' electricity. This method was chosen because it allows for identification of incremental development benefits or changes in socio-economic and environmental conditions of a particular community in relation to a baseline situation where there is no access to electricity. For the purpose of this study, we were able to identify communities with and without electricity that had similar baseline situations.

The study then used statistical techniques to analyse the differences observed between communities with and without electricity. The objective was to evaluate the strength of the correlation between electricity access and the improvements in MDG-related indicators. A strong correlation was confirmed when statistical analysis showed a low probability that the connection between electricity access and a particular indicator was due to chance.

In order to determine the extent to which development benefits, such as increased incomes, could be attributed specifically to electricity access rather than other factors such as geographical location or education levels, the study then used a software programme to perform statistical regression analysis. Using regression models, the study produced estimates quantifying the average development benefits gained by households with electricity. For those benefits related to development indicators such as income, expenditures and time allocation, an estimated monetary value was also determined.

Selection of sites for the survey

Out of 273 MHSs installed by REDP in 2008, six MHS installations were selected, located in the two districts

Table 2. MHSs selected in Baglung district

Scheme	VDC	Completion year	Power output	Number of beneficiary HH
Teulekhola MHDS	Sarkuwa	1999	24 kW	290
Gaudikhola MHDS	Dudilabhati	2002	24 kW	231
Urjakhola MHDS	Rangkhani	2000	26 kW	250

Table 3. MHSs selected in Kavre district

Scheme	VDC	Completion year	Power output	Number of beneficiary HH
Chaurikhola MHDS	Pokahrichauri	2000	22 kW	208
Daunekhola MHDS	Mangaltar	1998	12 kW	107
Chaurikhola MHDS	Kartike Deurali	2002	22 kW	200

of Baglung and Kavre (Tables 2 and 3, and see map in Annex 2). These MHSs are managed by Village Development Committees (VDC).[15] The two districts were selected out of 17 districts in which REDP is active, based on a number of criteria designed to enable evaluation of the potential benefits of electricity access in rural areas. First, only districts that contained at least three MHSs were selected. Second, selected MHSs had been in operation for at least five years and were providing services to at least 50 households. Third, each of the two districts contained communities with and without electricity that had similar baseline situations (e.g. population sizes, socio-economic development levels, and geographic situations such as similar ecological zones and distance to the river). Finally, electrified communities had some productive use of electricity (e.g. agro-processing, sawmills).

Collection of data

A number of questionnaires were developed to gather data on households, schools, health centres, and small businesses. The questionnaires were tested in the field prior to the survey and modified to ensure that questions were appropriate for rural households with and without electricity. A sample questionnaire used for households in communities with electricity is presented in Annex 3.

Each category of data collected in the field survey was selected for linkages to different Millennium Development Goals. For example, information on household income is linked with MDG 1, and therefore household income was used as an indicator to compare progress on MDG 1 in electrified and non-electrified households. Table 4 displays samples of collected data in relation to each of the MDGs.

The fieldwork was organized in close coordination with REDP and surveys were carried out in September and October 2008, after pre-testing of the questionnaires. Over 570 households were included in the survey, and responses to the questionnaires were largely obtained from heads of households.[16] The selection of the households surveyed was randomized. In each of the VDCs selected, the survey considered a similar number of households in electrified and non-electrified communities. To reduce biases, surveys were conducted both in households along the main trails/roads and households far from the trails/roads. Table 5 displays the number of people and households in the two selected districts, as well as the number of households surveyed in each of the electrified and non-electrified communities.

Table 4. MDGs and related indicators developed for the study

MDGs in Nepal	Sample of collected data in relation to each MDG
1. Reduce poverty and hunger	Household income; agricultural production; energy expenditures; number of new productive activities;
2. Achieve universal primary education	School enrolment; number of school days missed; time spent doing homework; time spent watching educational programmes; school grade level; household expenditures for school; number of students per school teacher;
3. Promote gender equality and empower women	Girls' school grade level; number of school days missed; time spent by women on income-generating activities; time spent cooking and cleaning; time spent receiving visitors; time spent watching TV; time spent reading;
4, 5 and 6. Reduce child mortality, improve maternal health, combat diseases	Health expenditures; number of visits to health centres; number of qualified health workers; cooking habits; kitchen types; toilet facilities; water supply;
7. Ensure environmental sustainability	Quantity of kerosene consumed; quantity of dry-cell batteries consumed; quantity of charcoal consumed; quantity of fuel wood consumed; avoided CO_2 emissions;
8. Develop a global partnership for development	Own a radio; own a TV;
Several MDGs	Time allocation: Bedtime in the evening; wake-up time in the morning; time spent cleaning, cooking; time spent on agro-processing activities.

Box 3. Definition of key concepts

Electrified communities	All households in close proximity to the MHS benefit from electricity, even if they do not live in the same village. Households in electrified communities have an electricity connection.
Non-electrified communities	In these communities, households do not have access to electricity from the MHS (or national grid).
Household income	This includes agricultural income (e.g. from crops, livestock), reported monetary value of items produced and consumed by the household, income from seasonal labour, income from activities using electrical equipment, income from activities carried out after daylight hours and income from other sources (e.g. remittances, wages).
Productive activities	These activities include all activities that create goods and services and generate some income. They do not include agricultural production.

Table 5. Sample of household survey

District	VDC	Number of households	Number of people	Electricity access[3]	Number of households interviewed
Baglung	Dudilabhati	1,115	5,573	No	43
				Yes	49
	Rangkhani	870	6,090	No	44
				Yes	45
	Sarkuwa	515	3,090	No	41
				Yes	45
Total Baglung		53,565[1]	268,937[1]	No	128
				Yes	139
Kavre	Dhusene Shiviliya[2]	379[1]	2,049[1]	No	55
	Pokahrichauri[2]	609[1]	3,879[1]	Yes	55
	Kartike Deurali	665	5,565	No	48
				Yes	48
	Mangaltar	661	3,855	No	49
				Yes	49
Total Kavre		70,509[1]	385,672[1]	No	152
				Yes	152
Total				**No**	**280**
				Yes	**291**

Notes:

1 Nepal, Census data 2001.

2. For the micro-hydropower site Chaurikhola, neighbouring non-electrified households were located in a different VDC (i.e., Dhusene Shiviliya VDC rather than Pokahrichauri VDC).

3. Less than 1 per cent of households interviewed owned a solar home system.

Table 6. Size of the interviewed sample per survey questionnaire

	Households	Schools	Health centres	Productive activities
With electricity access	291	7	3	40
Without electricity access	280	19	4	3
Total	571	26	7	43

In addition to households, staff from schools, health centres and owners of enterprises (e.g. agro-processing mills, sawmills) were also interviewed (Table 6).

At the village and VDC levels, focus group discussions were held. Wherever possible, input was also gathered from other stakeholders, including District Development Committees (DDCs), VDCs, MHS functional groups (see Box 2), community organizations and other agencies. After the document was peer-reviewed, additional investigation was carried out in 2010 in the selected sites with owners of enterprises engaged in productive activities. A few productive activities created after October 2008 were identified and included in the analysis.

Analysis of data

Various analysis techniques were used to compare and assess benefits from electricity access in households with and without electricity. Data analysis was performed using a software product, the 'Statistical Package for the Social Sciences' (SPSS).

Review of compiled data and analysis of general trends

For each of the datasets, information on the various MDGs was compiled and analysed to better understand general trends in relation to the differences between households with and without electricity. For example, regarding MDG 1, the survey results showed that average annual income in households with electricity tends to be higher than income levels in households without electricity. Key results of this set of analysis are found in the main report, and some additional outcomes are presented in Annex 4.

Identification of potential association between development indicators and access to electricity

While analysis of the compiled survey information in terms of the general trends provides a certain level of understanding with regard to the differences in communities with and without electricity, it does not show why such differences exist.

Inferential analysis techniques were used to assess whether there was a significant link between access to electricity and the various MDG-related development indicators. These techniques included (i) the *chi-square* test to test the association between the variable 'having/not having access to electricity' and other types of variables, and (ii) the *t-test* to compare the mean of quantitative development indicators with the variable 'having/not having access to electricity' (see Annex 5). The significance level is determined by the probability of an observed result happening by chance. A probability of .05 or less was applied, as this is commonly interpreted by social scientists as justification for rejecting the hypothesis that one variable is unrelated to the other variables.

Although such tests do not provide information on the magnitude and causality of a relationship, they do indicate a potential association between electricity access and other development indicators. See Annex 5 for additional information on inferential analysis.

Determination of the extent to which electricity access is associated with observed impacts

After using inferential analysis to identify which observed differences in development indicators from the survey results were associated with electricity access in a statistically meaningful manner, the next step involved determining the extent to which electricity alone could be viewed as responsible for the observed impacts. This is important because other factors such as levels of education, income, or geographical location may also contribute to the enhanced conditions of the communities with electricity.

The study applied statistical techniques to estimate *how much* of the observed differences between communities could be attributed specifically to electricity access by modelling the behaviour and the situations of people in households with and without electricity access. The use of regression models allowed distinctions to be made between electricity access and other factors that might account for the differences between communities with and without electricity.

Practical Action Nepal

Remote villages pose a challenge to energy provision

Regression analysis includes any techniques for modelling and analyzing several variables where the focus is on the relationship between a dependent variable and one or more independent variables. Regression analysis helps researchers understand how the typical value of the dependent variable (for example, a development indicator such as income or school attendance) changes when an independent variable (for example, having/not having electricity) is varied and other independent variables are held constant.

Regression modelling includes various techniques, such as linear regression, and binary or multinomial logistic regression. The choice of the model is made according to the number and type of variables. In this study, linear regressions were used to model continuous data such as income, and multinomial logistic regressions were used to model categorical data such as a student's school grade level. For each category, benefits were estimated for a household with the average development characteristics of sample households in communities with electricity. Annex 5 provides additional information on regression models and more details on how to choose appropriate tests.

Quantification of benefits in monetary terms

Quantitative estimates of the benefits of electricity can help policy makers determine whether their value is commensurate with programme costs. There are various economic methods that can be used to estimate monetary value of non-monetary benefits. These include:

(i) the 'human capital approach' used to measure the economic value of a person, which can be improved through, for example, education, better health or increased productivity;

(ii) the 'revealed preferences' method of measuring the values of goods and services through prices observed in the market place; or

(iii) 'contingent valuation' methods that use surveys to assess people's willingness to pay for goods in a hypothetical market (see Annex 1).

In this study, benefits of additional and new income are valued based on the 'human capital approach'; the economic values of people are measured through their earnings. Measures of the variations in expenditures are based on the 'revealed preferences' approach, as the survey provides information on the quantities and prices of goods and services bought by people. Contingent valuation methods, relying on hypothetical markets, were not necessary, as people with access to electricity could be questioned directly.

While benefits related to development indicators such as income, expenditures, and time allocation could be quantified monetarily, the limited survey data available did not allow the study to assess the monetary values of some benefits, such as education or health benefits. Indeed, valuing such benefits is particularly challenging when the benefits of electricity are not analysed over a long period of time.

For each category, benefits for households in surveyed areas were estimated based on the average household size in communities with electricity.

Table 7. Statistical and economics approaches applied to selected indicators

Benefit category	Indicator	Test whether the observed impact is associated with electricity access	Determine extent to which impact is associated with electricity access	Monetary value estimation made	
				Yes/No	Approach
Income	Increased income	Inferential analysis	Linear regression model	Yes	Human capital
	New income	-	-	Yes	
Expenditures	Energy	Inferential analysis	Linear regression model	Yes	Revealed preference
	Education	Inferential analysis	Linear regression model	Yes	
Education	School grade level	Inferential analysis	Multinomial logistic regression model	No	-
	Number of teachers	Inferential analysis	Linear regression model	No	
Women's empowerment	Girls' school grade level	Inferential analysis	Multinomial logistic regression model	No	-
Environment and energy	Kerosene consumption level	Inferential analysis	Multinomial logistic regression model	No	-
	Dry-cell batteries consumption level	Inferential analysis	Multinomial logistic regression model	No	-
	CO_2 avoided emissions	-	-	Yes	Revealed preference
Allocation of time	Increased day-time	-	-	No	-
	Saved time on agro-processing	-	-	Yes	Human capital

The statistical and economics approaches used in this study for different categories of benefits are shown in Table 7.

Limitations

The with/without methodology

The method used to assess potential benefits from electrification – comparisons of similar electrified and non-electrified communities – was selected because it allows identification of incremental benefits from electricity access in comparison to a baseline situation where there is no electricity. While the study tried to ensure selected communities with similar socio-economic and geographical situations, such as levels of education, number of adults, access to roads, etc., the report acknowledges that there are limits to this methodology, as much depends on the reliability of the choice of control villages, which may still differ from one another in their development characteristics. In addition, for a more accurate statistical analysis, a randomized selection of communities would be beneficial. However, in this case, due to the limited size of the sample communities and geographical conditions, the selection of the communities were not randomized.

Data quality and reliability

The collected data were cross-checked to improve the quality and reliability of the information, but the report acknowledges that some errors may remain in the dataset. Data gathered during the survey are subject to human error, which may have occurred while collecting data or during the data entry process. Errors made during the survey might have resulted from misunderstanding of the questions by either the interviewer or the respondent. The household questionnaire took almost two hours to complete. Some respondents were uncomfortable giving so much time to the survey and this might have influenced their answers, particularly those given towards the end of the questionnaire that asked about the use of time.

Econometric tools and number of observations

With 571 households (representing between 8 and 17 per cent of households in each VDC[17]), the sample size is relatively large and enables econometric analysis to be performed. However, while 100 per cent of schools, health centres and productive activities were interviewed in the selected sites, the small number of observations available limited the use of econometric tools (See Table 6).

Correlation versus causality

The econometrics and statistical techniques used in the study to assess benefits demonstrate links and correlations between electricity access and the selected indicators. However, those tools do not determine the causality and direction of the relationship between indicators.

Sample bias

To compare communities with similar development characteristics, the electrified and non-electrified communities selected were close to each other. The communities are primarily involved in agriculture, and are located at comparable distances to water sources. The close proximity of the surveyed communities means that households in non-electrified communities may also benefit from electricity services provided in the neighbouring communities.[18] Therefore, it is possible that electrification benefits are underestimated, as adjoining communities might benefit, for example, from services such as agro-processing, health centres, schools and battery-charging facilities.

Representativeness of the sample

Development indicators in the two surveyed districts are generally representative of Nepal, although some indicators related to education and access to media facilities are slightly above the national average. Therefore, the results are not necessarily representative of all rural areas of Nepal, but are useful in assessing the potential development benefits of electricity access.

3

Electricity access accelerates achievement of the MDGs in rural areas

- MDG 1 – reduce poverty and hunger
- MDG 2 – universal education
- MDG 3 – gender equality
- MDG 4, 5 and 6 – child health, maternal health, combating major diseases
- MDG 7 – environmental sustainability
- MDG 8 – global partnership
- Time allocation
- Summary of benefits

Electricity access accelerates achievement of the MDGs in rural areas

This chapter presents the findings of the development benefit analysis in terms of MDG indicators. The results show how expanding access to adequate, affordable and reliable electricity services can be a powerful step towards achieving the MDGs. In particular the study revealed positive correlations between electricity access and indicators relating to MDGs such as increased income (MDG 1), better education (MDG 2), women's empowerment (MDG 3), improved living conditions and health centres (MDG 4, 5, 6), GHG avoided (MDG 7), improved access to media and communication (MDG 8). The study estimated that the monetary value of the benefits from electricity access is about $150 per year for sample rural households, with an additional $912 for households that start a new productive activity. This figure can potentially be much higher as it excludes the many benefits that could not be monetized. A summary of general linkages between energy access and the MDGs is provided in Annex 7.

MDG 1

Income and agricultural production are significantly higher in communities with electricity, while energy expenditures are lower.

The economic benefits resulting from electricity access are primarily due to increased income from higher productivity, more hours worked thanks to electrical lights, and use of new electrical equipment. In some cases, a reduction in energy expenditures also results from switching over from traditional forms of energy to electricity.[19] Electrification programmes create employment in connection with the installation and operation of new MHSs. More important, access to electricity can provide opportunities for new types of productive uses and income-generating activities. Electricity access can also have direct and indirect impacts on nutrition, as increasing income and use of electricity can improve agricultural production, which in turn helps to reduce hunger.

Improved access to media and communications devices can also increase productivity and income, for example via access to timely market information, market prices, costs of input supply and business development services, and weather forecasts.

This study used inferential analysis to examine the relationships between development indicators related to MDG 1 and electricity access. Electricity access was found to be significantly associated with households' income, agricultural production and energy expenditures (Table 8; see Annex 8).

Box 4. MDG 1 in Nepal – Reduce poverty and hunger

About 31 per cent of the people in Nepal still live below the poverty line and 40 per cent live below the minimum level of dietary energy consumption (2003/04; Central Bureau of Statistics of Nepal, 2007b). Under MDG 1, the Government of Nepal has committed to reduce to 21 per cent the share of the population living below the poverty line by 2015, and to reduce to 25 per cent the percentage of the population below the minimum level of dietary energy consumption (Government of Nepal, National Planning Commission, UNDP, 2005).

Table 8. MDG 1 related indicators' association with electricity access and difference between households in communities with/without electricity

MDG 1 related indicator[1]	Relationship with electricity access	Mean difference[2]
Household income	Yes	+
Agricultural production	Yes	+
Energy expenditures	Yes	-

Notes:
1. Indicators selected here are used as proxy indicators for the MDGs and do not represent official MDG indicators as defined by the United Nations.
2. Compare the average indicator for electrified versus non-electrified households/people: (+) indicates that the indicator is higher for households/people with electricity access; (-) indicates that the indicator is lower for households/people with electricity access.

Increased incomes

This study estimates income as monetary income as well as the monetary value of items produced and consumed by households (see Annex 4). The values assigned to crops consumed, as well as eggs, milk or milk by-products from livestock, are based on average prices in local markets.

Households

The survey results showed that the distribution of household income improved in electrified communities compared to non-electrified communities: the percentage of households with very low income was lower in electrified communities while the percentage of households with 'middle' and 'high' income was higher in comparison with non-electrified communities (Figure 2).

In communities with electricity access, average household income is more than 25 per cent higher than in communities without electricity access.[20] The average yearly household income in the newly electrified communities surveyed in Nepal is $1,530, which is $317 higher than the average of $1,213 in similar communities without electricity (Figure 3).

The study estimated that about 8 per cent of the higher average annual income of households in communities with electricity is attributable to electricity access. To assess the variation of income attributed to electrification, the determinants of income[21] were modelled using this multiple linear regression[22] function:

Household income = ƒ [Electricity access (+), Farm land (+), Number of active adults (+), Education (+), Livestock (+), Time spent on activities generating income (+), Having a radio (+), Geographical location (+/-)]

The coefficient associated with electricity access is positive, which confirms that having electricity is positively associated with income.[23] The regression model indicates that the expected income for households with electricity access is approximately[24] 1.1 times greater than the average income for households without electricity. Therefore, the average increase attributable to electricity access is estimated to be around $121 annually based on the regression model. That represents about 8 per cent of the average annual income of electrified households reported in the survey results.[25,26] The survey data showed that the difference in income between households with

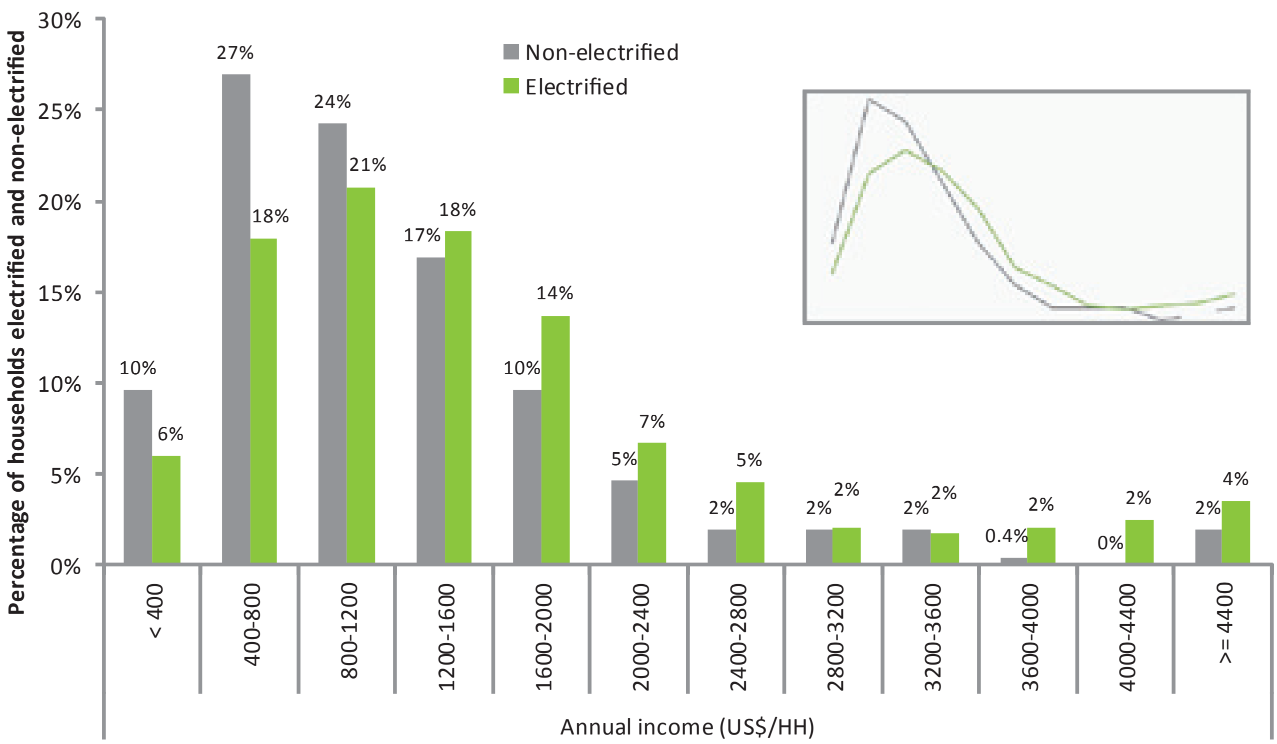


Figure 2. Distribution of annual income in electrified and non-electrified communities

and without electricity is about 25 per cent (i.e. $317 per year). Applying the results of the regression model to this data indicates that electricity access alone explains more than 30 per cent of the increase in expected average income for a sample household in an electrified community.

The model indicates that other factors are also positively associated with household income, including the amount and location of farmland and the number of livestock owned because most rural households are primarily involved in agriculture. Income is positively linked, as well, with the number of household members aged 16 to 60 and with time spent on income-generating activities. In addition, education correlates with income, as a higher level of education provides a wider range of employment and income-generating opportunities. Access to market information and weather forecasts via the radio also has a positive influence on income.

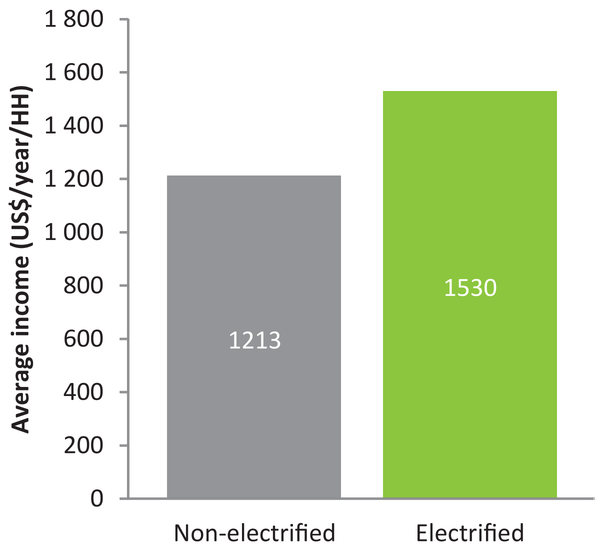


Figure 3. Average household income in electrified and non-electrified communities

Entrepreneurs

The introduction of electricity can improve the productivity of existing activities by allowing efficient operation of agro-processing units (such as rice-hullers, cereal grinders and oil expellers) to speed up the production process.[27] Improved agro-processing productivity can enable more agricultural products to be processed in a given period of time, which can lead to higher revenues. Greater productivity can also free up people's time to be invested in other productive or income-generating activities.

Practical Action/Jeremy Hartley

A rice milling enterprise can be more productive with the introduction of electricity.

Table 9. Agro-processing done by different methods and end-use technologies in Nepal

Methods/ technology	Processing capacity kg/hr			Human labour/ power needed	No. of households served (average)
	Grain grinding	Rice husking	Oil expelling		
Janto (manual grinder)	5			At least 1 person	Individual
Dhiki (manual husker)		9		At least 2 persons	Sometimes shared with neighbours
Kolu (manual expeller)			3	3 persons	Shard by at least 10-20 HH
Ghatta (traditional water mill)	20			0.5 – 1 kW	10 – 50
Ghatta (improved water mill)	40	150	10	1 – 5 kW	50 – 200
Mills (MHP mechanical/ electrical)	50-100	420	10-25	5 – 12 kW	100 – 700

Source: Compiled from Pokharel, 2006

Table 10. Average number of beneficiaries of the productive activities in surveyed areas

Enterprise type	Consumers (Number/month)			Origin of consumers (%)		
	Men	Women	Children	Same village	Neighbouring village	Another VDC
Agro-processing activities	145	234	62	51	37	12
Poultry farm	27	29	8	63	17	20
Sawmill/furniture	11	3		35	57	8

Note: Includes 17 productive activities from the 2008 survey.

Agro-processing involves the use of various devices, including grinders, huskers, expellers and water mills (Table 9). Mechanical/electric mills can grind grains at least 10 times faster than traditional technologies.

Providing modern, less labour-intensive and more efficient agro-processing services attracts new investments and clients from other villages. About half of all customers benefiting from improved agro-processing services live in the community, while clients from neighbouring areas account for the other half (Table 10). This allows entrepreneurs to increase their market base and, potentially, their profits.[28]

Productive activities increase

People living in communities with electricity have established new productive activities. More than 90 per cent of small businesses surveyed in the selected areas were created after electricity was introduced (Figure 4).[29] Of the 44 productive activities surveyed, just four were established before the MHS was installed.[30] The new businesses established after the MHSs were installed involve activities that rely on the use of electricity.

The most common entrepreneurial activities to emerge after electrification were food agro-processing

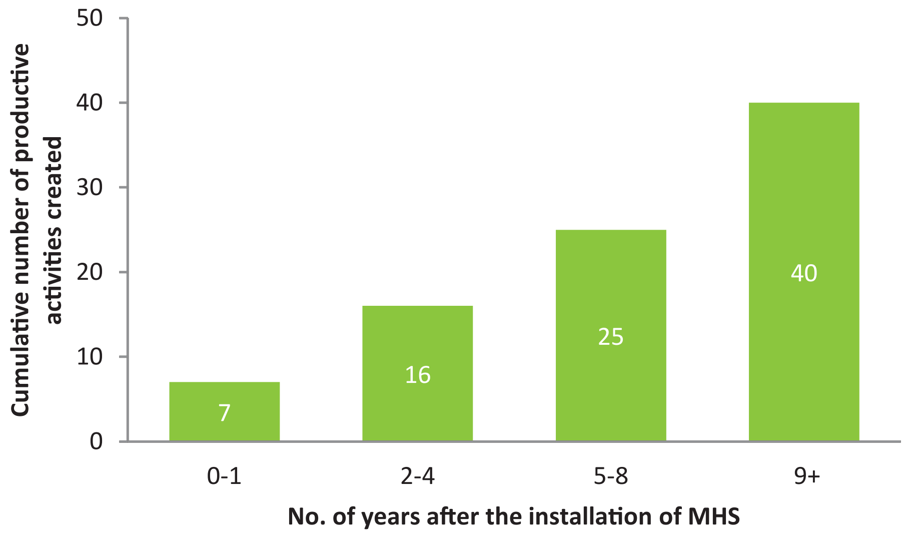


Figure 4. Productive activities created after the installation of MHS in selected areas

mills, poultry raising, and a few sawmill/furniture factories and services activities (e.g. computer, photo studio, sewing/knitting). Most activities are privately owned and managed, with the exception of some food-processing cooperatives.

However, only about 3.4 per cent of households have created a new activity since electrification. On average, 6.7 activities per MHS site were created following electrification. The number of new activities per site ranged from 1 to 19 (Table 11). While the provision of electricity can increase the opportunities for new productive activities, other factors, such as poor market access, lack of available capital and low skill levels, can prevent the development of activities that take advantage of newly available energy sources.

Training for the development of entrepreneurial capacities is important in supporting and promoting the creation of productive activities in rural areas. REDP's records indicate that more training on productive activities was conducted in the Kavre district than in Baglung, and the study found that three times as many businesses were developed in the Kavre district. Table 11 shows that only 10 productive activities have been developed in Baglung's selected MHS areas, compared to 30 in Kavre's selected MHS areas. This indicates that additional efforts to build local capacity could result in

Table 11. Productive activities developed in selected areas after MHS installation

District	VDC	Agro-processing	Poultry	Sawmill/ furniture	Services	All activities
Baglung	Dudilabhati	0	1	0	0	10
	Rangkhani	2	2	0	0	
	Sarkuwa	4	1	0	0	
Kavre	Dhusene Shiviliya/ Pokahrichauri	3	1	2	1	30
	Kartike Deurali	3	0	0	1	
	Mangaltar	3	11	1	4	
Total	**Total**	**15**	**16**	**3**	**6**	**40**

Note: Based on additional project information from selected areas (2010).

substantially higher income increases associated with MHSs.

In some areas, training was only performed a few years after the installation of the MHS.[31]

The creation of productive activities improves the local economy through new jobs, opportunities and dynamism, and directly benefits people working in the enterprises, many of whom are family members. In selected areas, net annual profits range from $32 for sewing/knitting activities to $2,667 for poultry farming or pig rearing, averaging $912 per year (2010 estimation). More than 60 per cent of those activities are performed for only a few hours per day.

The establishment of agro-processing and sawmill enterprises requires investments in machines and electricity. Data indicate that the payback periods for these investments range from less than one year to as many as eight years, with an average of two to three years. For sawmill enterprises, the average payback period is six months.

Increased agricultural production

In communities with electricity, average household agricultural production is almost 65 per cent higher than in those without electricity. More than 99.5 per cent of households surveyed are agricultural households (see Annex 4).[32] Across all surveyed communities, households grow an average of around 2,070 kg of crops per year, with rice and maize dominating. But households in communities with electricity grow an average of 2,560 kg annually, compared with only 1,560 kg in communities without electricity access. The largest differences appear in rice and potato production (Figure 5). Millet, grown on non-irrigated lands, is produced in larger quantity by households in non-electrified communities.

In communities with MHSs, water from the power canal is made available for irrigation. Those communities also have better access to tools and machinery that enhance productivity, and are more inclined to invest in productive assets, such as farm implements, tools, machinery and equipment, than communities without electricity.

Energy expenditures are reduced

Households

In communities with electricity, households are able to meet some of their energy needs with high quality services at less than half the price.[33] Households in non-electrified communities spend an average of $41 annually to buy kerosene and dry-cell batteries, while those in communities with electricity spend an average

Practical Action/Rakesh KC

A view of terraced agriculture. Agricultural productivity was boosted in areas with energy access.

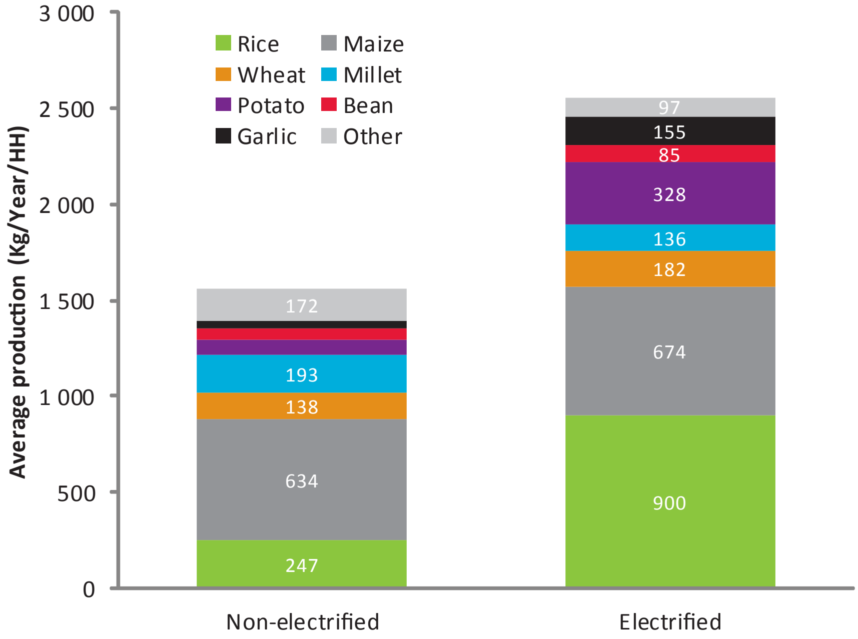


Figure 5. Annual household production in electrified and non-electrified communities

of about $19 to meet their energy needs – about $11 for electricity and $8 for kerosene and batteries (Figure 6).

Electricity access explains most of the observed variation in household energy expenditures for lighting and audio/media equipment. Household expenditures include current fixed/recurrent expenses for traditional energy sources such as kerosene, candles, and dry-cell batteries, as well as electricity. Electricity can be used to provide alternatives for lighting, radios and TVs, but is not used for cooking in the surveyed areas. Therefore, expenditures related to cooking (e.g. for fuelwood) are not impacted by electricity access, and fuelwood expenditures have not been included in the 'energy expenditures' indicator.

To assess the variation in energy expenditures attributable to electrification, the determinants of household expenses for energy were modelled using this multiple linear regression[34] function:

Energy expenditures = ƒ [Electricity access (-), Having a radio (+), Size of the house (+), Time spent cooking (+), No. of children going to school (+), Geographical location (+/-)]

The coefficient associated with electricity access is negative, which means that having electricity reduces the average energy expenditures.[35] The model indicates that expected energy expenditures for households with electricity access are approximately 0.4 times the average for households without electricity, other variables being constant.[36] Therefore, the average estimated decrease attributable to electricity access amounts to around 60 per cent of the actual energy expenditures for non-electrified households.[37]

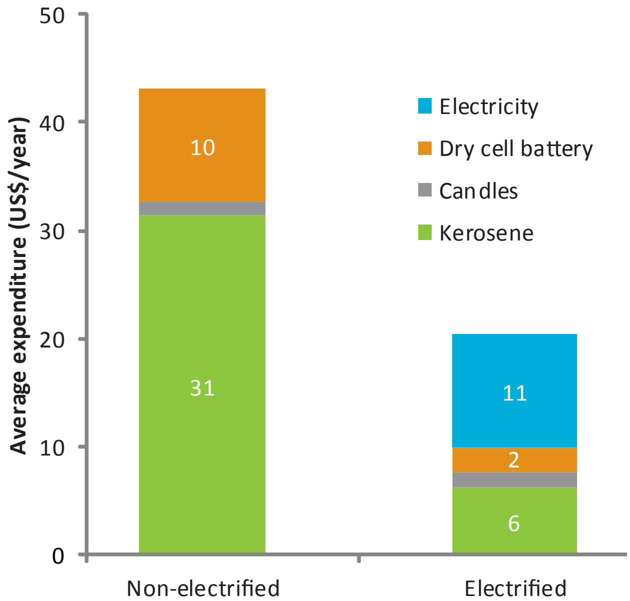


Figure 6. Average household expenditures for energy sources in electrified and non-electrified communities

The model also indicates that energy expenditures are not significantly linked to income, but do increase with the size of the house (number of rooms) as well as with time spent on domestic activities, such as cooking. Energy expenses also increase with the number of children going to school, perhaps indicating that children use lighting to do their homework. As expected, households with a radio spend more on energy, mainly because they buy dry-cell batteries.

Entrepreneurs

Use of electricity enables large reductions in energy costs for enterprises and productive activities. In general, mills run for about five hours per day, 300 days per year, and use around 1 litre of diesel per hour. Thus, switching from diesel to micro-hydropower electricity saves about 1,500 litres of diesel per mill per year, equivalent to about $1,200 (assuming a price of $0.80 per litre of diesel) (UNFCCC, 2006). The price paid for electricity for the same activity is approximately $650, i.e. 45 per cent lower.[38]

All new productive activities developed in the surveyed areas use electrical lighting. Some also use media equipment such as tape players, radios, TVs and/or videos (Table 12), mainly to improve working conditions and to attract more clients. Electricity is also used to run agro-processing devices such as hullers, expellers and grinders. In two cases, the source of energy is not electricity but mechanical power in which agro-processing units are directly linked to a rotating shaft of the water turbine, or a water flow is bifurcated to run a water turbine employed for agro-processing units, commonly known as multi-purpose power unit.

In the surveyed areas, average annual electricity bills range from $18 for poultry farms to $635 for agro-processing activities and $880 for sawmill activities. Using diesel instead of electricity would cost two or three times as much for energy to operate the machines.[39]

In 2007, 1.75 per cent of the GDP, or an estimated $180 million, was allocated to fuel subsidies (IMF, 2008). Savings that the government could make from reducing fossil fuel subsidies could be invested into micro-hydropower programmes or other clean energy services. In Nepal, micro-hydropower is subsidized. The subsidy amounts to about $733 per kW for new micro-hydropower projects up to 3 kW capacity and about $933 for installed capacity ranging from 3 to 100 kW. Subsidies are also provided for the rehabilitation or the expansion of existing projects and for the transportation of equipment and materials (AEPC, 2000).

Table 12. Average estimated electricity consumption for productive activities (kWh/Year)

Enterprise type	For lighting	For media facilities	For machinery	Total
Agro-processing activities	45	0	4568	4613
Poultry farm	879	0	0	879
Sawmill/furniture	75	99	8576	8750

Notes: Includes 17 productive activities from the 2008 survey.

MDG 2

Although electrification alone will not ensure that educational targets are met, it can help by improving the quality of schools, either by providing electricity-dependent equipment such as lights and computers, or by increasing the number of teachers working in rural areas. It also facilitates home study through better lighting and can help children to reach higher levels in school. Improved educational opportunities due to electricity access might encourage households to spend more on education than they otherwise would.

The study's inferential analysis showed that most education-related indicators are significantly associated with electricity access. Inferential analysis was used to check for the existence of relationships between development indicators related to MDG 2 and electricity access. All selected indicators are associated with electricity access and show an improvement in education (Table 13; see Annex 8).

Box 5. MDG 2 in Nepal – Achieve universal primary education

The Government of Nepal has introduced an 'Education for All' campaign that aims to achieve universal primary education in the country by 2015. The associated MDG target is to reach a net primary enrolment rate of 100 per cent, a literacy rate among young adults (aged 15-24) of 100 per cent, and 100 per cent of pupils reaching grade 5 (completion of primary school) (Government of Nepal, National Planning Commission, UNDP, 2005).

Table 13. MDG 2 related indicators' association with electricity access and difference between households in communities with/without electricity

MDG 2 related indicator[1]	Relationship with electricity access	Mean difference[2]
Number of students per primary school teacher	Yes	-
School enrolment of children 6-16	Yes	
Number of school days missed for children 6-16	Yes	-
Time spent doing homework for children 6-16	Yes	+
Time spent watching educational programmes on TV	Yes	+
School grade level of children 6-16	Yes	+
School expenditures	Yes	+

Notes:
1. Indicators selected here are used as proxy indicators for the MDGs and do not represent official MDG indicators as defined by the United Nations.
2. Compare the average indicator for electrified versus non-electrified households/people: (+) indicates that the indicator is higher for households/people with electricity access; (-) indicates that the indicator is lower for households/people with electricity access.

More teachers and lower student-to-teacher ratios

The number of students per primary school teacher is lower in schools with electricity than in schools without electricity. Communities with electricity are better able to attract and retain teachers due to better living and working facilities, and student-to-teacher ratios are much lower. This allows for more attention to be paid to each student and enhances the overall educational services provided. Results of the survey showed that primary schools with electricity average 16 students per teacher, compared to 33 students per teacher in schools without electricity in non-electrified areas (17 fewer students per teacher) (Figure 7). The situation is also better for schools without electricity but located in electrified areas, which average about 22 students per teacher (11 fewer students per teacher).

There are not enough government-funded teachers in Nepal. Therefore, community-level schools have authority to hire additional teachers, part-time or temporary, according to their needs and resources. Electrified communities are preferred by teachers.

There are no secondary schools in non-electrified communities of the surveyed areas.

The study's regression model estimated that about 70 per cent of the difference in the number of students per primary school teacher in electrified areas compared to schools without electricity in non-electrified areas is attributable to electricity access. To assess the variation

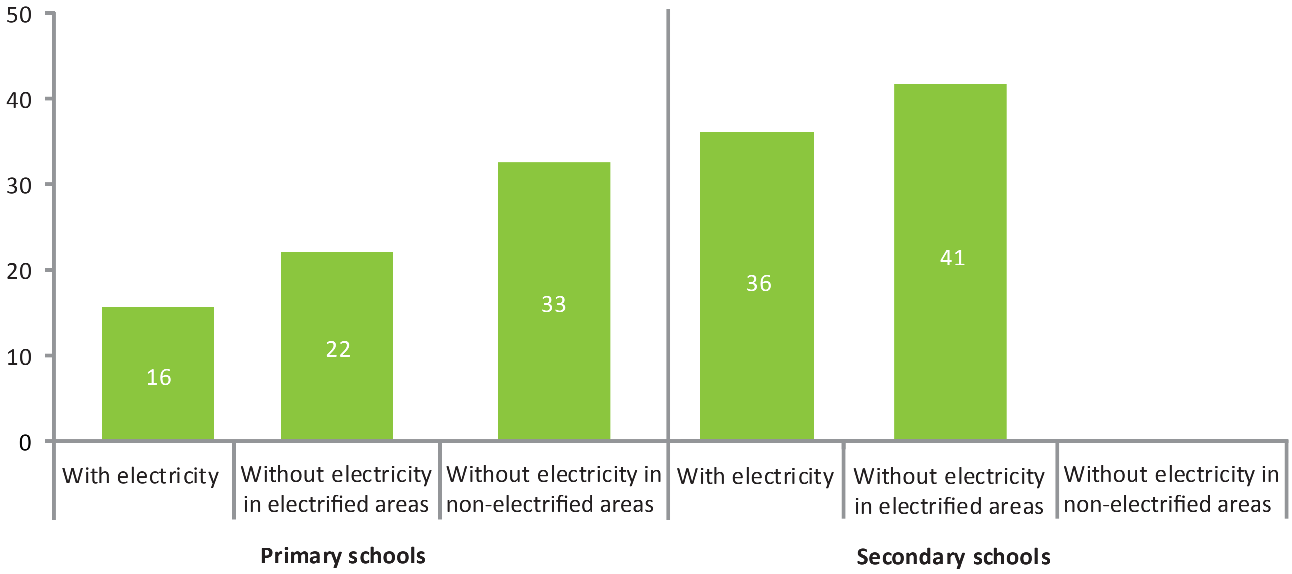


Figure 7. Number of students per teacher

in the students/teacher ratio that can be attributed to electrification, the determinants of the number of students per teacher were modelled using this multiple linear regression[40] function:

No. of students per primary school teacher = ƒ [Electrified community (-), Size of the school (-)]

Two independent variables—the size of the school (indicated by the number of rooms) and the electrification of the community—explain more than 60 per cent of the variation in the number of students per teacher. However, the interpretation should be understood in the context of just 18 observations and results should not be generalized.

The coefficient associated with electricity access is negative,[41] reflecting the fact that electrified communities have fewer students per primary school teachers. The model indicates that with a constant school size, primary schools in electrified areas would have an average of 12 fewer students per teacher than non-electrified schools in areas without electricity. This figure represents 70 per cent of the reduction in the number of students per teacher reported in the survey results (12/17).

The coefficient associated with the number of rooms per school is negative, which indicates that small primary schools have more students per teacher.

Children's education improves

School records indicate that the number of children who drop out of school is lower in electrified schools. In electrified communities, MHS project activities have raised parents' awareness about the importance of education, and they understand its value better. The percentage of girls dropping out of school is more than 10 times lower in electrified schools than in non-electrified schools: only 0.5 per cent of girls dropped out of schools with electricity, compared to 6.3 per cent from schools in communities without electricity (Figure 8). The overall number of children dropping out of school is also higher in non-electrified schools located in electrified areas.

Children living in electrified communities also have better school attendance than children living in non-electrified communities. School records for 2008 show that the number of school days missed by children since the beginning of the year is about 12 times lower in electrified schools than in non-electrified schools in areas without electricity. The number of school days missed by children is also lower in non-electrified schools located in electrified areas (Figure 9).

Survey data indicated that children living in electrified communities spend an average of three additional hours per week on educational activities such as reading, doing homework and listening to educational programmes (Figure 10). This is because having light in the evening

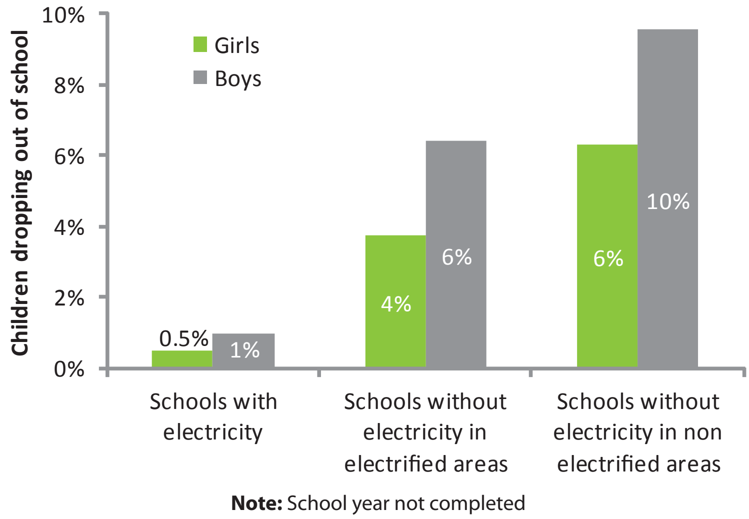
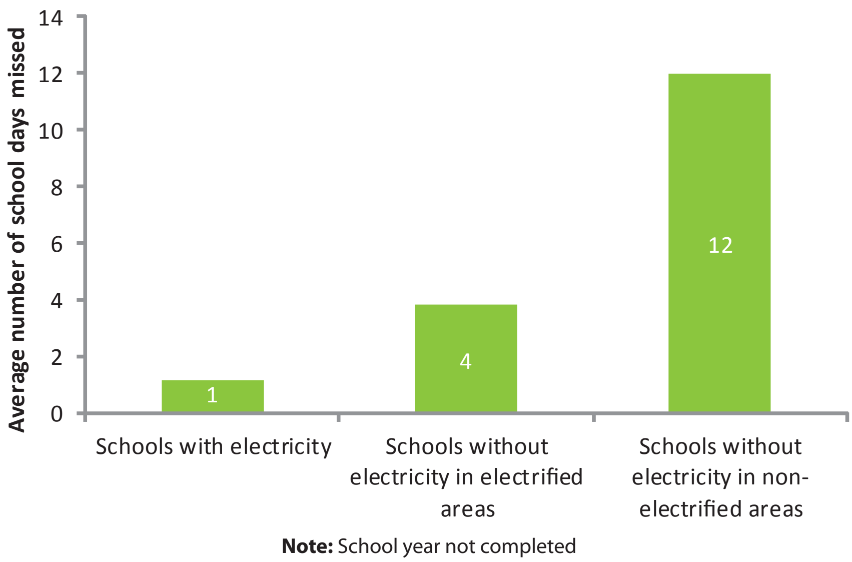


Figure 8. Average number of children dropping out of school in 2008

Figure 9. Average number of school days missed in 2008



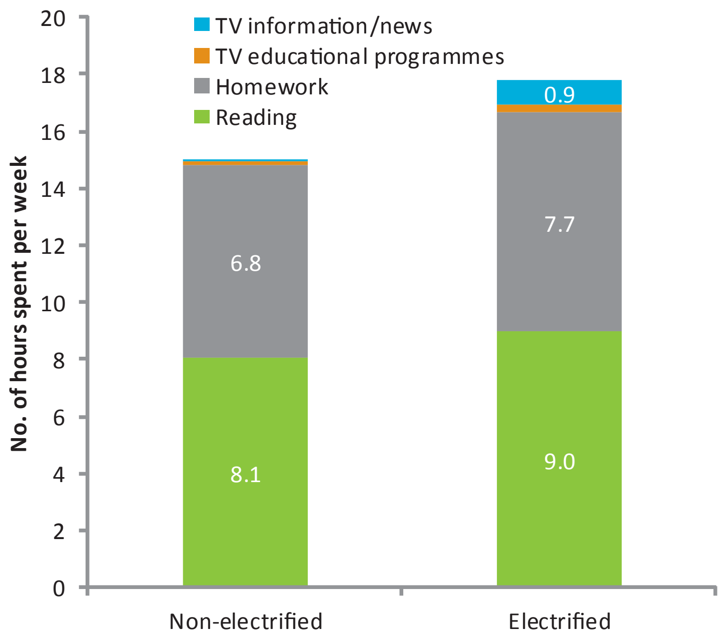


Figure 10. Average time spent per children aged 6 to 15 on educational activities

enables students to spend more time on educational activities.

Average net school enrolment rates[42] in secondary schools are higher for children living in electrified communities. While the survey results indicate that the average enrolment rate in primary school is about the same in both electrified and non-electrified communities, they show that enrolment rates in secondary schools are over 50 per cent higher for children living in communities with electricity (Figure 11). The distance to secondary school for non-electrified communities can explain part of that result. Indeed, in non-electrified areas there are no higher-level secondary schools, so students must commute to other areas that have secondary schools.

The study estimated that children in households with electricity are four to five times more likely to attend secondary school.[43] To assess the variation in school grade levels attributed to electrification, the determinants of school grade levels[44] for children aged 6 to 16 were modelled using this multinomial logistic regression[45] function:

School grade levels = ƒ [Electricity access (+), Age (+), No of children in the household (-), Adult education (+)]

The coefficients associated with access to electricity are significant and positive.[46] Children from electrified households are more likely to be in school grades above 1. The model indicates that, assuming other factors remain constant, children living in electrified communities are 1.7 times more likely to be in grade 4 or 5. They are 4.2 times more likely to be in grade 6 or 7, and 5.2 times more likely to be in grade 8 or higher.

As expected, age is positively associated with school grade levels. The model also indicates that the odds[47] of attaining higher school grade levels decrease with the number of children in the household. The level of education achieved by adults in the household is significant and positive in the case of high school grade levels (8+).

Households devote more resources to education

Households in communities with electricity spend twice as much on education as those without electricity. The survey data showed that on average, households in electrified communities spend $164 on school expenditures (including registration fees, school supplies, clothes, etc.), compared with $79 for households in communities without electricity access (Figure 12).[48]

The study estimated that average expected school expenditures for households in communities with electricity are about 1.5 times greater than the average expenditure for those without. To assess the variation in education expenditures attributable to electrification,

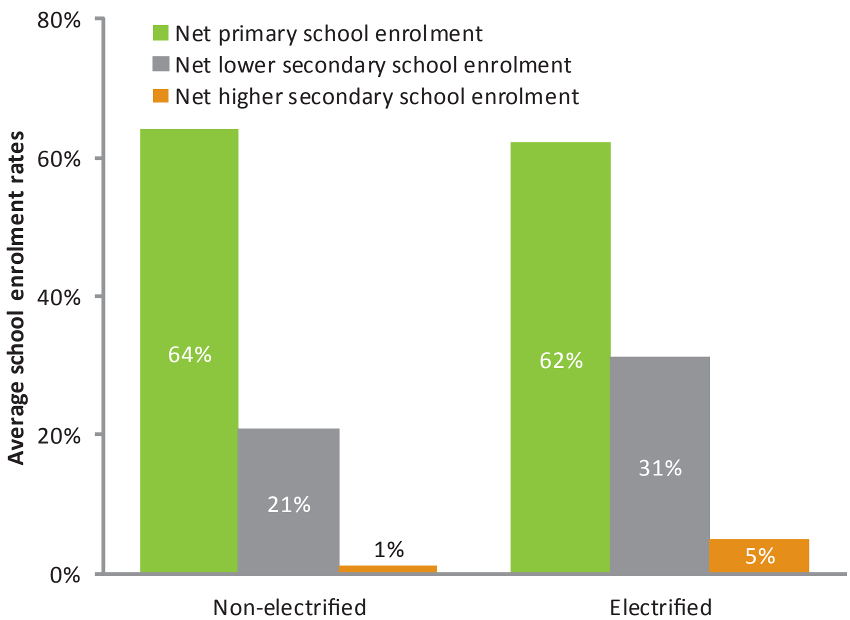


Figure 11. Average school enrolment rates in electrified and non-electrified communities

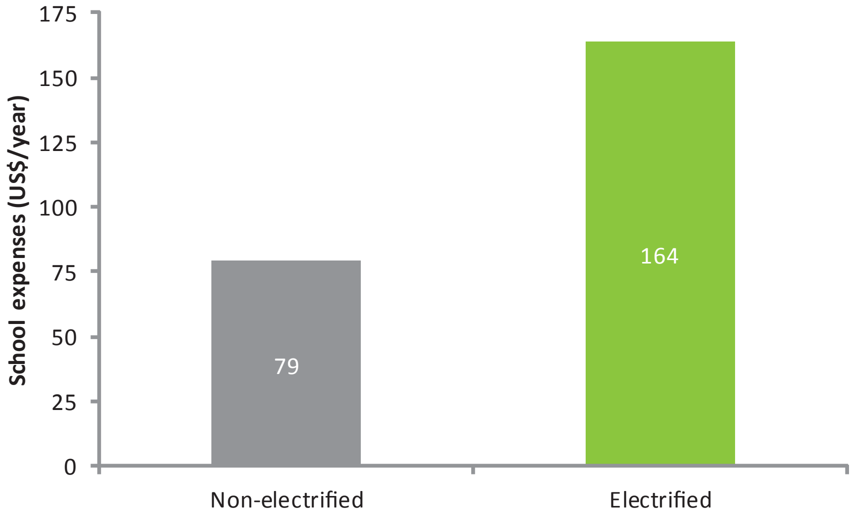


Figure 12. Average school expenditures in households with/without electricity access

the determinants of household expenses for school[49] were modelled using this multiple linear regression[50] function:

School expenditures = ƒ [Electricity access (+), Education (+), No of students in the house (+), Income (+), Geographical location (+/-)]

The coefficient associated with electricity access is positive, which means that having electricity is positively associated with expenditures for education.[51] The model indicates that expected school expenditures for households in communities with electricity access is approximately 1.54 times greater than the average expenditures for those without.[52] Therefore, the average increase attributable to electricity is estimated to be $43 annually, or about 26 per cent of electrified households' average school expenditures.[53] This represents about half of the observed difference in expenditures between households in electrified and non-electrified communities.

The level of education achieved by household members has the highest impact on the budget allocated to education. As expected, expenses for education are also positively associated with the number of people, both adults and children, who are students. Income is also positively associated with school expenditures, showing that a larger share of income is allocated to education when more funds become available. In most cases, location is also significantly linked to education expenditures.

MDG 3

Electricity access is correlated with women's access to education and outside information. Inferential analysis was used to check for the existence of relationships between selected development indicators related to MDG 3 and electricity access. Education and time spent on receiving visitors and watching TV are linked to electricity access. However, the inferential analysis found no significant relationship between electricity and the

Box 6. MDG 3 in Nepal – Promote gender equality and empower women

The target for MDG 3 in Nepal is to eliminate gender disparity in all levels of education by 2015 (Government of Nepal, National Planning Commission, UNDP, 2005). In 2005/06, the ratio of girls to boys enrolled in school was 0.94 in primary schools and 0.86 for secondary schools (Central Bureau of Statistics of Nepal, 2007b).

Table 14. MDG 3 related indicators' association with electricity access and difference between households in communities with/without electricity

MDG 3 related indicator[1]	Relationship with electricity access	Mean difference[2]
Number of school days missed by girls 6-16	Yes	-
School grade level of girls 6-16	Yes	+
Time spent on income-generating activities for women older than 15	No	
Time spent cooking/cleaning for women older than 8	No	
Time spent receiving visitors for women older than 15	Yes	+
Time spent watching TV	Yes	+
Time spent reading	No	

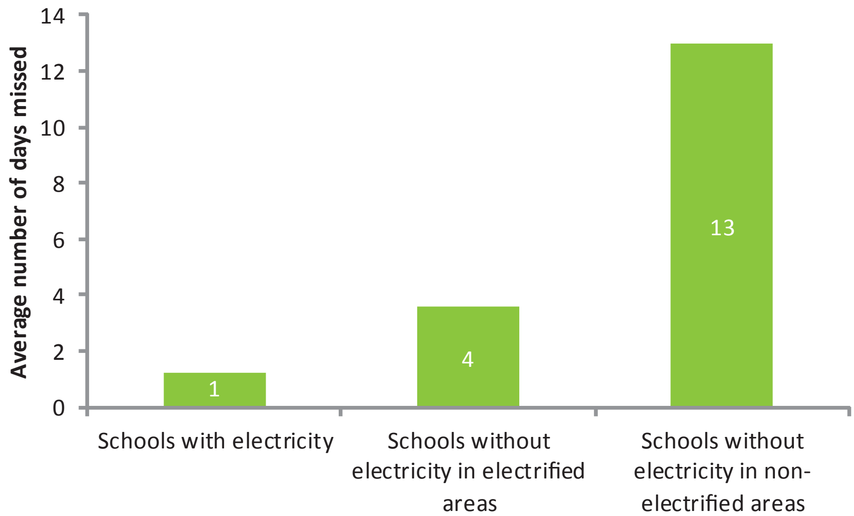
Notes:
1. Indicators selected here are used as proxy indicators for the MDGs and do not represent official MDG indicators as defined by the United Nations.
2. Compare the average indicator for electrified versus non-electrified households/people: (+) indicates that the indicator is higher for households/people with electricity access; (-) indicates that the indicator is lower for households/people with electricity access.

time spent by women on income-generating activities (Table 14), on reading or on cleaning and cooking (electricity is not used for cooking).[54]

Girls' education improves

Girls living in electrified communities have better school attendance than girls living in communities without electricity. The survey data indicated that girls living in electrified communities missed, over the last month, an average of 0.25 days, compared to 0.7 days for girls living in non-electrified communities. Similarly, a review of school records indicated that in 2008 girls studying in electrified schools missed one day, but those in non-electrified areas missed 13 days, and that the number of school days missed is also lower for non-electrified schools in electrified areas (Figure 13).

The survey data showed that girls living in electrified communities reach higher school levels than girls living



Note: School year not completed

Figure 13. Average number of school days missed by girls in 2008

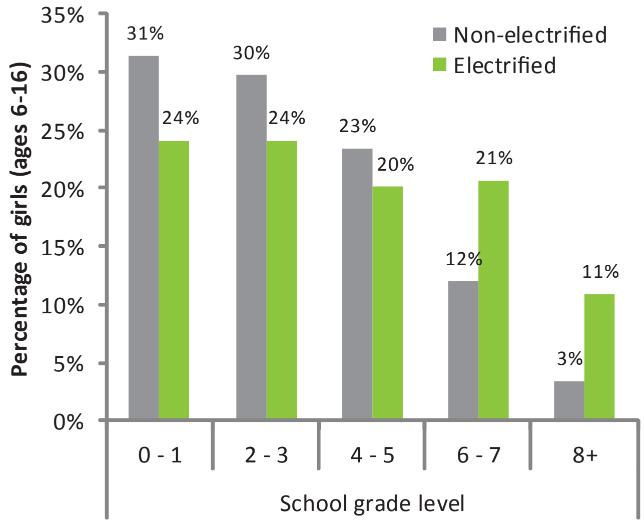


Figure 14. School grade levels of girls living in electrified and non-electrified communities

in communities without electricity access. The average attendance for girls living in electrified communities is grade 4, compared with grade 3 for girls living in non-electrified communities. The share of girls attending grades 6 and above is higher in electrified communities, while the share of girls attending grades 5 or less is higher in non-electrified communities (Figure 14).

The study estimated that girls living in electrified communities are 7 to 15 times more likely to go to secondary school.[55] To assess the variation in school grade levels attributable to electrification, the determinants of school grade levels[56] for girls aged 6 to 16 were modelled using this multinomial logistic regression[57] function:

Girls' school grade levels = ƒ [Electricity access (+), Age (+), No of children in the household (-)]

The coefficients associated with electricity access are positive. Girls in households with electricity are more likely to be in school at grade 1 or above.[58] The model also shows that, other factors holding constant, girls living in electrified communities are 2.2 times more likely to be in grades 4 or 5; are 7 times more likely to be in grades 6 or 7; and are 15 times more likely to be in grade 8 or higher.

As expected, age is also positively associated with school grade levels. The model also shows that the chances of reaching higher school grade levels decrease with the number of children in the household. In this model, the level of education of adults in the household was not significant.

Women have greater access to communications equipment

In communities with electricity, women have greater access to television and communications equipment (78 televisions in electrified communities versus 1 in the non-electrified ones)[59]. Thus, women can become more informed about news and events (including weather and market information), more educated about important matters such as local and national politics and health issues, and more exposed to examples of women taking active roles in business and public affairs. This increased access to information can be critical for improving women's participation in community development activities and entrepreneurial activities.

Thus, the likelihood of increased women's participation, involvement and leadership in community development activities, non-formal education, adult literacy, entrepreneurial activities and childcare is higher in communities with electricity than in those without.

Women have more time to spend on leisure activities

Access to electricity for motorized equipment reduces the amount of time women have to spend grinding grains, hulling rice and pressing oils by hand. The survey showed that significantly more women than men are beneficiaries/consumers of new agro-processing activities (234 women compared with 145 men).[60] The

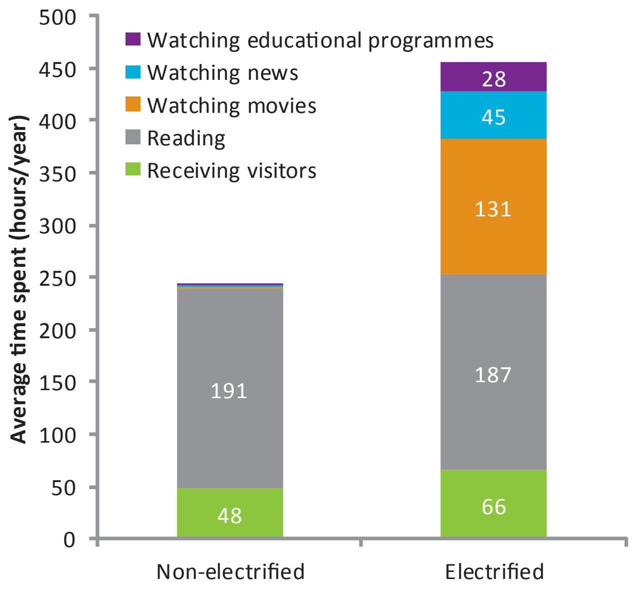


Figure 15. Time spent by women on leisure activities in communities with/without electricity

Women were found to have more time for leisure and socializing in communities with electricity access.

UNDP/Nepal

study estimated that the use of electric mills instead of manual agro-processing would save about 155 hours per year for women.[61]

Women in communities with electricity spend more than twice as much time on activities such as receiving visitors, and watching/listening to news and educational programmes (Figure 15). While the time spent on receiving visitors or watching TV is significantly higher in households in electrified communities, the time spent reading is about the same in electrified and non-electrified communities.[62]

MDG 4, 5 and 6

Replacing solid fuels used for cooking with electricity greatly improves people's health due to improved indoor air quality. However, electricity is rarely used for cooking, and then only in some urban areas.[63] In the communities surveyed for this study, households continue to use solid fuels for cooking, but many have adopted improved cooking stoves. These stoves produce less indoor air pollution than traditional stoves. Reduced reliance on candles and kerosene lamps for lighting also improves indoor air quality (especially reducing the incidence of acute respiratory infections and eye irritations among

Box 7. MDG 4, 5 and 6 in Nepal – Reduce child mortality, improve maternal health, combat diseases

The Government of Nepal is committed to reducing the country's under-five mortality rate by two-thirds (MDG 4), and the maternal mortality rate by three-quarters (MDG 5) by 2015, with the reductions based on 1990 levels. It also expects to have halted and begun to reverse the spread of HIV/AIDS and the incidence of malaria and other major diseases by 2015 (MDG 6) (Government of Nepal, National Planning Commission, UNDP, 2005).

Table 15. MDG 4, 5 and 6 related indicators' association with electricity access

MDG 4, 5 and 6 related indicator[1]	Relationship with electricity access
Cooking habits (traditional stoves/improved stoves)	Yes
Kitchen type (open/closed spaces)	No
Toilet facility	Yes
Water supply	Yes
Health expenditures	No

Notes:

1. Indicators selected here are used as proxy indicators for the MDGs and do not represent official MDG indicators as defined by the United Nations. Inferential analysis could not be applied to health centre data, as the number of observations was too low (seven health centres in the communities surveyed).

women and children) and reduces burn injuries from kerosene lamps. Electrification can also provide health benefits by improving the quality of health centres, either by allowing the use of electrical equipment, or by increasing the number of medical workers. Moreover, in some places, electricity enhances drinking water supply systems and encourages the use of hygienic latrines.

The study found that cooking habits, toilet facilities and water supply are significantly associated with electricity access (Table 15). However, inferential analysis showed no significant relationship between electricity access and the type of kitchen used (open or closed spaces), or the amount of money allocated to health care.[64] More than electrification itself, these improvements in electrified communities might be the result of other development activities initiated by REDP in the villages.

Cooking and sanitation conditions improve

All households, regardless of electricity access, use solid fuels as primary cooking fuel, but there is more use of improved stoves in REDP communities. While only 6 per cent of households in communities without electricity use improved cooking stoves, over 20 per cent in communities benefiting from REDP's electrification programme use them. In addition, 13 per cent of households in electrified communities occasionally use gas or biogas for cooking (Figure 16).

The share of households with access to a private water supply is higher in communities benefiting from REDP's electrification programme than in communities without electricity access. While 17 per cent of households in communities with electricity have either a private well

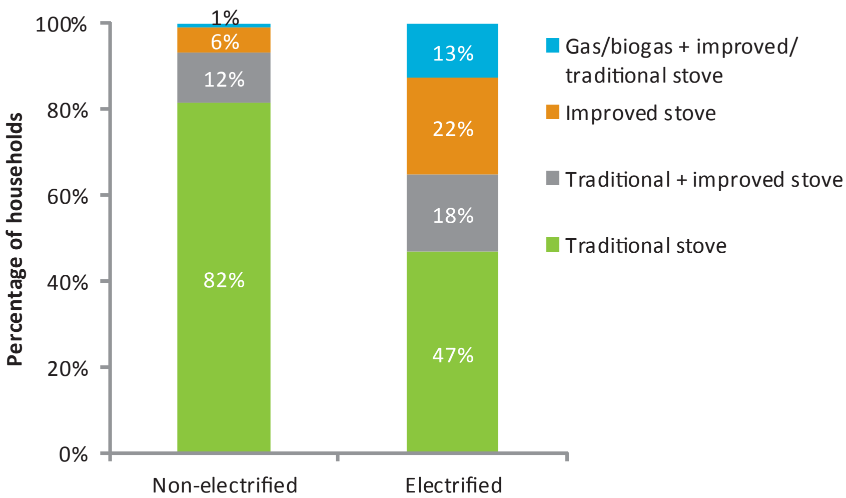


Figure 16. Cooking habits in electrified and non-electrified communities

or a private pipe inside the house, only 7 per cent of households in non-electrified communities have such access (Figure 17).

Households in REDP communities tend to have better toilet facilities than households in communities without electricity. Less than 40 per cent of households in communities without electricity have permanent toilets, compared to almost 65 per cent for households in electrified communities (Figure 18). Permanent toilets include toilet-attached biogas plants promoted by REDP.

Number of qualified health workers increases

The number of health workers per unit of population is much greater in communities with electricity than in those without. Collected data suggest that health workers are more likely to live and work in remote areas if they have access to electricity. Indeed, electrified health posts average 11 health workers per 10,000 people, compared with only two in non-electrified health posts in non-electrified areas (Figure 19).[65]

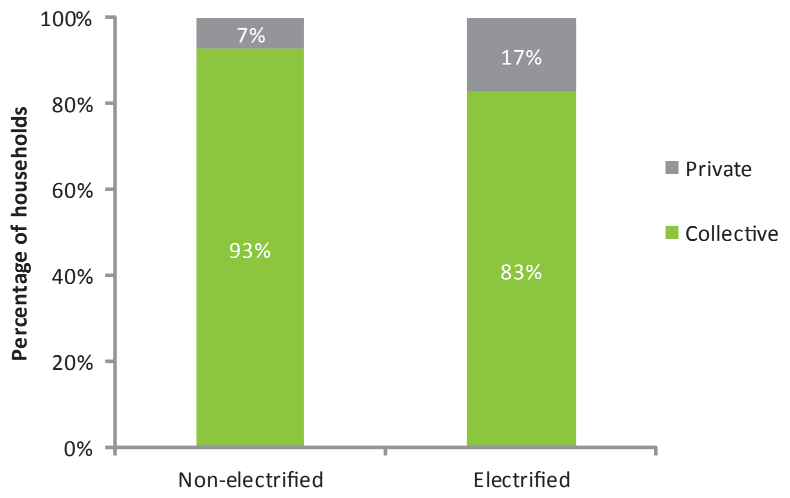


Figure 17. Water supply in electrified and non-electrified communities

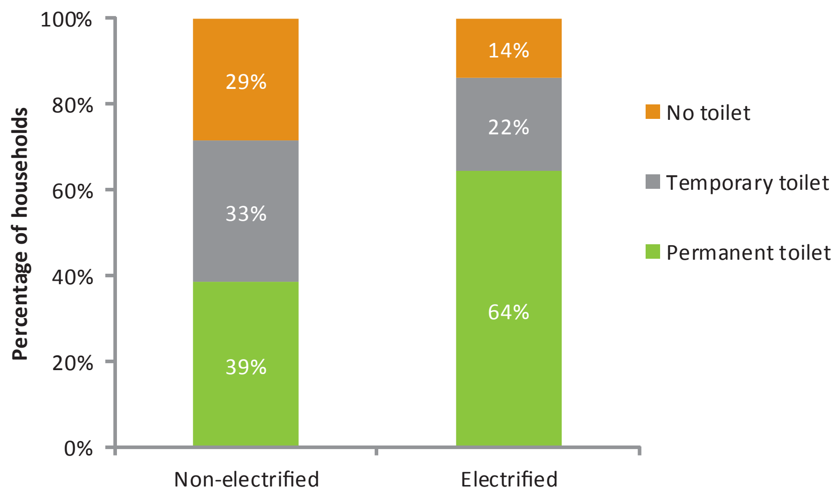


Figure 18. Toilet facilities in electrified and non-electrified communities

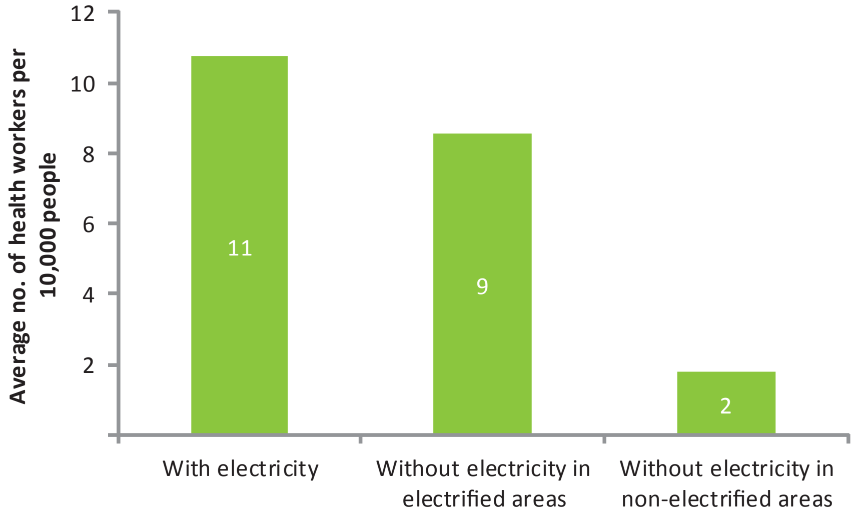


Figure 19. Average number of health workers in health posts

People visit health centres more often

The number of health visits per person per year is greater in health centres with electricity. Health centre records show that there are almost twice as many visits to electrified health facilities than to those without electricity (Figure 20).[66] People might visit their health centre more often as a result of raised awareness engendered by the REDP programme on the importance of health. Increased income in electrified communities also makes health facilities more affordable for community members. However, records also indicate that there are fewer visits to health centres without electricity but located in electrified areas than in health centres with electricity or in non-electrified areas. This might indicate that people in electrified areas believe in the importance of having lights and electrical equipment in health centres.

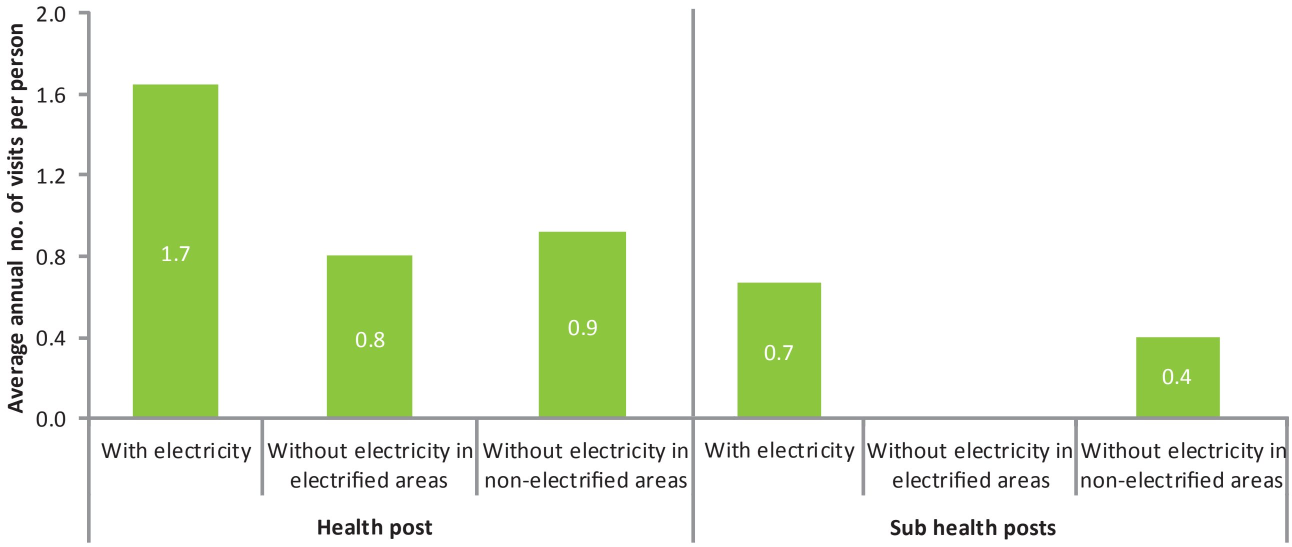


Figure 20. Average annual number of visits to health centres

MDG 7

Combustion of fuels such as wood, charcoal, kerosene and diesel emits greenhouse gases and pollutes indoor air, which particularly affects the health of women and children. Open disposal of used batteries causes environmental hazards by exposing land and water to lead and acid, and by exposing people to strong corrosive acids that may cause burns or danger to eyes and skin. When burned, dry-cell batteries can pollute rivers and streams, as the metals vaporize.[67] By reducing the consumption of fossil fuels and dry-cell batteries, and by avoiding the use of diesel generators, hydroelectricity benefits both local and global environments.

Communities participating in the REDP's MHS programme are more aware of the need for sustainable management of critical watersheds and biodiversity conservation, and understand the benefits of sustainable land and water management practices better than communities without access to MHS projects.

The study found that the quantity of kerosene, mainly used for lighting, and dry-cell batteries consumed is significantly and negatively associated with electricity access. However, inferential analysis did not indicate any significant relationship between electricity access and consumption of fuelwood[68] or charcoal (Table 16).[69] Indeed, in the surveyed areas, electricity is not used for cooking or heating, and household consumption of fuelwood is about the same in electrified and non-electrified communities.[70]

REDP's electrification programmes generally have positive impacts on forests, even though electricity has not replaced fuelwood for cooking. During installation of the MHSs, REDP focuses on deforestation issues and tree planting projects. Trees are planted along the water channel (0.5 to 3 km in length) to stabilize the slope of the path, and seedlings are distributed. Installation of MHSs also involves bioengineering activities, as well as activities that encourage the implementation of community forestry programmes to promote sustainable use of the resource.[71] Community Forestry Groups establish rules that make fuelwood available to members at specific times of the year for a nominal charge.

Consumption of batteries and kerosene declines

Communities with electricity consume less kerosene, mainly used for lighting, and fewer dry-cell batteries.

Box 8. MDG 7 in Nepal – Ensure environmental sustainability

The MDG related to environmental sustainability calls for integrating the principles of sustainable development into country policies and programmes, and reversing the loss of environmental resources (Government of Nepal, National Planning Commission, UNDP, 2005).

Table 16. MDG 7 related indicators' association with electricity access and difference between households in communities with/without electricity

MDG 7 related indicator[1]	Relationship with electricity access	Mean difference[2]
Quantity of kerosene consumed	Yes	-
Quantity of dry-cell batteries consumed	Yes	-
Quantity of charcoal consumed	No	-
Quantity of fuelwood consumed	Yes	≈

Notes:
1. Indicators selected here are used as proxy indicators for the MDGs and do not represent official MDG indicators as defined by the United Nations.
2. Compares the average indicator for electrified versus non-electrified households/people: (+) indicates that the indicator is higher for households/people with electricity access; (-) indicates that the indicator is lower for households/people with electricity access; (≈) indicates that the difference is not significant.

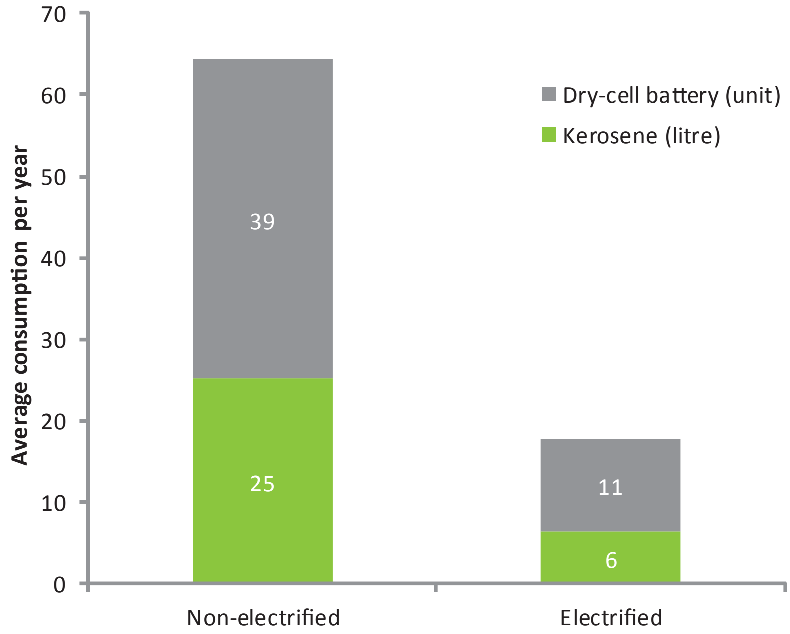


Figure 21. Average consumption of kerosene and batteries in electrified and non-electrified communities

They are therefore less likely to experience environmental damage associated with the use of these energy sources (Figure 21).

The study estimated that access to electricity reduces the likelihood of using dry-cell batteries by more than 85 per cent. To assess the variation in dry-cell consumption attributable to electrification, the determinants of dry-cell battery consumption levels[72] were modelled using this multinomial logistic regression[73] function:

Dry-cell batteries consumption = ƒ [Electricity access (-), Having a radio (+), Time spent on cooking (+), Time spent on cleaning (-), Land owned (-), Geographical location (+/-)]

Coefficients associated with access to electricity are significant and negative.[74] This indicates that electrification reduces the chances that dry-cell batteries will be used. More specifically, the model indicates that, other factors being constant and rather than not using any battery, access to electricity decreases the odds of using one or two batteries per month by 88 per cent, while the likelihood of using more than two batteries per month falls by 98 to 99 per cent.

Having a radio increases the odds of consuming more batteries. In households consuming more than two dry-cell batteries per month, the model suggests that the likelihood of consuming more batteries increases with the time spent on cooking. This could be explained by the fact that local people like listening to songs and news that are aired during cooking times, mostly in the morning and evening. The likelihood of using more batteries, however, falls as time spent on cleaning increases. Having larger land holdings reduces the odds of consuming more batteries, which might be explained by household members spending more time outside.

The study's analysis estimated that having electricity reduces the likelihood of consuming kerosene by more than 80 per cent. To assess the variation in kerosene consumption attributable to electrification, the determinants of kerosene consumption levels[75] were modelled using this multinomial logistic regression[76] function:

Kerosene consumption = ƒ [Electricity access (-), No of people in the household (+), Time spent on cooking (+), geographical location (+/-)]

Coefficients associated with having access to electricity are significant and negative.[77] That means that having electricity reduces the odds of consuming kerosene. More specifically, the model indicates that, other factors being constant, access to electricity decreases the likelihood of consuming an amount less than one litre of kerosene per month by 83 per cent, while the odds for consuming more than one litre per month falls by 98 to 100 per cent.

The model also indicates that the likelihood of consuming more than one litre of kerosene increases with the number of people living in the house, as well as the time spent on cooking, which requires lighting in the morning and the evening.

Greenhouse gas emissions are avoided

Using MHSs instead of diesel generators to produce electricity avoids GHG emissions. Generating electricity with micro-hydropower systems does not require diesel and therefore avoids GHG emissions. In the six surveyed communities, all with electricity, it is estimated that using MHSs to generate electricity instead of diesel avoids the emission of 517 tons of CO_2 per year.[78] On average, this represents an annual reduction in CO_2 emissions of 4 tons per kW installed.

Assuming that 1 ton of CO_2 is worth $10[79], the sale of certified emission reductions (CERs) would yield about $5,175 per annum for the six MHSs selected, or about $3.80 per household per annum.

MDG 8

The indicators for Target 8F under MDG 8 deal mainly with telephone lines or cellular subscribers, along with personal computers and the numbers of Internet users. Electricity access is a prerequisite for accessing those technologies, as well as other communications and information equipment such as TV sets. Access to information and technology enhances the power and empowerment of rural people.

While access to radio or TV is primarily associated with MDG 8, it can also help achieve other MDGs, because it facilitates health awareness, education, and can even provide useful information for other activities, such as weather forecasts for farmers.

For this study, inferential analysis was used to identify relationships between indicators related to MDG 8 and electricity access. TV ownership is significantly linked to electricity access, while radio ownership is not (Table 17), although households with electricity use both dry-cell batteries and electricity to power radios.

The survey found that communities with electricity have access to TV programmes, and households in communities without electricity do not. Indeed, in selected communities without electricity, (dry-cell) batteries are used for radios, but (car) batteries are not used for TVs. Therefore, only households in communities with electricity currently have access to TV programmes (Figure 22).

Time allocation

Time saved due to electricity access can benefit numerous development processes; therefore, it is not associated with just a single MDG. Time saved can be used for a range of activities, including income-generation and agriculture (MDG 1), education (MDGs 2 and 3), women's involvement in the community (MDG 3), information and communication activities (MDGs 1 to 7), and health care (MDGs 4, 5 and 6).

Box 9. MDG 8 in Nepal – Develop a global partnership for development

MDG 8 includes a focus on information and communications technologies (Target 8F). The government's objective is to make available, in cooperation with the private sector, the benefits of new technologies, especially for access to information and communication (Government of Nepal, National Planning Commission, UNDP, 2005).

Table 17. MDG 8 related indicators' association with electricity access

MDG 8 related indicator[1]	Relationship with electricity access
Own a radio	No
Own a TV	Yes

Notes:
1. Indicators selected here are used as proxy indicators for the MDGs and do not represent official MDG indicators as defined by the United Nations.

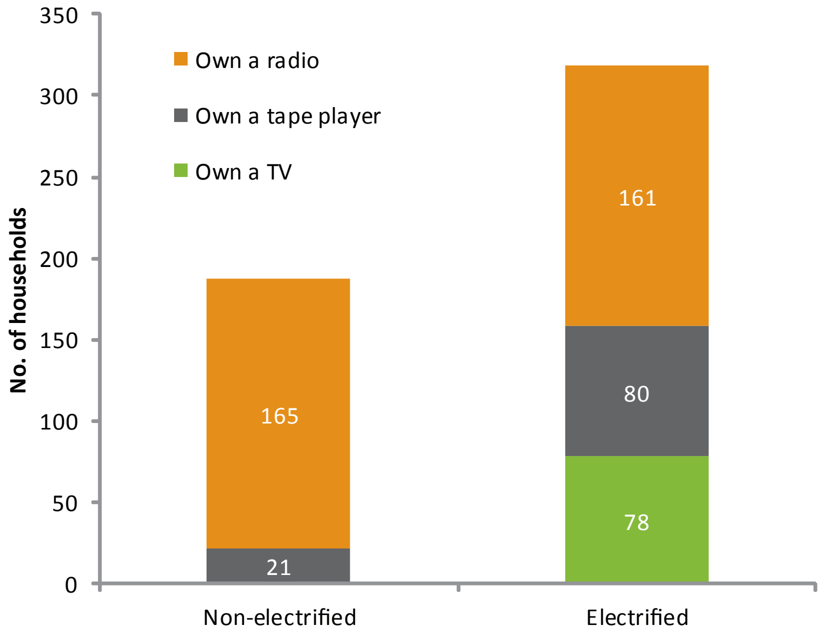


Figure 22. Media facilities in communities with/without electricity access

Table 18. Time allocation's association with electricity access and difference between households in communities with/without electricity

Indicator	Relationship with electricity access	Mean difference[1]
Bed-time in the evening	Yes	+
Wake-up time in the morning	Yes	-
Time spent cleaning for people older than 8 years old	Yes	≈
Time spent cooking for people older than 8 years old	Yes	≈

Notes:

1. Compare the average indicator for electrified versus non-electrified households/people: (+) indicates that the indicator is higher for households/people with electricity access; (-) indicates that the indicator is lower for households/people with electricity access; (≈) indicates that the difference is not significant.

Inferential analysis was used to identify relationships between time allocation and electricity access (Table 18).[80] An association was found between electricity access and the average times for waking up and going to bed, however no significant difference was found between the average time spent on cleaning and cooking for people older than eight. Households with electricity access still use fuelwood as the principle source of cooking fuel.[81]

Reduced time spent on agro-processing activities

It is estimated that use of MHSs to operate agro-processing enterprises can allow households to save up to 240 hours per year. Access to electricity for agro-processing can dramatically reduce the time spent, mainly by women, on laborious tasks such as grinding corn, de-husking rice and extracting oil. In the surveyed areas, about 75 per cent of agricultural production

Table 19. Methods of agro-processing technologies in Nepal and average time spent for food processing in surveyed areas

Methods/technology	Processing capacity kg/hr[1]		Average time spent for food processing in surveyed areas (hours/year)[2]				Average time spent for food processing in surveyed areas (hours/year)
	Grain grinding	Rice de-husking	580 kg of rice	655 kg of maize	160 kg of wheat	164 kg of millet	
Janto (manual grinder)	5			131	32	33	196
Dhiki (manual husker)		9	64.5				64.5
Ghatta (traditional water mill)	20			33	8	8	49
Mills (MHP mechanical/ electrical)	50-100	420	1.4	6.5-13	1.6-3.2	1.6-3.3	11.1-20.9

Notes:
1. Compiled from Pokharel G.R., 2006.
2. Crop quantities presented in the table represent the average quantity produced by sample households.

consists of crops such as rice, maize and wheat that require processing.[82] Assuming that maize, wheat and millet are ground, and husks are removed from rice, using electrical mills rather than manually, the time saved by an average sample household could be as much as 240 hours[83] annually. If electrical mills substitute for traditional *ghattas* (water mills) around 100 hours[84] could be saved annually (Table 19).[85, 86]

The study estimated that the income equivalent of the time saved using electrical mills could reach $37 annually per household. The survey found that women contribute 65 per cent of the time spent on agro-processing activities, and men contribute 35 per cent. Therefore, it is estimated that the use of electrical mills instead of manual agro-processing would save about 155 hours per year for women and 85 hours for men.[87] Time saved can be used to rest or for activities such as education, leisure and production. If the time saved is used for additional income-generating activities, the annual increase in earnings could reach $19 for women and $18 for men, an average of about $37 per household.[88]

More time in the day

The survey results indicated that people with electricity access gain time each morning and evening thanks to electric lighting. On average, people aged 15 years or older in electrified communities save an additional 20 to 30 minutes each day.

Summary of benefits

The study estimated that the monetary value of the benefits from electricity access is about $150 per year for sample rural households, with an additional $912 for households that start a new productive activity. While electricity access generates many development benefits for households, not all could be measured in this study in monetary terms. This study's results include only additional income, reduced expenditures on energy, and the value of avoided GHG emissions. In particular, it was not possible with data available to assess educational or health benefits in monetary terms. However, some of those benefits may be indirectly captured through increased incomes, with better health and education allowing households to increase their income (Table 20).

In estimating the total development benefits presented in Table 20:

- the category 'Additional income from existing activity' estimates income generated by increased productivity and additional time available (and does not include benefits from new productive activities, which are estimated separately);
- net benefits from activities relying on electricity and created after the introduction of an MHS are attributed to electricity access;[89]
- time saved from increased day-time or from reduced time spent on agro-processing activities is not

Table 20. Summary of electricity access benefits valued in monetary terms for sample households and beneficiaries

Benefit category	Estimated development benefit value ($/year/household)	Estimated development benefit value ($/year/beneficiary)[3]
Additional income from existing activity	121	18.6
Reduced energy expenditures	25	3.8
Avoided GHG emissions[1]	4	0.6
Total estimated benefits for a household without new activity	*150*	*23*
Average estimated benefits for a new productive activity[2]	*912*	*140*

Notes:

1. Sale of CERs at $10 per ton of CO_2.
2. Average net benefit for a new activity using hydro electricity power.
3. Average of 6.5 people per household in communities surveyed.

included in the total benefits so as to avoid double-counting (in increased income or new productive activity); and

- benefits from avoided greenhouse gas emissions are taken into account in estimating the total development benefits.

The estimated benefits from electricity access from a micro-hydropower system to a sample rural household amount to about $150 annually for households not developing a new business (or about $23 per household member, given an average of about 6.5 people per household in the communities surveyed). Additional benefits from a new productive activity are estimated to average $912 annually per household (about 140 per beneficiary).[90] For households developing a new activity, the total estimated household benefit would be about $1062 annually, or about $163 per household member.

In addition to monetarily quantifiable benefits, there are other benefits that can be attributed to electricity access. Although available data did not cover all development issues and indicators, the benefits that were quantified for a range of social and environmental benefits suggest a significant association with electricity access. With access to electricity:

- households spend more on education, with electricity contributing to half of the increased investment;
- children are four to five times more likely to attend secondary school;
- girls are 7 to 15 times more likely to go to secondary school;
- there are almost 40 per cent fewer students per primary school teacher;
- the likelihood of consuming kerosene and dry-cell batteries falls by over 80 per cent.

The cumulative development benefits far outweigh the investment costs of a micro-hydropower system. Given the total development benefit of $ 150 per beneficiary and assuming the average household size of 6.5 people and a 15-year lifespan for a micro-hydro system in Nepal, the total over-the-lifespan development benefits would be $345 per beneficiary. This is significantly larger than the average cost of an installed micro-hydropower system, which was $85 per beneficiary for the areas surveyed. If a productive activity is added, the total cost-benefit performance will be even greater.

4

Policy implications and conclusions

Policy implications and conclusions

This chapter provides conclusions and lessons learned for policy makers, development practitioners and aid organizations on the benefits of investing in expanding electricity services to enhance socio-economic growth in rural communities, including acceleration of progress in meeting MDG targets. Nepal's experience with hydropower suggests that the cumulative development benefits of electrification justify the investments made. Community mobilization, capacity development at national as well as local levels, and promotion of productive uses of electricity are critical to successfully implement and scale up such programme. Moreover, this study lends weight to the participation from both public and private sector to scale up Nepal's current installed micro-hydropower capacity of 13.5 MW to the estimated full potential of 150 MW in order to boost the country's progress towards achieving the MDGs. While this study concentrates on micro-hydropower as an entry point for rural development, other clean and renewable energy technologies can provide similar social, economic and environmental benefits.

The following implications emerge from the study.

1. Decentralized energy policy frameworks play a significant role in facilitating the development and scale-up of energy access programmes such as rural electrification schemes in areas where there is a great need to bring vast socio-economic opportunities to the poor.

In Nepal, rural electrification is one of government's priority programmes as it is reflected in its national development plan and poverty reduction strategy. This has played a catalytic role in developing innovative and sustainable policies that bring together various actors including the private sector to further facilitate scaling-up rural electrification programmes.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National power line distribution often bypasses poor and dispersed communities on its way to urban centres.

2. Integration of renewable energy sources such as hydro, solar, and biomass in energy policy frameworks and programmes as a fuel option to expand access to energy services to the poor yields double dividends in terms of achievement of the MDGs and the fight against climate change.

Harnessing and utilization of renewable sources of energy is an integral part of the government's strategy to meet the populations' energy needs in Nepal. The country's rich renewable energy resources offer an opportunity for the government to minimize its dependence on fossil-fuel based technologies while reducing impacts on climate change. Increasing the use of renewable energy for decentralized systems is more appropriate and efficient, particularly in the provision of electricity in remote and rural areas.

Further scaling up of the REDP MHS programme to capture the 150 MW nationwide potential would have an enormous impact on Nepal's development. It would expand electricity access to roughly 6.3 million rural people (about 1.2 million households). This could result in potential cumulative quantifiable benefits of $217 million per year (Table 21). These projected benefits consider only those benefits that were quantified in this study. If other potential benefits of MHS development, such as improved living standards, safety, health, education and others, could be expressed in monetary terms, the total benefits to Nepal's rural population would be even higher. In 2008, only 34 per cent of the rural population in Nepal had access to electricity (UNDP, WHO, 2009). Capturing the full potential of 150 MW of micro-hydropower would greatly increase the number of people and households with electricity access – approximately 15 per cent of the rural population could gain from the associated development and environmental benefits (Table 22).

In addition to the potential impacts of off-grid electricity access on achieving the MDGs, scaling up such interventions can also enhance local capacity to overcome other significant challenges such as climate change. While difficult to quantify, the REDP micro-hydropower programme in Nepal has provided electricity services without adding to greenhouse gas emissions, and also contributed to communities' capacity to adapt to climate change. The REDP programme has helped restore ecosystems by reducing pressures on soils and forests, improving post-harvest processing, allowing for better management of water for drinking and irrigation, and building people's capacity to adapt and respond to climate shocks.

While this study focuses on benefits gained through rural off-grid decentralized electrification programmes as an entry point to development activities in rural Nepal, similar aggregated development benefits can be achieved in other countries and regions. They can transform the lives of millions of rural people while boosting progress towards achieving the MDGs and fighting climate change.

3. Documentation and quantitative estimation of the development benefits of off-grid decentralized rural electrification schemes provide a basis for evaluating the long-term cost-effectiveness of these investments.

As with any other development intervention, illustration of the social, economic, and environmental benefits and impacts of rural electrification programmes presents the much-needed evidence and justification for further financing and investment to scale-up of such programmes.

This study's comparison of villages with and without electricity, and estimates of the value of benefits attributable to electrification, indicate that expanding access to electricity is an excellent, cost-effective entry point for development programmes

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Villagers examine a micro-hydro powerhouse.

Table 21. Estimated value of potential benefits from scaling up the MHS programme in Nepal	
Benefit category	**Benefit value for 1.2 million households ($ million/year)**
Additional income	145
New productive activity (3.4 per cent of households)	37.2
Reduced energy expenditures	30
Avoided GHG emissions[1]	4.8
Total	217

Notes:
1. Sale of CERs at $10 per ton of CO_2

Table 22. Likely impacts of scaling up the REDP MHS project in Nepal		
Area	**MDG**	**Likely impacts**
Poverty	1	About 1.2 million households in rural and remote areas could earn an additional $0.33/day
Education	2	The chance of children entering secondary school increases more than fourfold
Gender	3	The chance of girls entering secondary school increases more than sevenfold
Health	4, 5 & 6	Enhances household sanitation and increases number of health staff available in health centres who can provide more and better quality health services to the population
Environment	7	Reduced pollution due to 80 per cent reduction in kerosene consumption and 85 per cent reduction in use of dry-cell batteries
Global Partnership	8	Increases access to information and communications technologies that can facilitate development of partnerships and dialogue

that aim to improve the livelihoods of rural populations and accelerate MDGs achievement in remote areas. Electricity services allow people in rural areas to earn higher incomes through the use of new equipment for existing agro-processing activities, longer working hours made possible by electric lights, better access to market information and weather forecasts, and new income-generating activities based on access to electricity.

Energy services also bring social benefits to remote villages through access to high-quality lighting, better communications and entertainment equipment, improved education and health services, and reduced time and labour burdens for women.

In many developing countries, particularly where public funding is limited, the high capital costs of expanding the electricity grid to remote rural areas can discourage national governments and their partners from undertaking programmes to provide electricity to remote rural populations. However, this study offers evidence that investing in an off-grid decentralized rural electrification programme can be a successful and cost-effective solution.

Nepal's experience with micro-hydropower systems suggests that the cumulative development benefits of electrification justify the investments made. In the areas selected for this study, the total estimated costs of the MHS programme amounted to

$85 per beneficiary (see Introduction for more details on programme costs). The annual development benefits reached about $23 per beneficiary, with an additional $140 per beneficiary for those who developed a new productive activity (see Table 20).

4. Capacity development is critical to successful scaling up of decentralized rural electrification schemes.

Rural decentralized off-grid electrification based on clean energy technologies is an effective entry point for reducing poverty and promoting sustainable development. But to enhance the development benefits of electrification, micro-hydropower projects should be integrated in a holistic approach to rural development. That requires capacity development at the national level to create the necessary framework and policy environments for scale-up and replication of cost-effective solutions. It also demands an enhanced capacity of local actors and community members to plan, implement, manage and maintain new energy technology systems.

REDP's experience demonstrates that rural electrification schemes and adoption of off-grid energy technologies, particularly in dispersed and geographically challenging environments, requires substantial assistance to provide guidance to national governments, local authorities, private entities, as well as communities and civil society organizations. Capacity development in areas such as developing policy and regulatory frameworks, mobilizing financing, enhancing institutional structures and performance, communications and community mobilization, planning, management, and oversight of the programme are critical parts of energy service delivery to the poor and must be reflected in rural electrification plans and budgets accordingly.

Raising awareness and enhancing the capacity of end-users on various components such as health issues, forest management or skills enhancement to undertake various economic activities or increase productivity is also critical. Women's involvement in local development and new livelihood opportunities

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Electricity services allow people to earn higher incomes through the use of new equipment for agro-processing activities.

will only be possible if their domestic workload is reduced, for example, by reducing the time they spend collecting energy sources. Above all, programmes should inform the population about the negative health effects of using solid fuels for cooking and should promote alternative solutions, such as liquefied petroleum gas (LPG), biogas and improved cooking stoves. Consumer education along with capacity development would then enable people to achieve a greater range of benefits.

5. Scaling-up successful decentralized rural electrification schemes is financially feasible but requires great participation from both the public and private sector.

There are enormous opportunities for scaling up the micro-hydropower programme in Nepal, which would help put the country on a fast track towards achieving the MDGs, and also limiting greenhouse gas emissions. The installed MHS capacity is currently only about 13.5 MW. An earlier study by UNDP and AEPC estimated that the full potential for micro-hydropower in Nepal is about 150 MW, and that it could be installed for about $435 million (Box 10). It also shows that public investment is dominant at the beginning of the programme to build local and national capacities. However, with increasing capacity of local and national level actors, these public investments can attract substantial financing from private sectors, which gradually take over a greater portion of the overall investments.

Box 10. Cost of expanding the MHS programme in Nepal

Between 1996 and 2006, the total cost for the REDP MHS programme (2500 kW installed) – including upfront capacity development costs as well as equipment and other 'hard' costs required to implement and successfully scale up the programme – was in the order of $14.3 million. This is equivalent to about $110 per beneficiary. Reductions in per-unit programme costs over time were driven by progressive declines in capacity development costs, which decreased by 84 per cent between 1996 and 2006. Assuming that costs continue to decline, UNDP and AEPC estimates suggest that scaling up the programme to meet its full potential of 150 MW by 2030 would cost about $435 million. While a large part of the funding has until now been provided from public resources, it is expected that private funding will gradually account for a greater portion of the overall investments, making up to about 60 per cent of future funding needs (UNDP, AEPC, 2010).

6 Promoting income-generating activities using newly available electricity must be a clear priority for boosting economic growth in remote rural areas.

Promoting productive uses of electricity and enhancing the capacity of local actors to establish income-generating activities have proved critical in boosting rural economies by raising people's incomes, and in encouraging greater participation from the private sector, including microfinance and other sources such as carbon financing.

This study demonstrates that the greatest benefits of electricity access go to households that develop a new productive activity. In Kavre district, where the REDP programme has emphasized training on productive activities, about 6 per cent of households have developed an activity compared to only 1.3 per cent in Baglung, where the programme focused more on health and environmental awareness. To enhance development benefits, decentralized off-grid programmes need to strongly emphasize the importance of skills enhancement for productive and income-generating activities. They could, for instance, establish facilities that provide a combination of enterprise development funds as seed capital and business development services to entrepreneurs in newly electrified communities seeking to start up or expand new productive activities.[91] Initiatives promoting local development

▼ Off-grid decentralized rural electrification schemes offer good solutions for improving the livelihoods of millions of people living in remote rural areas.

Practical Action Nepal

and strengthening cross-sectoral collaboration could also support the development of income-generating activities. In parallel, women, vulnerable groups and the very poor should have access to microcredit. While this might not drive industrial development, it will provide impetus to start home businesses, which in the later stages can become medium- to large-size enterprises and enhance the development benefits of electricity access.

7. Local people have the ability to implement and manage rural energy systems for productive applications with appropriate guidance and capacity development, and community mobilization in all areas of organizational development, skills enhancement, capital formation, technology promotion, environment management and vulnerable community empowerment.

The community mobilization process developed by REDP – organizational development, skills enhancement, capital formation, technology promotion, environment management and vulnerable community empowerment – is part of the MHS programme. Unlike many electrification schemes, the programme implemented by REDP has enabled the benefits of electricity access to reach even the poorest households, increasing the development benefits for the whole community. The programme has proven that decentralized off-grid energy systems offer a high level of development benefits and are capable of reaching all people in remote villages. Projects should also work on sustainability by developing ownership among local government bodies, communities and stakeholders.

This assessment confirms that electrification from MHSs, along with community mobilization and capacity development, has many positive impacts on rural development. Although investment costs are relatively high, they are substantially less than the cumulative potential development benefits. Efforts should be strengthened at the national, local, and community level in a collaborative manner between the public, private, and civil society organizations to scale up rural off-grid decentralized electrification as part of the poverty reduction strategies of Nepal and other developing countries with populations without access to electricity in remote rural areas.

Box 11. Harnessing people's potential to develop rural energy systems

The best approach to harnessing people's potential to develop rural energy systems is the provision of self-governing institutional mechanisms for inclusive participation and empowerment based on a decision-making process that is transparent and builds consensus. Community mobilization of community members is key to building their capacity, and motivating and encouraging both men and women to participate equally in the development process. Local people have the ability to implement and manage rural energy systems with appropriate guidance and capacity building. Decentralized institutional frameworks and operational modalities are required for wide scale promotion of rural energy systems (Neupane M., Sharma B., 2006).

▼ Micro-hydro schemes are managed at the community level and benefit all households in a given community.

Practical Action Nepal

5

Annexes

- Annex 1: Overview of methodologies to quantify benefits
- Annex 2: Map of Nepal
- Annex 3: Sample questionnaire – households with electricity access
- Annex 4: Additional statistics on communities surveyed
- Annex 5: Data analysis
- Annex 6: Estimation of consumer surplus
- Annex 7: Linkages between energy and the MDGs
- Annex 8: Findings from inferential analysis
- Annex 9: Findings from regression models analysis
- Annex 10: Estimation of avoided CO_2 emissions in selected sites

Annexes

Annex 1: Overview of methodologies to quantify benefits

Overview of economic methods to value benefits

There are various economic methods to put a value on benefits. Economists generally use three approaches: the human capital approach, revealed preferences and contingent valuation (Hutton and Rehfuess, 2006).

The human capital approach measures the economic value of a person, which can be improved through, for instance, education, better health or increased productivity. This approach uses labour market prices to value changes. For example, better health will result in fewer working days lost and will improve a person's productivity. A gross wage rate is used to value the time of an individual on the labour market, while a shadow wage estimates the time saved from non-paid productive activities, such as subsistence farming or homemaking. The shadow wage can equal the wage that a person could earn in the formal sector or the cost of replacing the person doing the non-paid activity with paid labour using the current market wage for the type of work undertaken.

While this approach is often used in healthcare literature, it is criticized by welfare economists, mainly because it does not reflect changes in individual welfare. Individuals might value not only their wage-earning time, but also the time for the pursuit of other activities along with their quality of life. It does not take account of the declining marginal utility of consumption as income rises. Another issue concerns the sum of individual benefits, which do not reflect the overall impact at the societal level, unless it is a society without unemployment (e.g. increased time saved can easily be used to earn money, a sick person cannot be replaced by another). This approach is hindered by undervaluing people outside the labour force, such as children and retired people.

Revealed preferences are based on economic values derived from human behaviour revealed through observations. This approach uses techniques such as the hedonic pricing method[92], the travel cost method[93], time allocation models or estimation of the consumer surplus. In these techniques, the values of goods or services are measured using prices that can be observed in the marketplace. The strength of these methods is that they value actual consumer choices. It also includes welfare effects in addition to labour market effects.

The consumer surplus is the difference between the price actually paid for a good and the maximum amount that an individual is willing to pay for it. When it includes many individuals, the consumer surplus measures the aggregate benefit that consumers obtain from buying goods in a market (Pindyck and Rubinfeld, 1995). The basic idea of consumer surplus is to attach a monetary value to the change in welfare resulting either from a change in consumption or from a change in prices and budget (Deaton and Muellbauer, 1980). For example, the consumer surplus from switching to electrical lighting is the amount by which the cost for a given amount of lighting using traditional energies (e.g. candles, kerosene) exceeds the cost of supplying the same quantity of lighting electrically. The surplus, or economic benefit, comes from the fact that the initial amount of energy, for which the consumer is willing to pay, is in fact acquired at a lower price.

Contingent valuation methods use hypothetical survey methods to make explicit people's willingness to pay for goods in a hypothetical market. It is referred to as a 'stated preference' method, because people are asked directly to state their value or what they would do and pay, while the 'revealed preference' method observes their actual behaviour. The main weakness of any contingent valuation analysis lies in the variety of biases to which the technique is prone (e.g. strategic bias, starting point bias, hypothetical bias). However, if properly designed, contingent valuation methods provide useful results.

While contingent valuation methods are not used in this study, valuation of electricity benefits implicitly refers to revealed preferences and human capital approaches. Table 23 summarizes the approaches used to value various categories of electricity benefits.

Overview of methods applied in the literature to value monetary benefits

ESMAP's study on electrification benefits in the Philippines (ESMAP, 2002) estimates in monetary terms some electrification development benefits that were not previously measured. Since its publication, there have been other studies of electrification projects, for example by GTZ, WHO and WB/IEG. An overview of the methods applied is presented below.

Time saved

Time saved from household chores, longer days, avoided trips for battery charging, etc. can be valued using the opportunity cost of labour.

Table 23. Overview of approaches applied to value benefits from electrification	
Benefit category	**Approach to valuing benefits**
Income	Human capital (additional/new income)
Expenditures	Revealed preferences (market prices and consumer choices)
Energy consumption	Revealed preferences (market prices and consumer choices)
Time allocation	Human capital (shadow wage)

Notes:
Human capital approaches can also be used to value benefits from electrification on education, health or women's empowerment. However, in this study, benefits could not be valued due to lack of data.

In ESMAP's study of rural electrification in the Philippines, the authors use the average wage estimated from the survey data to value time saved in monetary terms. This assumes that people use the time saved to earn income. In practice, even if work is available (which might not be the case) time saved might be used for non-productive purposes.

WHO suggests that valuing time spent on non-paid productive activities would require the application of a shadow wage. The shadow wage can equal either the wage that a person could earn in the formal sector or the cost of replacing the homemaker with paid labour using the current market wage for the type of work undertaken (Hutton and Rehfuess, 2006).

In a study made on a GTZ's improved cooking stoves project in Uganda, the author suggests applying 50 per cent of the time saved as time used for productive activities. A monetary value, derived from the mean monthly income of a household in the local area, is then assigned to the productive time-period (Habermehl 2007).

WB/IEG underlines that time should be valued at its opportunity cost, which will depend on whose time is being valued. It takes average income per capita as the opportunity cost, rather than the wage, to allow for the distribution of household tasks across all household members. Clearly, a more age- and gender-specific analysis is preferable, but that requires more data (IEG, 2008).

Following those assessments, the current study values time saved at the opportunity cost of labour on the selected areas, differentiating wages for men and women.

Productive uses

In its assessment of rural electrification in the Philippines, ESMAP proposes that increases in productivity might be measured by the market value of the increased output. It estimates the benefits of electricity for a home business by placing a value on the number of additional hours spent conducting the business. This additional time is valued at the average wage in the area. Benefits then have to be adjusted to reflect the proportion of households owning a home business.

To assess new businesses, the authors estimate the difference in the relative number of households running a home business between electrified and non-electrified households. They conclude that electricity has encouraged a certain per cent of households to develop a new business. It then applies the average income from home businesses to the percentage of non-electrified household that are expected to start a new business. However, this does not take into account the local development influences on establishing a new business.

When feasible, the easiest and most cost-effective way to assess impacts is to compare income from similar productive activities with and without electricity. These activities should be in the same village, or at least in areas that have similar access to road, markets, microcredit and have similar standards of living.

In the current study, the lack of businesses not using electricity did not allow to compare productive activities with and without access to electricity. However new businesses were developed after the electricity was introduced and the related average income was estimated.

Access to media and better lighting

Using the World Bank's economic analyses, valuation of some benefits from electrification can be based on consumer's surplus. The consumer surplus represents the benefits received by a household from acquiring energy at a lower price than it was actually willing to pay. Consumer surplus can also be described as the amount by which the cost for a given amount of energy using traditional energy sources exceeds the cost of supplying the same quantity of energy with electricity.

The economic benefit of lighting is the amount by which the cost for a given amount of traditional lighting (e.g. candles, kerosene) exceeds the cost of supplying the same quantity of lighting with electricity (i.e. comparison of prices and quantity of lumen available[94]).

The demand curve for TV or radio is used to calculate the benefits from watching TV or listening to radio. Here, the unit of consumption is hours of television watched or hours spent listening to the radio. In the absence of a grid connection, TVs are operated using car batteries, while dry-cell batteries power radios.

Calculating the consumer surplus depends on the shape of the demand curve. Since a linear demand curve overestimates benefits, it is preferable to use either a non-linear demand curve or to take only a percentage of the surplus estimated with a linear demand curve. Another option is to integrate income elasticities within the demand curve. This has been done by, for example, NORAD (EmCON, 2008), which defines the demand of kWh Q_{kWh} as a function of the price per kWh based on this relationship: $Q_{kWh} = \theta_i \, p^{\mu i} * I^{\alpha i}$ where p is the price per kWh, μ_i and α_i represents the (negative) price elasticity and income elasticity of demand respectively, and θ_i is a constant. That method might be more accurate, but it is more complex and requires data on income that may not always be easy to collect. An alternative suggested by IEG (2008) is to use a log linear demand curve that assumes constant elasticity.

Multiplying the consumer surplus by the number of households with access gives an estimate of the total benefit. Estimating several demand curves linked to the standard of living will allow correction of the limitation of a single demand curve ignoring possible shifts in demand as household income rises.

An attempt has been made in the current study to use the consumer surplus technique suggested by the World Bank to assess benefits from better lighting and increased use of the radio. However, in the surveyed communities, electricity fees are not a function of the quantity of energy consumed, but are based on the power available to households.[95] In addition, it is the whole community that benefits from electricity access and not just the better-off households. For these reasons, benefits estimated from the consumer surplus may not be captured properly (see Annex 6).

Education benefits

In the reviewed literature, only the World Bank's studies have tried to give education benefits a monetary value. Benefits are estimated from higher future earnings coming from higher educational attainment achieved with improved access to electricity. Specifically, incremental earnings are assumed to occur from ages 16 to 60, which are discounted back to their present value. This present value is then converted to a monthly 'annuity' (IEG, 2008).

Data available from the survey describe a specific point in time and do not provide information over a period; therefore they did not allow monetary values of such benefits to be assessed.

Health benefits

According to one GTZ study (Habermehl, 2007), the value of health benefits comes from saved time and reduced costs for health care from health damages (e.g. indoor air pollution). The author estimates the number of working hours recovered due to a reduction in the inability to work, visits to health centres, and nursing time, then assigns a monetary value (shadow wage) to 50 per cent of the time saved due to better health. Saved costs for health are based on the reduced annual costs of health care per household using electricity.

WHO also distinguishes between time and cost savings (Larson and Rosen, 2000):

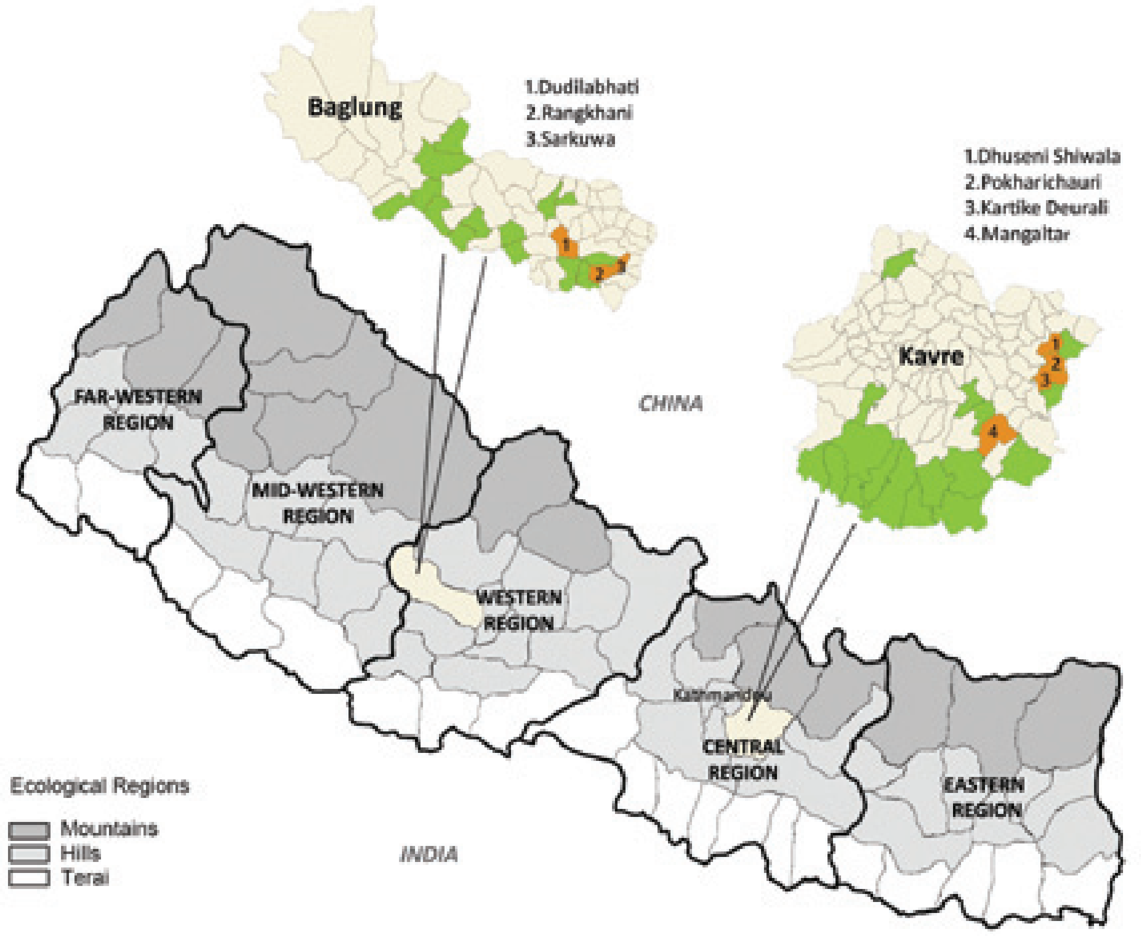
- savings that occur within the health system (costs of consultations and medical treatments);
- savings that occur outside the health system, such as transport to and from health facilities, food and non-medical supplies for the duration of health care; and
- income effects, via annual sickness time avoided.

For IEG (2008), health benefits come from improvements in health facilities, knowledge of health through increased access to media, better nutrition from improved knowledge and access to refrigeration, as well as cleaner indoor air. IEG estimates that the value of reduced mortality as a result of improved indoor air quality from switching from kerosene lamps to electrical lighting has a monthly annuity value of $0.02. It also offers a monetary calculation of the health benefits from improved access to knowledge and corresponding reductions in fertility levels. Knowledge of health and fertility comes from media sources accessed using electricity. It is valued as the cost of reproductive health programmes to achieve reduced levels of fertility. The lower limit of these benefits is placed at $10, equivalent to a monthly annuity of $0.08.

In the current study, data on time saved due to better health, mortality, morbidity or fertility were not available from the survey to quantify health benefits following those approaches. Information on health expenditure was available, however, the analysis showed no significant relationship with electrification.

Annex 2: Map of Nepal

Nepal is divided administratively into 75 districts, which are grouped into five regions. Each district is further divided into Village Development Committees (VDCs). A VDC is the lowest local level administrative unit in the district, and there are more than 3,900 VDCs in the country. Nepal is also split into three ecological regions: mountains, hill and terai.[96]



Map 1 Map of Nepal and areas surveyed

Notes:
1. Based on the map provided in the Demographic Health Survey Report 2006. Green-shaded areas indicate VDCs where REDP is involved (Source: REDP map). Orange-shaded VDCs are those selected for the survey.
2. The boundaries and names shown on this map do not imply official endorsement or acceptance by the United Nations.

The survey selected Baglung and Kabhrepalanchok (also called Kavre) districts. They are located in the Western and the Central Regions of Nepal and are both in hilly zones, where 47 per cent of the population live (Central Bureau of Statistics of Nepal, 2002). The last census in Nepal (2001) indicates a total population of 22.7 million people, distributed in about 4.2 million of households. Baglung and Kavre, with 1.2 and 1.7 per cent of the population respectively, include 53,500 and 70,500 households, of which 4,712 and 2,107 respectively benefit from the MHS.[97]

Annex 3: Sample questionnaire – households with electricity access

Household questionnaire

Electrified

No_______________

NOTES FOR INTERVIEWER:
Only one questionnaire should be filled out per household.
For the last question (on time use), please only interview women and girls. It is recommended that all the men and boys not be in the room when the women and girls are being interviewed.

1. Name of interviewer ___________________________

2. Date of interview ___________________________

3. Village settlement ___________________________

4. Ward ___________________________

5. VDC____

6. District ____________________________________

Interviewee

7. Household family name __________________

8. Name of the interviewee________________

Household information

9. Household members

Name	Relation to household head[1/]	Male/ female	Age	Occupation[2/]	Education[3/]
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					
9.					
10.					
11.					
12.					

1/ Household member:
1. Head of the family 2. Spouse 3. Children 4. Father/mother 5. Other relatives 6. Other

2/ Main occupation:
1. Farmer 2. Livestock raising 3. Artisan/craftsperson 4. Shopkeeper/owner 5. Labourer 6. Enterprise owner
7. Student 8. No activities outside house 9. Others

3/ Education completed:
1. Illiterate 2. Primary school 3. Lower secondary school 4. Higher secondary school 5. University

10. Housing characteristics

Occupancy status[1/]	Number of rooms	Roof type[2/]	Wall type[3/]	House conditions[4/]	Kitchen type[5/]	Toilet facility[6/]	Water supply[7/]

1/ Occupancy status:
1. Owner 2. Renter 3. Rent free 4. Other

2/ Roof type:
1. Straw/ Khar 2. Slate/Tile 3. Galvanized Sheet 4. Concrete 5. Wood and bamboo mat 6. Other

3/ Wall type:
1. Cement bonded bricks/stones and concrete 2. Mud bonded bricks/stones 3. Wood/branches 4. Other

4/ Housing condition:
1. Newly built 2. Old but renovated 3. Old and in poor state 4. Moderate

5/ Kitchen characteristic:
1. Open space in the house 2. Close space in the house 3. In a separated building 4. Outside

6/ Toilet facility:
1. Permanent toilet 2. Temporary toilet 3. No toilet 4. Community toilet

7/ Water supply:
1. Collective place 2. Private well 3. Private pipe outside the house 4. Pipe inside the house
5. Rainwater collection 6. Other

Farming production

11. Land use and ownership

	Farm land irrigated (khet)	Farm land not irrigated (bari)	Grazing land (charan)	Others
Number of ropani				
Ownership1/				

1/ Ownership status:
1. Owned by user 2. Rented/leased by owner 3. User rents/leases 4. Other (please describe)

12. Agricultural production in the last 12 months

Crop	**Quantity produced**	**Quantity sold**	**Income**
Rice paddy			
Maize			
Wheat			
Barley			
Millet			
Potato			
Soybean			
Other_____________			
Other_____________			
Other_____________			

13. Livestock ownership in the last 12 months

Livestock	Number owned	Ownership (man/woman)	Income (sale of meat or milk)
Cow			
Buffalo			
Goat			
Sheep			
Other_____________			
Other_____________			
Other_____________			

Energy

14. Cooking habits

- ❑ Traditional stove
- ❑ Improved stove
- ❑ Open fire place
- ❑ Kerosene / gas stove
- ❑ Gas cooker
- ❑ Other_______________
- ❑ Electricity

15. Heating habits

- ❑ Fuelwood
- ❑ Other _______________
- ❑ Electricity
- ❑ None

16. Lighting habits

Type of lighting	Number	Number of hours use[1/]
1. Bulbs / neon		/ day
2. Candles		/ year
3. Oil lamp		/ year
4. Kerosene lamp		/ year
5. Pine stem (bhari)		/ year
6. Other _______________		/ year
7. Other _______________		/ year
8. Other _______________		/ year

1/ If there are several items of the same category (candles, kerosene lamps), add the number of hours for each.

17. Electric equipment at home

	Number of hours use / day[1/]	Equipment power (W)	Energy source[2/]
1. Low consumption bulbs			
2. Incandescent bulbs			
3. Neon tube			
4. Radio / Hi-fi / Cassette			
5. Tape player			
6. TV			
7. Video tape/DVD			
8. Refrigerator			
9. Fan			
10. Rice cooker			
11. Electrical cooker			
12. Water pump			
13. Other _______________			
14. Other _______________			
15. Other _______________			

1/ If there are several equipments of the same category (bulbs, radios), add the number of hours for each equipment
2/ Energy sources:
1. Electricity 2. Dry cell batteries 3. Lead acid battery 4. Solar battery 5. Other (please describe)

18. Sources of energy:

Energy sources	Quantity / months	Expenses / month (Rs)	Use(s) 1/
1. Electricity (kWh)			
2. Solar home system (Pick Watts)			
3. Kerosene (ltr)			
4. Candles (no.)			
5. Dry cell batteries (number)			
6. Lead acid battery (no. of recharge)			
7. LPG (cylinder)			
8. Biogas (m3)			
9. Charcoal (pack)			
10. Fuelwood (bhari)			
11. Agricultural wastes, dung, etc. (bhari)			
12. Other ______________________			
13. Other ______________________			
14. Other ______________________			

1/ Indicate more than one type of use where there are multiple uses for each type of energy source.
Use(s):
1. Lighting 2. Cooking 3. Space heating and cooling 4. Water boiling 5. Radio/Hifi/Cassette
6. TV/DVD/Video 7. Others

Education

19. Education for all children between 4 and 16 years of age

Name of child	Boy (B) / Girl (G)	School enrolment 1/	Grade level (last year completed)	Number of school days missed (over the last month)

1/ School enrolment:
1. Never attended school 2. Attended school in the past 3. Currently attending school

Health

20. Household members' health

Name of household member										
Woman (W), Man (M), Girl (G), Boy (B)[1/]										
a. Total number of days where the following symptoms occurred during the last month:										
Blackening of nose and itching of eyes caused by traditional lamps										
Burns caused by traditional lamps										
Injuries due to grinding, milling and hulling										
Injuries due to electricity										
b. Total number of school/work day missed in the last month due to:										
Blackening of nose and itching of eyes caused by traditional lamps										
Burns caused by traditional lamps										
Injuries due to grinding, milling and hulling										
Injuries due to electricity										

1/ Boy or girl refers to child under the age of 15 years.

Household expenditures and income

21. Household expenditures

a. Average monthly expenditures: |__|__|__|__|__|__| Rs

b. Detailed expenditures	Rs	Frequency[1/]
1. School expenses (registration, educational stationery, clothes…)		
2. Health expenses (visit to the health centre/doctor, medicine…)		
3. Household electrical equipments (radio, TV…)		

1/ Frequency:
1. Day 2. Week 3. Two weeks 4. Month 5. Two months 6. Three months 7. Six months 8. Annual

22. Household income over the last 12 months

a. Income from seasonal labour: |__|__|__|__|__|__| Rs
b. Income from activities using electrical equipments: |__|__|__|__|__|__| Rs
c. Income from activities realized at home after daylight hours: |__|__|__|__|__|__| Rs
d. Income from other sources: |__|__|__|__|__|__| Rs

Remarks

Time use

23. Household members time use

	Average time use for household members																	
Name of household member																		
Woman (W) / Man (M) / Girl (G) / Boy (B)																		
Number of hours / day (H)																		
Frequency (F)[3/]																		
1. Cleaning / washing																		
2. Cooking																		
3. Fetching water																		
4. Fetching fuelwood																		
5. Fetching fodder, agricultural waste, dung, etc.																		
6.Watching TV / DVD (movies/ divertissement)																		
7.Watching TV																		
(information/news)																		
8.Watching TV (documentary / educational programs)																		
9. Reading																		
10. Doing school homework																		

Average time use for household members																		
Name of household member																		
Woman (W) / Man (M) / Girl (G) / Boy (B)																		
Number of hours / day (H)																		
Frequency (F)[3/]																		
11. Receive visitors																		
12. Grinding																		
13. Milling																		
14. Hulling																		
15. Oil pressing																		
16. Bitten rice making																		
17. Irrigation																		
18. Other income generating activities																		
19. Other________________																		
9. Reading																		
Average night hours routine																		
20.Bed time in the evening																		
21.Rising time in the morning																		

3/ Frequency:
1. Every day 2. Twice a week 3. Week 4. Two weeks 5. Month 6. Two months 7. Three months 8. Six months 9. Annual

Annex 4: Additional statistics on communities surveyed

MDG 1 related additional statistics

Income

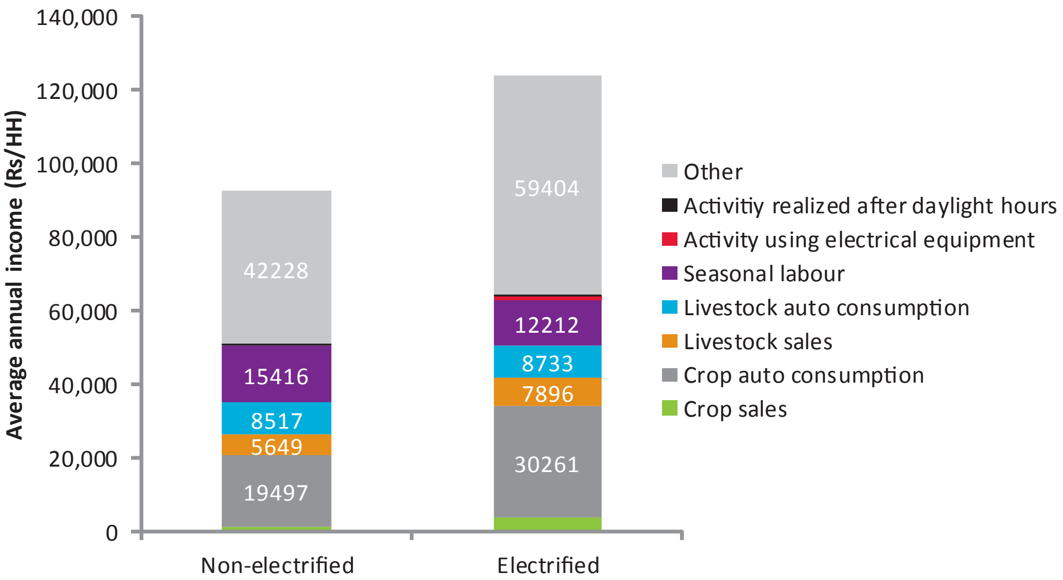


Figure 23. Average annual income by source of revenue (Rs)

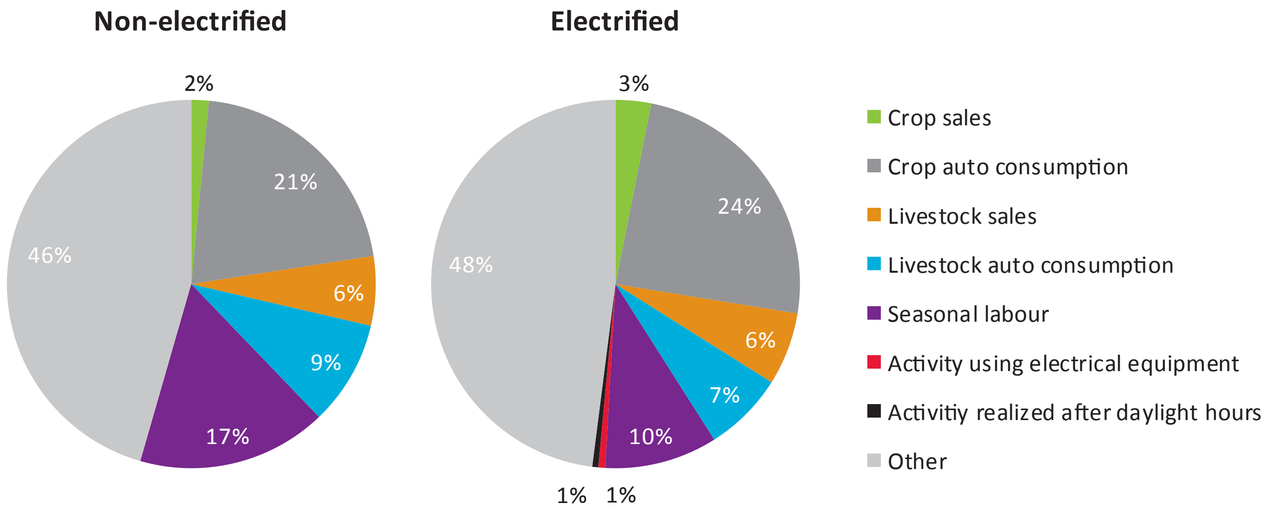


Figure 24. Distribution of annual income by source of revenue (Rs)

Time spent on income-generating activities

Table 24. Average time spent on activities generating income for men and women

Gender	Electricity	All people (hours)	People involved (%)	People involved (hours)
Men	No	6.2	11	55.3
	Yes	5.0	8.5	58.9
Women	No	1.0	3	34.8
	Yes	1.3	3	46.9

Agricultural assets

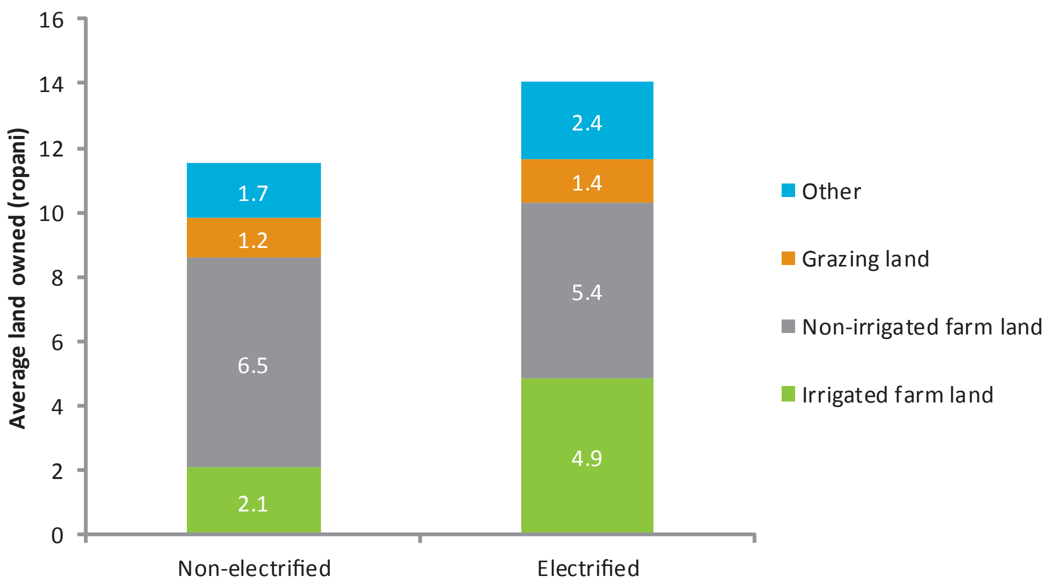


Figure 25. Land use in electrified and non-electrified households

Table 25. Average livestock owned per household at the time of the survey, by surveyed area

District	Electricity	Cow	Buffalo	Goat	Sheep	Pig	Hen	Ox
Baglung	No	0.3	1.7	1.5	0.0	0.2	2.2	0.2
	Yes	0.4	1.4	1.2	0.2	0.1	3.0	0.3
Kavre	No	0.8	1.3	3.8	0.0	0.0	2.5	0.2
	Yes	0.7	1.6	4.9	0.0	0.0	3.1	0.3

Energy expenditures

Table 26. Electricity access and average energy expenditures by type of energy and area surveyed (Rs/month)

District	Electricity access	Electricity	Kerosene	Candles	Dry-cell batteries	LPG	Biogas	Charcoal	Fuelwood
Baglung	No	0	168	19	44	0	0	4	12
	Yes	77	66	15	23	27	4	0	136
Kavre	No	0	221	0	83	8	0	22	98
	Yes	56	18	2	8	0	0	21	184

Notes:
Electricity expenses are not a function of electricity consumption in kWh, but a lump sum defined locally according to service used in households. Official local rates for the selected VDCs are:

- in Dudilabhati Rs10/month per 15W bulb;
- in Sarkuwa Rs90/month per 100W bulb;
- in Rangkhani Rs60/month per 100W bulb;
- in Mangaltar, Rs10/month per 25W bulb use;
- in Pokahrichauri, Rs75/month per 100W bulb use;
- in Kartike Deurali, Rs 40/month per 50W bulb use for households using CFL, Rs75/month per 100W bulb use for households using CFL and Rs60/month per 50W bulb use for households not using CFL.

In reality, however, households owned different type of bulbs and it is difficult to link those rates to the price households said they paid.

Table 27. Average energy expenditures by type of energy used and area surveyed (Rs/month)*

District	VDC	Electricity	Kerosene	Candles	Dry-cell batteries	LPG	Biogas	Charcoal	Fuelwood
Baglung	Dudilabhati	107 (53)	164 (66)	47 (48)	67 (46)	471 (9)	(0)	300 (1)	444 (18)
	Rangkhani	44 (51)	131 (84)	67 (11)	50 (16)	(0)	(0)	150 (1)	488 (7)
	Sarkuwa	75 (52)	173 (73)	54 (38)	89 (59)	(0)	500 (1.2)	(0)	380 (31)
Kavre	Dhusene Shiviliya/ Pokahrichauri	75 (50)	187 (80)	10 (6)	100 (52)	(0)	50 (0.9)	1084 (3)	323 (60)
	Kartike Deurali	52 (50)	212 (50)	5 (1)	77 (48)	(0)	(0)	1135 (3)	390 (39)
	Mangaltar	38 (50)	249 (40)	11 (15)	85 (54)	1200 (1)	(0)	(0)	325 (21)

* Figures in parentheses represent the per cent of household using that energy source.
Note: Electricity expenses are not function of electricity consumption in kWh, but are a lump sum defined locally according to the services used by households. Official local rates for the selected VDC are detailed in Table 26, above.

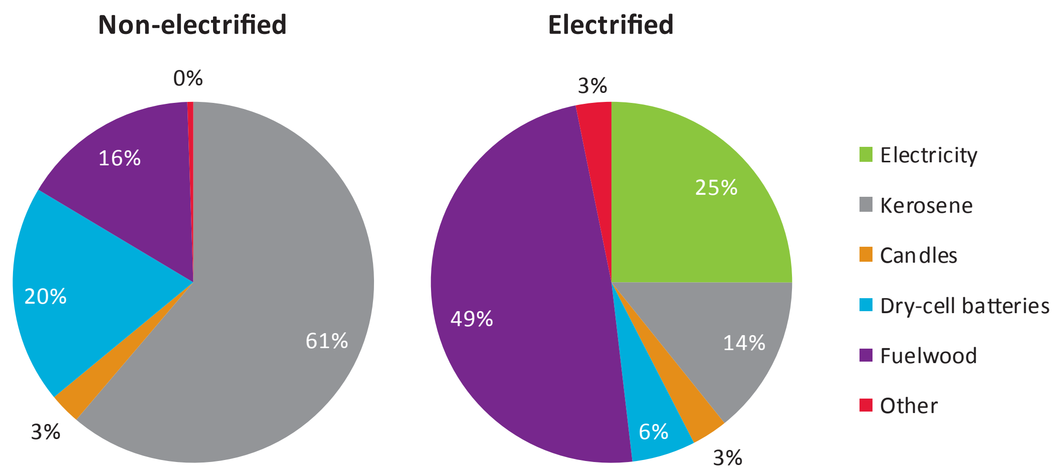


Figure 26. Distribution of energy expenditures in non-electrified and electrified sample households

MDG 2 and 3 related additional statistics

Number of staff teaching in schools

Table 28. Average number of students per school staff by district and types of school

Type of school	District	Electrified area	Number of students per teacher	Number of students per school staff
Primary school	Baglung	No	30.0	27.1
		Yes	20.0	18.5
	Kavre	No	32.9	26.4
		Yes	22.0	17.2
Secondary school	Baglung	No	-	-
		Yes	34.7	31.6
	Kavre	No	38.4	35.6
		Yes	41.1	37.8

School enrolment and attendance rates

Table 29. Average school enrolment per household for girls and boys aged between 4 and 16

Gender	Electricity	School enrolment per household (% of children)			Number of school days missed[1]
		Currently attending	Attended in the past	Never attended	
Girls	No	59.3	33.9	6.4	0.6
	Yes	61.9	34.0	4.1	0.4
Boys	No	56.4	35.3	7.4	0.6
	Yes	58.2	36.4	4.9	0.5

Notes:
1. Average per child over the preceding month.

Time spent on activities

Table 30. Average time spent on educative activities, by gender (hours/week)

Gender	Electricity	Reading	Doing homework	Watching TV	
				Educational / documentaries	Information/ news
Boys	No	5.7	5.5	0.0	0.0
	Yes	6.7	5.8	0.3	0.6
Girls	No	6.3	5.0	0.0	0.0
	Yes	5.8	5.7	0.3	0.6

Table 31. Average time spent on leisure activities, by gender						
Gender	Electricity	Reading (hours/week)	Receiving visitors (hours/month)	Watching TV (hours/week)		
				Movies/entertainment	Educational / documentary	Information/news
Boys	No	5.7	0.5	0.0	0.0	0.0
	Yes	6.7	0.1	1.7	0.3	0.6
Girls	No	6.3	0.2	0.0	0.0	0.0
	Yes	5.8	0.2	2.2	0.3	0.6
Men	No	2.5	4.3	0.2	0.1	0.1
	Yes	3.1	6.6	2.6	0.8	1.3
Women	No	2.4	5.9	0.0	0.0	0.1
	Yes	2.8	7.4	2.6	0.6	1.0

Notes:
1 Boys and girls include people up to 15 years old.

Table 32. Electricity access and average time spent on cleaning and cooking, by gender (hours per week)			
Gender	Electricity	Cleaning	Cooking
Boys	No	0.3	0.2
	Yes	0.6	0.1
Girls	No	0.5	0.6
	Yes	0.8	0.5
Men	No	1.7	0.8
	Yes	1.8	0.6
Women	No	5.9	9.0
	Yes	6.5	8.5

Notes:
1 Boys and girls include people up to 15 years old.

MDG 4, 5 and 6 related additional statistics

Table 33. Health centres' statistics							
Type of health centre	Electrified area	Electrified health centre	Coverage (no. of people)	No. of visitors during the last 12 months	Average no. of visits/people	No. of people/health worker	No. of people/staff
Health post	No	No	19,504	17,746	0.9	6,774	3,221
		Yes	-	-	-	-	-
	Yes	No	3,500	2,800	0.8	1,167	875
		Yes	4,646	7,666	1.7	929	422
Sub health post	No	No	4,715	1,872	0.4	1,572	1,179
		Yes	-	-	-	-	-
	Yes	No	-	-	-	-	-
		Yes	5,011	3,198	0.7	1,670	1,021

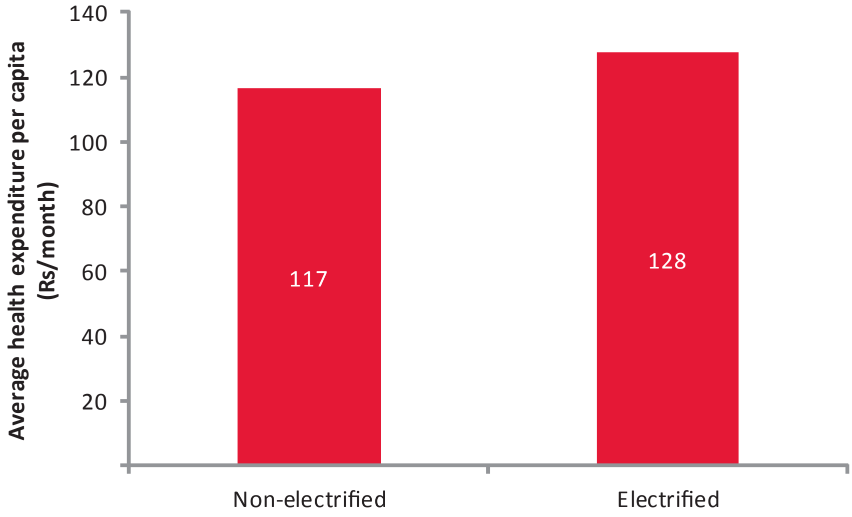


Figure 27. Average health expenditures per capita (Rs/month)

MDG 7 related additional statistics

Table 34. Kerosene, fuelwood and dry-cell batteries consumption in areas surveyed

District	Electricity access	Litres of kerosene consumed per month	Number of dry-cell batteries used per month	*Bhari* of fuelwood consumed per month
Baglung	No	1.9	2.3	10.1
	Yes	0.9	1.4	10.7
Kavre	No	2.3	4.1	7.6
	Yes	0.2	0.5	7.5

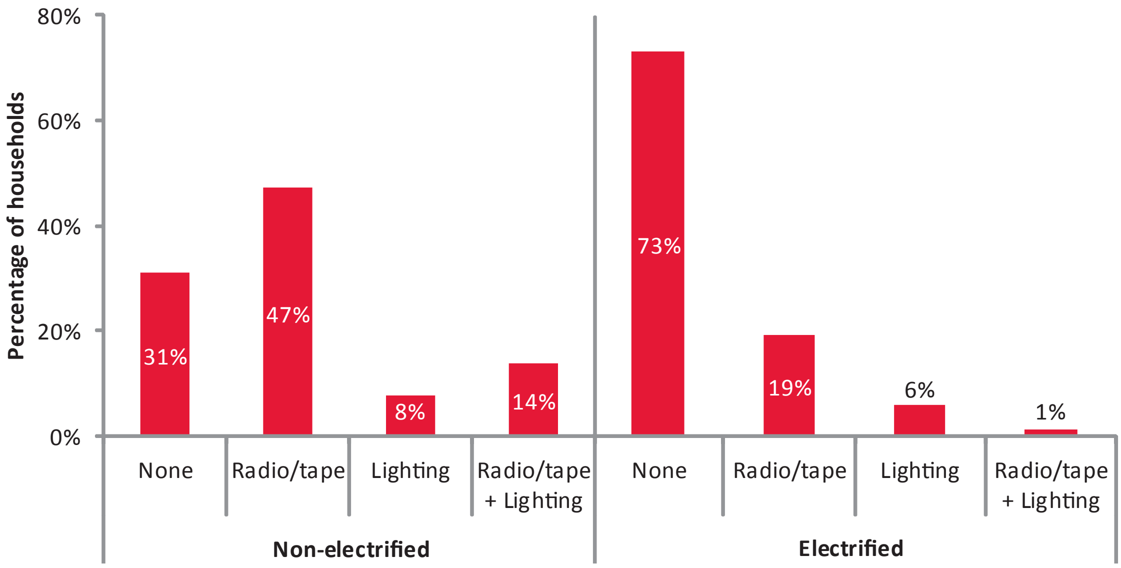


Figure 28. Use of dry-cell batteries

Annex 5: Data analysis

Inferential analysis

Inferential statistics are used to test hypotheses[98] and verify whether the data are consistent with the research prediction. The formal statistical procedure for performing a hypothesis test is to state two hypotheses and to use an appropriate statistical test to reject one and therefore accept the other. The two hypotheses are generally described as the *null hypothesis* (also called H_0) and the alternative hypothesis (also called H_1).

Various statistical techniques are available for this type of analysis. In this study, the analysis is based on[99]:

(i) the *chi-square* method that tests the association between the variable 'having/not having access to electricity' and other variables; and

(ii) the *t-test* to compare the mean of quantitative development indicators with the variable 'having/not having access to electricity'.[100]

Although such tests do not provide information on the magnitude of relationships, they provide information on the significance of association or difference among the variables.[101] Therefore, by identifying the existence of an association or difference between 'having/not having access to electricity' and other factors, they facilitate the selection of relevant indicators for further analysis.

Regression models

Descriptive statistics are not always sufficient to quantify rural electrification benefits. Indeed, the effects of other development factors that could also have contributed to the observable impacts need to be separated. In such cases, econometric tools such as regression models enable us to distinguish between the benefits accrued from access to electricity and the effect of other socio-economic factors such as level of education, income and geographical location.

Regression models test whether a given variable has an effect on another variable in situations where there may be many related variables. It is a collective term for techniques that model and analyse numerical data consisting of a dependent variable and of one or more independent variables. In this study, electricity access (an independent variable) is tested to understand its impact on development indicators (the dependent variables), knowing that many other factors might influence development. The dependent variables are modelled as a function of the independent variables, corresponding parameters and an error term. Although all appropriate independent indicators have been tested in the models developed in this study, they do not all appear in the findings because relationships with the dependent indicator were not statistically significant for many, or they were correlated to other independent variables. Different types of regression, such as linear regression or multinomial logistic regression, are used. The choice of the model is made according to the nature of the dependent variable: Linear regressions are used when dependant variables are quantitative and multinomial logistic regressions are used when they are qualitative.

How to select statistical tests

To select the right statistical test, two questions have to be answered: what kind of data are available and what are the objectives. According to the number and the type of the data (whether it is continuous, ordinal or categorical variable, and whether it is normally distributed) and the goal of the analysis (for example describe one group, compare two groups, predict values, quantify association…) a specific test is most adapted.

For example to measure a variable with a normal distribution (Gaussian distribution) parametric tests such as t test, ANOVA, Pearson correlation, linear or nonlinear regressions have to be applied. But in the case of non-normal distribution tests such as Wilcoxon test, Mann-Whitney test, Krustal-Wallis test, Friedman test, Spearman correlation, nonparametric regression have to be used.

Table 35 presents what test is most adapted according to the number and type of dependent and independent variables and the measure to be performed.

Table 35. Choosing the correct statistical test

Number of dependent variables	Number of independent variables	Type of dependent variable(s)	Type of Independent Variable(s)	Measure	Test(s)
1	0 (1 population)	continuous normal	not applicable (none)	mean	one-sample t-test
		continuous non-normal		median	one-sample median
		categorical		proportions	Chi Square goodness-of-fit, binomial test
	1 (2 independent populations)	normal	2 categories	mean	2 independent sample t-test
		non-normal		medians	Mann Whitney, Wilcoxon rank sum test
		categorical		proportions	Chi square test, Fisher's Exact test
	0 (1 population measured twice) or 1 (2 matched populations)	normal	not applicable/ categorical	means	paired t-test
		non-normal		medians	Wilcoxon signed ranks test
		categorical		proportions	McNemar, Chi-square test
	1 (3 or more populations)	normal	categorical	means	one-way ANOVA
		non-normal		medians	Kruskal Wallis
		categorical		proportions	Chi square test
	2 or more (e.g., 2-way ANOVA)	normal	categorical	means	factorial ANOVA
		non-normal		medians	Friedman test
		categorical		proportions	log-linear, logistic regression
	0 (1 population measured 3 or more times)	normal	not applicable	means	repeated measures ANOVA
	1	normal	continuous		correlation simple linear regression
					non-parametric correlation
		non-normal	categorical or continuous		logistic regression
		categorical	continuous		discriminant analysis
	2 or more	normal	continuous		multiple linear regression
		non-normal			
		categorical			logistic regression
		normal	mixed categorical and continuous		analysis of Covariance multiple linear regression
		non-normal			
		categorical			logistic regression
2	2 or more	normal	categorical		Manova
2 or more	2 or more	normal	continuous		multivariate multiple linear regression
2 sets of 2 or more	0	normal	not applicable		canonical correlation
2 or more	0	normal	not applicable		factor analysis

Adapted from James D. Leeper, Multivariate Methods in Health Statistics, 2007. Choosing the Correct Statistical Test.
Note: Heavier shadded areas correspond to the cases found in this study.

Annex 6: Estimation of consumer surplus

Estimation of the consumer surplus has to be taken with caution, because pricing schemes in the survey areas are linked to the number and power of bulbs owned by households rather than to the number of kWh consumed. Therefore, a house using lights for several hours a day, for example, will pay the same amount of money as one using lights for just one hour. Moreover, for households using electricity, the time spent listening to the radio is also independent of the price paid (which is not the case for people using dry-cell batteries).

Despite these issues, an attempt has been made to estimate a typical consumer surplus for lighting and radio/tape listening in the selected areas. Estimations of the consumer surplus associated with television use could not be made, because households without electricity do not use traditional energy resources to power their TV.

Lighting

The different steps used to estimate the average consumer surplus are described below, first for electrified households and then for non-electrified households.

Estimations for electrified households

1. Estimation of an average price (Rs) per kWh: on average, electrified households spend about Rs4.50 ($0.06) per kWh consumed.[102]

2. Estimation of kWh consumed for electric lighting: on average, electrified households consume 34 kWh per month for lighting.[103]

3. Estimation of lumen generated by electric lighting[104]: on average, 463 kilo lumens are generated by electric lighting per household each month.[105]

4. Estimation of lumens generated by traditional lighting in electrified households: on average 550 lumens are generated from candles and kerosene lamps per month in electrified households.

5. Estimation of price paid for traditional lighting (candles and kerosene): about Rs50 ($0.67) per household per month.

Estimations for non-electrified households

1. On average, non-electrified households spend Rs206 ($2.75) per month for candles and kerosene.

2. On average, 6,610 lumens are generated per month from traditional lighting from candles and kerosene.

Following IEG's suggestion,[106] a non-linear demand (with constant elasticity) is assumed to estimate the consumer surplus:

Consumer's surplus = $Qt*(Pt-Pe) + K/(\eta+1)*(Q_e^{\eta+1}-Q_t^{\eta+1})-(Q_e - Q_t)*Pe$

With $\eta = (\ln(P_t)-\ln(P_e)) / (\ln(Q_t) - \ln(Q_e))$ and $K = P / Q^\eta$

Average estimations from the survey data are:

P_e = 203 Rs Q_e = 463.5 kilolumens

P_t = 206 Rs Q_t = 6.6 kilolumens

Therefore, the average surplus for a household with access to electricity and electric lights is about Rs320 per month ($4.60).[107] For comparison, lighting benefits for households have been estimated at $5.60 per month in the Lao PDR and $7.60 in the Philippines (IEG, 2008).

Radio listening

The steps used to estimate the average consumer surplus are described below.

Estimations for electrified households

1. Estimation of an average price (Rs) per kWh: on average, electrified households spend about Rs4.50 per kWh consumed.

2. Estimation of kWh consumed for listening to the radio and tape player: on average electrified households with a radio consume 1.5 kWh per month to listen to the radio, and those with a tape player consume 1.6 kWh.

3. Estimation of the price paid to listen to the radio and the tape player: electricity cost around Rs14 per month. In addition, some households still use dry-cell batteries with an average cost of Rs15.50 per month.

4. Estimation of hours of listening: on average, households with a radio and/or a tape player spend about 3.8 hours per day, or 115 hours per month, listening to the radio and/or tapes.

Estimations for non-electrified households

1. On average, non-electrified households spend Rs53 per month to buy dry-cell batteries for the radio and the tape player.
2. On average, non-electrified households with a radio and/or a tape player spend about three hours per day, or 94 hours per month, listening to the radio and/or tapes.

Assuming a non-linear demand to estimate the consumer's surplus, the equation is:

Consumer surplus = $Qt*(P_t-P_e) + K/(\eta+1)*(Q_e^{\eta+1}-Q_t^{\eta+1})-(Q_e-Q_t)*P_e$

With $\eta = (\ln(P_t)-\ln(P_e)) / (\ln(Q_t) - \ln(Q_e))$ and $K = P / Q^{\eta}$

Average estimations from the survey data are the following:

P_e = 29.5 Rs $\quad$ Q_e = 115 hours

P_t = 53 Rs $\quad$ Q_t = 94 hours

Therefore, for a household that listens to the radio and/or tape player, the average surplus gained from access to electricity is about Rs2,420 per month (or about $34.60). For comparison, radio and TV benefits for households have been estimated at $15.10 per month in the Philippines (IEG, 2008). The high estimation found in this report might be explained by the fact that electricity bills paid by households in the survey areas are not linked to the time spent listening to the radio. The surplus from using televisions with electricity is not estimated, because people without electricity do not have televisions.

Annex 7: Linkages between energy and the MDGs

Table 36. Linkages between energy and the MDGs

MDG goal and targets[1]	Role of energy[2]
1. Eradicate extreme poverty and hunger *Target 1A*: Halve, between 1990 and 2015, the proportion of people whose income is less than a dollar a day *Target 1B*: Achieve full and productive employment and decent work for all, including women and young people *Target 1C*: Halve, between 1990 and 2015, the proportion of people who suffer from hunger	• Electrical lighting extends daylight hours and time spent on income-generating activities; • Access to electricity facilitates economic development of micro-enterprises, livelihood activities, locally-owned businesses that create employment, and others; and assists in reducing extreme poverty; • Electricity for irrigation (through electric water pumps) improves food production; • Electricity can be used to pump underground water and cook food (95 per cent of staple foods require cooking), thus reducing hunger and improving access to safe drinking water; • Electricity makes post-harvest processing easier for home consumption and for generating surpluses.
2. Achieve universal primary education *Target 2A*: Ensure that, by 2015, all boys and girls will be able to complete a full course of primary schooling	• Using electricity can reduce the time spent by school-going children (especially girls) on household chores; • Lighting permits home study, increases security, and allows educational media and communication to be used in schools; • Electricity at home enables distance learning; • Access to modern energy helps retain teachers in remote villages.
3. Promote gender equality and empower women *Target 3A*: Eliminate gender disparity in primary and secondary education preferably by 2005, and in all levels of education no later than 2015	• Time saved by women and girls on household chores can be used for education or income-generating activities; • Electric cooking equipment reduces exposure to indoor air pollution and improves the health of girls and women; • Street lights improve women's safety.
4. Reduce child mortality *Target 4A*: Reduce by two thirds, between 1990 and 2015, the under-five mortality rate	• Electricity is a key component of a functional health system, contributing, for example, to lighting operating theatres, refrigerating vaccines and other life-saving drugs, and sterilizing equipment; • Use of electricity for lighting, cooking and heating reduces the indoor air pollution that contributes to respiratory infections; • Provision of nutritious cooked food, space heating and boiled water contributes to better health; • Electricity enables water to be pumped and purified; • Access to electricity helps retain medical staff in remote
5. Improve maternal health *Target 5A*: Reduce by three quarters the maternal mortality ratio *Target 5B*: Achieve, by 2015, universal access to reproductive health	• In addition to its core role in the health system, modern energy can have an important impact on maternal mortality by reducing indoor air pollution; • Access to electricity help retain medical staff in remote villages; • Electricity improves medical facilities for maternal care using modern systems; • Electricity used for lighting, cooking and heating will reduce excessive household workload and heavy manual labour (carrying heavy loads of fuelwood and water); • Access to educational programmes on TV can inform women about reproductive health.
6. Combat HIV/AIDS, malaria, and other diseases *Target 6A*: Have halted by 2015 and begun to reverse the spread of HIV/AIDS *Target 6B*: Achieve, by 2010, universal access to treatment for HIV/AIDS for all those who need it *Target 6C*: Have halted by 2015 and begun to reverse the incidence of malaria and other major diseases	• Access to educational programmes on TV/radio can promote awareness of measures to prevent HIV/AIDS, malaria and other diseases; • Electricity for communications and medical equipment improves blood donation systems, reuse facilities, distribution systems and communications systems using ICTs; it also allows facilities to sterilize, refrigerate and store vaccines; • Access to electricity helps to retain medical staff in remote villages.

Table 36. Linkages between energy and the MDGs

7. Ensure environmental stability *Target 7A*: Integrate the principles of sustainable development into country policies and programmes; reverse loss of environmental resources *Target 7B*: Reduce biodiversity loss, achieving, by 2010, a significant reduction in the rate of loss *Target 7C*: Halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation *Target 7D*: Achieve significant improvement in lives of at least 100 million slum dwellers, by 2020	• Traditional fuel use contributes to erosion, deforestation and desertification, reduces soil fertility; • Use of clean and renewable electricity alleviates the burden on the local environment and reduces greenhouse gas emissions; • Use of electricity improves energy efficiency; • Electricity can be used to purify water or pump clean ground water locally.
8. Develop a global partnership for development *Target 8F*: In cooperation with the private sector, make available benefits of new technologies, especially information and communications	• Access to electricity is a prerequisite for access to new technologies, especially information and communications.

Note:
1. Millennium Development Goals, official website of UNDP (http://www.undp.org/mdg/).
2. Based on Modi V., McDade, S., Lallement D. and Saghir J., 2006 and GNESD, 2007.

Annex 8: Findings from inferential analysis

Inferential analysis allows us to determine if a relationship exists between selected indicators and electricity access. When an association exists, tests on the means' difference indicate whether the difference is significant and how it is expressed between households or people with and without electricity access. The relationships observed are associational and not necessarily causal in nature.

MDG 1 related indicators

The chi-square test analysis[108] found an association between electricity access and income levels, agricultural production, and expenditures on energy (Table 37). However, there is no significant association between the time spent on income generation activities and the availability of electricity.

The independent sample t-test compares the mean of indicators for people living in electrified and non-electrified households.[109] Table 38 shows that:

- electrified households are better off than non-electrified households in terms of total income;
- electrified households produce more crops than non-electrified households; and
- electrified households spend less on energy than non-electrified households.

Table 37. Tests of association for indicators related to MDG1

Indicator	Distribution	Electricity access		N	Chi-square	p value
		No	Yes			
Total income (Rs/year, thousands)	<30	25	18	43	20.281	0.009*
	30-60	70	50	120		
	60-90	63	59	122		
	90-120	44	52	96		
	120-150	25	39	64		
	150-180	12	19	31		
	180-210	5	13	18		
	210-300	11	17	28		
	>=300	5	17	22		
Agricultural production (kg/year)	<=1,000	79	49	128	36.879	0.000*
	1,000-2,000	126	102	228		
	2,000-3,000	54	70	124		
	>3,000	20	67	87		
Energy expenditures (Rs/month)	<= 150	60	133	193	49.272	0.000*
	150 – 300	85	55	140		
	300 – 450	77	36	113		
	> 450	58	66	124		

Table 38. Tests of difference for indicators related to MDG 1					
Indicator	Electricity access	N	Mean	t-test	p value
Total income (Rs / year)[1]	No	259	90,964	3.9	0.000*
	Yes	279	114,767		
Agricultural production (kg/year)[2]	No	279	1,563	6.414	0.000*
	Yes	288	2,348		
Energy expenditures (Rs/month)[3]	No	276	265	11.842	0.000*
	Yes	287	135		

* The p-value is < 0.05 therefore the result is significant.

Notes:

1. Incomes higher than Rs450,000 are considered as extreme values and excluded from the analysis.
2. Values higher than 15,000 kg are considered as extreme values and therefore not included in the analysis.
3. Energy expenditures exclude fuelwood expenses. Values higher than Rs700 are extreme and therefore have been excluded from the analysis.

MDG 2 related indicators

The chi-square test analysis[110] confirms an association between electricity access and the following education indicators:

- school grade level of children aged 6 to 16;
- school enrolment of children aged 6 to 16;
- number of school days missed by children aged 6 to 16;
- time spent on doing homework by children aged 6 to 16;
- time spent on reading by people older than 6 years old;
- time spent watching educational programmes on TV by people older than 6 years old; and
- school expenditures.

The independent sample t-test compares the averages of indicators for people living in electrified and non-electrified households (Table 40):[111]

- children between 6 and 16 years old living in electrified households reach higher school grade levels compared to children living in non-electrified households;
- children aged 6 to 16 living in electrified households miss fewer school days than children in non-electrified households;
- children living in electrified households spend more time doing homework than children living in non-electrified households;
- people older than 6 years and living in electrified households spend more time watching educational programmes on TV than people living in non-electrified households;
- primary schools in electrified areas have fewer students per teacher than primary schools in non-electrified areas; and
- electrified households spend more on education than non-electrified households.

While the average difference in time spent reading by people older than six years of age is not significant between people with and without electricity access, a difference is observed when only readers are taken into account. This means that electricity does not encourage people that did not read previously to start reading, but it does allow people with established reading habits to spend more time reading.

MDG 3 related indicators

The chi-square test analysis[112] found a significant association between electricity access and the following women's empowerment indicators:

- the school grade level of girls aged 6 to 16;
- the number of school days missed by girls aged 6 to 16; and

Table 39. Tests of association for indicators related to MDG 2						
Indicator	Distribution	Electricity access		N[3]	Chi-square	p value
		No	Yes			
School grade level[1]	0-1	96	86	182	18.488	0.001*
	2-3	98	81	179		
	4-5	80	74	154		
	6-7	47	78	125		
	8+	16	38	54		
School enrolment[1]	Never attended school	16	4	20	7.887	0.019*
	Attended school in the past	166	176	342		
	Currently attending school	255	275	530		
Number of school days missed per child[1] during the last month	0	331	381	712	11.508	0.003*
	1-2	63	50	113		
	>= 3	43	22	65		
Time spent doing homework[1] (hours/week)	=< 5	135	119	254	10.471	0.015*
	5 – 10	220	222	442		
	10 – 15	69	80	149		
	> 15	14	35	49		
Time spent reading[2]	0	946	1,164	2,110	9.760	0.021*
	< 7	238	257	495		
	7 – 15	121	126	247		
	> 15	92	156	248		
Time spent watching educational programmes on TV[2] (hours/week)	0	1,419	1,517	2,936	177.108	0.000*
	< 5	2	139	141		
	> 5	5	84	89		
School expenditures (Rs/month)	<= 500	188	115	303	51.020	0.000*
	500 – 1,500	60	87	147		
	1,500 – 3,000	18	43	61		
	> 3,000	13	46	59		

* The p-value is <0.05 therefore the result is significant.

Notes:

1. For children aged 6 to 16.
2. For people older than 6 years old.
3. 0 cells have expected count less than 5.

Table 40. Tests of difference for indicators related to MDG 2

Indicator	Electricity access	N	Mean	t-test	p value
School grade[1]	No	337	3.28	3.845	0.000*
	Yes	357	4.01		
Number of school days missed over the last month[1]	No	437	0.68	-3.686	0.000*
	Yes	453	0.33		
Time spent doing homework[1] (hours/week)[2]	No	434	6.4	2.777	0.006*
	Yes	449	7.4		
Time spent on reading[4] (hours/week)[3]	No	1,392	3.7	0.985	0.325
	Yes	1,697	3.9		
Time spent by readers on reading[4] (hours/week)[3]	No	446	11.4	2.331	0.020*
	Yes	533	12.4		
Time spent watching educational programmes on TV (hours/week)	No	1,426	0.05	9.068	0.000*
	Yes	1,740	0.61		
Number of students/teacher	No	9	31.3	-3.021	0.008*
	Yes	9	20.9		
School expenditures (Rs/month)[5]	No	269	592	7.281	0.000*
	Yes	274	1,231		

* The p-value is < 0.05 therefore the result is significant.

Notes:

1. For children aged 6 to 16.
2. Values higher than 25 hours are considered as extreme values and therefore not included in the analysis.
3. Values higher than 35 hours are considered as extreme values and therefore not included in the analysis.
4. For people older than 6 years old.
5. Values higher than Rs1,000 are extreme and have therefore been excluded from the analysis.

- the time spent receiving visitors by women older than 15 years of age.

However, there is no association between the time spent on income generation activities by women older than 15 years old and access to electricity. There is no association either with the time spent on cleaning and cooking for women older than 8.

The independent sample t-test compares averages for people living in electrified and non-electrified households.[113] Table 42 shows that:

- girls living in electrified households attain higher school grades compared to girls living in non-electrified households; and
- girls living in electrified households miss fewer school days than girls living in non-electrified households.

However, there is no significant difference on the average time spent cleaning between women living in households with electricity and those in households without electricity.

Table 41. Tests of association for indicators related to MDG 3

Indicator	Distribution	Electricity access		N[1]	Chi-square	p value
		No	Yes			
Girls school grade level[2]	0-1	55	42	97	13.984	0.007*
	2-3	52	42	94		
	4-5	41	35	76		
	6-7	21	36	57		
	8+	6	19	25		
Number of school days missed during the last month by girls[2]	0	168	188	356	11.696	0.003*
	1-2	35	26	61		
	>= 3	24	7	31		
Time spent by women on income generation activities[3] (hours/week)	0	499	635	1134	1.011	0.799
	=< 40	8	7	15		
	40-60	4	6	10		
	> 60	3	6	9		
Time spent cleaning/ cooking for women[4] (hours/week)	0	182	225	407	1.687	0.640
	=< 10	147	176	323		
	10 – 20	145	150	295		
	> 20	212	260	472		
Time spent by women receiving visitors[3] (hours/month)	0	248	342	590	8.961	0.030*
	=< 4	110	96	206		
	4 – 16	78	107	185		
	> 16	78	109	187		
Time spent reading for women[4] (hours/week)	0	463	574	1037	7.640	0.054
	< 7	109	119	228		
	7 -15	68	52	120		
	> 15	46	66	112		

* The p-value is <0.05 therefore the result is significant.

Notes:

1. 0 cells have expected count less than 5.
2. For girls between 6 and 16 years old.
3. Women aged above 15.
4. Women aged above 8.

Table 42. Tests of difference for indicators related to MDG 3					
Indicator	**Electricity access**	**N**	**Mean**	**t-test**	**p value**
School grade of girls	No	175	3.1	3.369	0.001*
	Yes	174	4		
Number of school days missed over the last month by girls[1]	No	227	0.7	-3.806	0.000*
	Yes	221	0.26		
Time spent receiving visitors for women[2] (hours/ month)	No	514	6	1.985	0.047*
	Yes	654	7.7		

* The p-value is < 0.05 therefore the result is significant.

Notes:
1. Girls aged 6 to 16.
2. Women more than 15 years old.

MDG 4, 5 and 6 related indicators

Very few data directly linked to health indicators are available. Other than budgetary expenditures on health care, only indirect indicators such as cooking habits, kitchen type, water supply or use of improved toilet facilities are available.

Table 43. Tests of association for indicators related to MDG 4, 5 and 6						
Indicator	**Distribution**	**Electricity access**		**N[1]**	Chi-square	p value
		No	**Yes**			
Health expenditures (Rs/month)	< 200	97	81	178	5.325	0.150
	200 – 500	94	95	189		
	500 – 1000	64	76	140		
	>= 1000	25	39	64		
Cooking habits	Traditional stove	222	136	358	85.985	0.000*
	Traditional & improved stoves	32	52	84		
	Improved stove	16	65	81		
	Gas/biogas & traditional/ improved stoves	2	37	39		
Toilet facility	Permanent toilet	107	186	293	38.936	0.000*
	Temporary toilet	91	63	154		
	No toilet	79	40	119		
Water supply	Collective place	257	240	497	23.710	0.000*
	Private well	9	4	13		
	Private pipe	11	46	57		
Kitchen type	Open space in the house	239	231	470	3.684	0.159
	Closed space in the house	34	48	82		
	In a separated building	4	8	12		

* The p-value is <0.05 therefore the result is significant.

Notes:
1. 0 cells have expected count less than 5.

MDG 7 related indicators

The chi-square test analysis[114] found a significant association between electricity access and the level consumption of kerosene, dry-cell batteries and fuelwood. However, there is no significant association between the quantity of charcoal consumed and access to electricity.

Table 44. Tests of association for indicators on energy

Indicator	Distribution	Electricity access		N[1]	Chi-square	p value
		No	Yes			
Quantity of kerosene used (litres/month)	0	29	167	196	243.123	0.000*
	=< 1	48	94	142		
	1 – 2	107	23	130		
	> 2	96	7	103		
Dry-cell batteries consumed (no./month)	0	88	211	299	120.071	0.000*
	<= 2	37	40	76		
	2 – 4	87	28	115		
	> 4	66	11	81		
Charcoal consumed (pack/month)	0	229	216	445	5.295	0.071
	=< 1	35	51	86		
	> 1	14	23	37		
Fuelwood consumed (bhari/month)	<= 5	53	66	119	12.511	0.006*
	5 – 10	69	50	119		
	10	96	93	189		
	> 10	36	66	102		

* The p-value is <0.05 therefore the result is significant.
Notes:
1. 0 cells have expected count less than 5.

The independent sample t-test compares indicator averages for people living in electrified and non-electrified households.[115] Table 45 shows that:

- households with electricity consume less kerosene than households without electricity; and
- households with electricity consume fewer dry-cell batteries than households without electricity.

However, there is no significant difference between electrified and non-electrified households in the average quantity of fuelwood consumed per month. Electrified households do not use electricity for cooking or heating.

Table 45. Tests of difference for indicators on energy consumption

Indicator	Electricity access	N	Mean	t-test	p value
Kerosene consumed (litre/month)	No	280	2.09	-17.981	0.000*
	Yes	290	0.45		
Dry-cell batteries consumed (nr/month)	No	278	3.17	-11.457	0.000*
	Yes	290	0.89		
Fuelwood consumed (bhari/month)[1]	No	252	8.54	1.235	0.217
	Yes	274	8.93		

* The p-value is < 0.05 therefore the result is significant.
Note: Values higher than 20 *bhari* are considered as extreme values and therefore not included in the analysis

MDG 8 related indicators

The chi-square test analysis[116] found a relationship between access to electricity and owning a television set. There is, however, no relationship between owning a radio and access to electricity.

Table 46. Tests of association for indicators on media facilities

Indicator	Distribution	Electricity access		N	Chi-square	p value
		No	Yes			
Own a radio (at least one)	No	115	130	245	0.756	0.385
	Yes	165	161	326		
Own a TV (at least one)	No	279	213	792	83.7	0.000*
	Yes	1	78	79		

* The p-value is <0.05 therefore the result is significant.
Notes: 0 cells have expected count less than 5.

Time allocation related indicators

The chi-square test analysis[117] found a significant association between electricity access and the following indicators on time allocation:

- the time people go to bed in the evening and the time they wake-up in the morning;
- the time spent on cleaning and on cooking for people older than 8 years of age.

Table 47. Tests of association for indicators on allocation of time

Indicator	Distribution	Electricity access		N[1]	Chi-square	p value
		No	Yes			
Bed time in the evening	8:00 or before	533	297	830	212.555	0.000*
	Between 8:00 and 9:00	600	645	1,245		
	After 9:00	351	775	1,126		
Wake-up time in the morning	4:30 or before	135	227	362	212.555	0.000*
	Between 4:30 and 5:30	644	755	1,399		
	Between 5:30 and 6:30	591	607	1,198		
	After 6:30	113	116	229		
Time spent on cleaning[2] (hours/week)	0	609	815	1,424	39.361	0.000*
	=< 3,5	266	218	484		
	3,5 – 7	346	391	737		
	> 7	99	197	296		
Time spent on cooking[2] (hours/week)	0	799	1,066	1,865	11.690	0.009*
	=< 7	254	242	496		
	7 – 15	199	228	427		
	> 15	68	85	153		

* The p-value is <0.05 therefore the result is significant.
Notes:
1. 0 cells have expected count less than 5.
2. For people older than 8 years of age.

The independent sample t-test compares indicators' averages for people living in electrified and non-electrified households (Table 48)[118]:

- people living in electrified households go to bed later and get up earlier than people living in non-electrified households; and
- there is more time available during the day for households with electricity than for those without.

This shows that electrical lighting allows people to extend the number of hours available in the day.

Mean differences are not significant for the number of hours spent cleaning and cooking, which means that the time spent is about the same for people living in electrified and non-electrified households.

Table 48. Tests of difference for indicators on allocation of time

Indicator	Electricity access	N	Mean	t-test	p value
Bed time in the evening	No	1,484	8:48	14.323	0.000*
	Yes	1,717	9:16		
Wake-up time	No	1,483	5:30	-3.996	0.000*
	Yes	1,705	5:22		
Time available during the day (hours)	No	1,483	14:18	10.215	0.000*
	Yes	1,705	14:39		
Time spent cleaning[1] (hours/week)[2]	No	1,317	3.2	0.998	0.318
	Yes	1,595	3.36		
Time spent cooking[1] (hours/week)[3]	No	1,320	4.17	-1.193	0.233
	Yes	1,617	3.87		

* The p-value is < 0.05 therefore the result is significant.

Notes:

1. For people older than 8 years of age.
2. Values higher than 20 hours are considered as extreme values and therefore not included in the analysis.
3. Values higher than 28 hours are considered as extreme values and therefore not included in the analysis.

Annex 9: Findings from regression models analysis

All appropriate independent indicators have been tested in the models developed by this study. However, they do not all appear in the findings, because in many cases the relationship with the dependent indicator was not statistically significant, or they were correlated to other independent variables. Only the most relevant or statistically significant variables have been kept.

Table 49. Determinant of household income

Model[1]	Coefficients		t-stat	p value
	A	Std. Error		
(Constant)	10.623	.082	130.017	.000
Electricity access (0=No, 1= Yes)	.086	.049	1.752	.080
Education index[2]	.206	.050	4.152	.000
Livestock index[3]	.006	.002	3.380	.001
Farm land owned (in ropani)	.022	.004	5.100	.000
Number of active adults (aged 16-60)/household	.077	.017	4.601	.000
Time spent on activities generating income (hours/week)	.002	.001	3.341	.001
Having a radio (0=No, 1= Yes)	.126	.049	2.557	.011
VDC [Rangkani]	.002	.083	.019	.985
VDC [Sarkuwa]	-.246	.091	-2.716	.007
VDC [Dhusene Shiviliya/Pokharichauri]	-.518	.091	-5.690	.000
VDC [Kartike Deurali]	-.249	.087	-2.849	.005
VDC [Mangaltar]	-.189	.089	-2.128	.034

Notes:

1. The dependent variable is Ln(income). Adjusted R^2=0.33. About 536 observations are included in the model. Breusch-Pagan/Cook-Weisberg test for heteroskedasticity (no heteroskedasticity). The variable 'electricity access' is significant at 10%. 'Robustness checks' have been conducted on the model.
2. An average index is calculated per household, applicable to each adult, the following coefficient: 0 for illiterate; 1 for primary education; 2 for lower secondary education; 3 for higher secondary education; 4 for university.
3. The livestock index is estimated according to the following coefficients: 1 for hen; 2 for sheep; 3 for goat and ox; 4 for pig and cow; 5 for buffalo.

Table 50. Determinant of household expenses for energy

Model	Coefficients A	Coefficients Std. Error	t-stat	p value
(Constant)	5.101	.453	11.254	.000
Electricity access (0=No, 1= Yes)	-.904	.057	-15.951	.000
Income	-.005	.041	-.123	.902
Cooking (hours/week)	.007	.002	3.395	.001
Reading (hours/week)	.002	.001	1.591	.112
Number of rooms	.086	.017	4.996	.000
Having a radio (0=No, 1= Yes)	.343	.058	5.955	.000
No. of kids between 4 and 16 currently going to school	.056	.024	2.364	.018
VDC [Rangkani]	-.455	.094	-4.863	.000
VDC [Sarkuwa]	.004	.099	.039	.969
VDC [Dhusene Shiviliya/Pokharichauri]	-.119	.095	-1.261	.208
VDC [Kartike Deurali]	-.574	.098	-5.849	.000
VDC [Mangaltar]	-.638	.101	-6.323	.000

Notes:
The dependent variable is Ln(monthly energy expenditures – fuelwood expenses). Adjusted R^2=0.48. There are 499 observations included in the model. The variable VDC shows that Rangkani and Kartike Deurali are not statistically significant. Heteroskedasticity was not detected at 5% level. 'Robustness checks' have been conducted on the model.

Table 51. Determinant of the number of students per primary school teachers

Model	Coefficients A	Coefficients Std. Error	t-stat	p value
(Constant)	50.465	5.644	8.941	.000
Electrified area (0=No. 1= Yes)	-12.126	2.661	-4.558	.000
Number of rooms	-3.023	.842	-3.590	.003

Notes:
The dependent variable is the number of students per primary school teacher. Adjusted R^2=0.61. There are only 18 observations in this model. 'Robustness checks' have been conducted on the model.

Table 52. Determinant of school grade levels for children aged 6 to 16

School grade levels[a]		B	Standard Error	Wald	Sig.	Exp(B)
2 – 3	Constant	-6.042	.781	59.847	.000	
	Age	.769	.083	85.483	.000	2.158
	No.of children/household	-.343	.097	12.363	.000	.710
	Adult education index[c]	.008	.039	.045	.832	1.008
	[Electricity=Yes]	.477	.281	2.886	.089	1.611
	[Electricity=No]	0[b]	.	.	.	.
4 – 5	Constant	-12.364	1.116	122.714	.000	
	Age	1.356	.107	159.195	.000	3.881
	No. of children/household	-.543	.120	20.546	.000	.581
	Adult education index[c]	.007	.049	.022	.882	1.007
	[Electricity=Yes]	1.002	.344	8.483	.004	2.723
	[Electricity=No]	0[b]	.	.	.	.
6 – 7	Constant	-20.213	1.545	171.171	.000	
	Age	1.923	.132	211.306	.000	6.838
	No. of children/household	-.638	.139	20.996	.000	.528
	Adult education index[c]	.066	.056	1.371	.242	1.068
	[Electricity=Yes]	1.643	.398	17.068	.000	5.172
	[Electricity=No]	0[b]	.	.	.	.
8+	Constant	-32.121	2.818	129.952	.000	
	Age	2.675	.206	168.947	.000	14.518
	No. of children/household	-.783	.183	18.381	.000	.457
	Adult education index[c]	.173	.071	5.938	.015	1.188
	[Electricity=Yes]	1.825	.509	12.846	.000	6.205
	[Electricity=No]	0[b]	.	.	.	.

Notes:

a. The reference category is: school grade level 1 or less (kindergarten). There are 694 valid observations in this model. Pseudo R2 from Nagelkerke=0.7.

b. This parameter is set to zero because it is redundant.

c. An average index is calculated per household, applying for each adult, the following coefficient: 0 for illiterate; 1 for primary education; 2 for lower secondary education; 3 for higher secondary education; 4 for university. .

Table 53. Determinant of household expenses for education

Model[1]	Coefficients A	Coefficients Std. Error	t-stat	p value
(Constant)	3.44	.788	4.36	.000
Electricity access (0=No, 1= Yes)	.435	.091	4.79	.000
Income (Rs)	.251	.087	2.87	.004
Number of children students	.165	.047	3.49	.001
Number of adults students	.322	.086	3.73	.000
Education index[2]	.520	.119	4.36	.000
VDC [Dhusene Shiviliya/Pokharichauri]	-.702	.152	-4.62	.000
VDC [Kartike Deurali]	-.686	.166	-4.14	.000
VDC [Mangaltar]	-.952	.165	-5.76	.000
VDC [Rangkani]	-.163	.179	-0.91	.363
VDC [Sarkuwa]	-1.389	.177	-7.84	.000

Notes:

1. The dependent variable is Ln(monthly school expenditures). Adjusted $R^2 = 0.42$. There are 435 observations included in the model. The variable 'living in Rangkani' is not significant. Results have been corrected for heteroskedasticity using Breusch-Pagan/Cook-Weisberg correction techniques. 'Robustness checks' have been conducted on the model.
2. An average index is calculated per household, applying for each adult, the following coefficient: 0 for illiterate; 1 for primary education; 2 for lower secondary education; 3 for higher secondary education; 4 for university.

Table 54. Determinant of school grade level for girls aged 6 to 16

School grade levels[a]		B	Standard Error	Wald	Sig.	Exp(B)
2 – 3	Constant	-6.532	1.056	38.247	.000	
	Age	.824	.119	47.821	.000	2.280
	No.of children/household	-.336	.131	6.525	.011	.715
	[Electricity=Yes]	.661	.367	3.242	.072	1.937
	[Electricity=No]	0[b]	.	.	.	.
4 – 5	Constant	-12.667	1.529	68.608	.000	
	Age	1.394	.152	83.721	.000	4.031
	No. of children/household	-.544	.162	11.300	.001	.580
	[Electricity=Yes]	1.171	.460	6.487	.011	3.226
	[Electricity=No]	0[b]	.	.	.	.
6 – 7	Constant	-20.342	2.181	87.005	.000	
	Age	1.948	.188	107.307	.000	7.014
	No. of children/household	-.634	.191	10.947	.001	.531
	[Electricity=Yes]	2.079	.546	14.488	.000	7.999
	[Electricity=No]	0[b]	.	.	.	.
8+	Constant	-33.93	4.434	58.551	.000	
	Age	2.836	.322	77.652	.000	17.053
	No. of children/household	-.800	.259	9.539	.002	.449
	[Electricity=Yes]	2.768	.731	14.340	.000	15.932
	[Electricity=No]	0[b]	.	.	.	.

Notes:

a. The reference category is: school grade level 1 or less. There are 346 valid observations in this model. Pseudo R2 from Nagelkerke=0.7.
b. This parameter is set to zero because it is redundant.

Table 55. Determinant of dry-cell batteries consumption levels

Dry-cell batteries consumption (month)[a]		B	Standard Error	Wald	Signif.	Exp(B)
<=2	Constant	3.051	.593	26.432	.000	
	Time spent on cooking (hours/week)	.002	.016	.015	.903	1.002
	Time spent on cleaning (hours/week)	.016	.015	1.090	.296	1.016
	Land owned	-.076	.022	12.369	.000	.927
	[Electricity=Yes]	-2.094	.393	28.393	.000	.123
	[Electricity=No]	0[b]	.	.	.	.
	[Has radio = No]	-4.369	.519	70.785	.000	.013
	[Has radio = Yes]	0[b]	.	.	.	.
	[VDC = Dudilabhati]	-.909	.513	3.141	.076	.403
	[VDC = Rangkani]	-2.802	.632	19.647	.000	.061
	[VDC = Sarkuwa]	-21.379	.000	.	.	5.190E-10
	[VDC = Dhusene / Pokahrichauri]	-.393	.481	.667	.414	.675
	[VDC = Kartike Deurali]	-1.254	.518	5.863	.015	.285
	[VDC = Mangaltar]	0[b]	.	.	.	.
2-4	Constant	2.349	.614	14.651	.000	
	Time spent on cooking (hours/week)	.072	.016	19.839	.000	1.075
	Time spent on cleaning (hours/week)	-.064	.017	14.093	.000	.938
	Land owned	-.021	.018	1.341	.247	.979
	[Electricity=Yes]	-3.757	.426	77.951	.000	.023
	[Electricity=No]	0[b]	.	.	.	.
	[Has radio = No]	-3.615	.415	75.960	.000	.027
	[Has radio = Yes]	0[b]	.	.	.	.
	[VDC = Dudilabhati]	-.512	.561	.832	.362	.600
	[VDC = Rangkani]	-2.375	.693	11.758	.001	.093
	[VDC = Sarkuwa]	2.770	.614	20.329	.000	15.954
	[VDC = Dhusene/Pokahrichauri]	-.386	.529	.534	.465	.679
	[VDC = Kartike Deurali]	-.611	.533	1.314	.252	.543
	[VDC = Mangaltar]	0[b]	.	.	.	.
> 4	Constant	2.235	.605	13.659	.000	
	Time spent on cooking (hours/week)	.104	.018	34.491	.000	1.110
	Time spent on cleaning (hours/week)	-.051	.017	8.669	.003	.950
	Land owned	-.044	.021	4.590	.032	.957
	[Electricity=Yes]	-4.496	.502	80.182	.000	.011
	[Electricity=No]	0[b]	.	.	.	.
	[Has radio = No]	-2.820	.430	42.931	.000	.060
	[Has radio = Yes]	0[b]	.	.	.	.
	[VDC = Dudilabhati]	-2.273	.635	12.818	.000	.103
	[VDC = Rangkani]	-5.155	1.140	20.428	.000	.006
	[VDC = Sarkuwa]	1.725	.636	7.345	.007	5.610
	[VDC = Dhusene/Pokahrichauri]	-1.026	.514	3.988	.046	.359
	[VDC = Kartike Deurali]	-1.562	.545	8.200	.004	.210
	[VDC = Mangaltar]	0[b]	.	.	.	.

Notes:

a. The reference category is: 0. There are 571 valid observations in this model. Pseudo R2 from Nagelkerke=0.67.

b. This parameter is set to zero, because it is redundant.

Table 56. Determinant of kerosene consumption levels

Kerosene consumption (litre/month)[a]		B	Standard Error	Wald	Signif.	Exp(B)
<=1	Constant	-1.154	.515	5.026	.025	
	Time spent on cooking (hours/week)	.008	.012	.479	.489	1.008
	Time spent on cleaning (hours/week)	.020	.011	3.240	.072	1.020
	No. of people in the household	-.019	.061	.100	.752	.981
	[Electricity=Yes]	-1.787	.344	26.963	.000	.168
	[Electricity=No]	0[b]	.	.	.	.
	[VDC = Dudilabhati]	1.695	.505	11.264	.001	5.447
	[VDC = Rangkani]	3.065	.523	34.378	.000	21.425
	[VDC = Sarkuwa]	2.225	.538	17.089	.000	9.252
	[VDC = Dhusene/Pokahrichauri]	2.744	.501	30.024	.000	15.552
	[VDC = Kartike Deurali]	.666	.506	1.733	.188	1.946
	[VDC = Mangaltar]	0[b]	.	.	.	.
1-2	Constant	-.546	.544	1.009	.315	
	Time spent on cooking (hours/week)	.033	.014	6.002	.014	1.034
	Time spent on cleaning (hours/week)	-.034	.015	5.403	.020	.966
	No. of people in the household	.065	.074	.784	.376	1.068
	[Electricity=Yes]	-4.003	.391	104.643	.000	.018
	[Electricity=No]	0[b]	.	.	.	.
	[VDC = Dudilabhati]	2.367	.533	19.756	.000	10.666
	[VDC = Rangkani]	3.098	.568	29.703	.000	22.156
	[VDC = Sarkuwa]	2.364	.650	13.229	.000	10.636
	[VDC = Dhusene/Pokahrichauri]	2.685	.547	24.093	.000	14.664
	[VDC = Kartike Deurali]	.655	.505	1.683	.195	1.925
	[VDC = Mangaltar]	0[b]	.	.	.	.
> 2	Constant	-2.163	.631	11.772	.001	
	Time spent on cooking (hours/week)	.041	.016	6.475	.011	1.041
	Time spent on cleaning (hours/week)	-.013	.017	.620	.431	.987
	No. of people in the household	.282	.084	11.294	.001	1.326
	[Electricity=Yes]	-5.623	.550	104.547	.000	.004
	[Electricity=No]	0[b]	.	.	.	.
	[VDC = Dudilabhati]	1.073	.652	2.711	.100	2.925
	[VDC = Rangkani]	.902	.806	1.252	.263	2.465
	[VDC = Sarkuwa]	3.972	.641	38.409	.000	53.074
	[VDC = Dhusene/Pokahrichauri]	2.380	.576	17.050	.000	10.800
	[VDC = Kartike Deurali]	.543	.524	1.075	.300	1.722
	[VDC = Mangaltar]	0[b]	.	.	.	.

Notes:
a. The reference category is: 0. Pseudo R2 from Nagelkerke=0.62. There are 571 valid observations in this model.
b. This parameter is set to zero, because it is redundant.

Annex 10: Estimation of avoided CO_2 emissions in selected sites

The MHP project developed by REDP has submitted a request for registration as a small-scale CDM project. As detailed in the Project Designed Document[119], the methodology chosen to estimate baseline energy is:

$$E_B = \Sigma_i O_i / (1 - l)$$

where

E_B = annual energy baseline in kWh per year

Σ_i = the sum over the group of 'i' renewable energy technologies (e.g. solar home systems, solar pumps) implemented as part of the project

O_i = the estimated annual output of the renewable energy technologies of the group of 'i' renewable energy technologies installed (in kWh per year)

l = average technical distribution losses that would have been observed in diesel powered mini-grids installed by public programs or distribution companies in isolated areas, expressed as a fraction

Baseline calculations made in the Project Designed Document are based on an average monthly consumption value of 18 kWh per household for domestic use and 9 kWh for productive use. Therefore a value of 27 kWh is used per household.[120] It is also assumed that an average of 10 households is served by each kW of installation.

According to survey data, estimated annual outputs (Oi) for the various MHS sites[121] are:

In the selected areas, households consume an average of 35.5 kWh per month, and 10 households are served by each kW of installation. The total annual output is estimated at around 575,000 kWh.

In the Project Designed Document, 'average technical distribution losses, is taken as 10 per cent for calculations since this is the maximum limit for losses set by AEPC for plants constructed under its programmes'. The same assumption is retained here to estimate the baseline emissions from the surveyed areas. The baseline emissions are then the baseline energy multiplied by the carbon dioxide emission coefficient for the fuel displaced (a default value of 0.9 kg CO_2eq/kWh is accepted for this type of project).

With these assumptions, the annual baseline emissions in tons of CO_2 is:

Baseline Emissions (tCO_2/yr) = EB (kWh) * 0.9 kg CO_2eq/kWh * 1/1000 = 517.5

Table 57. MHS and electricity consumption

District	VDC	MHS Power Output	No. of consumer in 2007	Av. kWh consumed/month/HH	Estimated annual output kWh/year
Baglung	Sarkuwa	24 kW	290	31.5	110,000
	Dudilabhati	24 kW	280	13.3	45,000
	Rangkhani	26 kW	243	16.2	50,000
Kavre	Pokahrichauri	22 kW	229	93.1*	255,000
	Mangaltar	12 kW	130	28.2	45,000
	Kartike Deurali	22 kW	185	30.6	70,000

* This higher value can be explained in part by households using more lighting for income-generating activities. Income from activities produced with the help of domestic lighting is more than 3.5 times higher in Pokahrichauri than the average of electrified communities. Further, the time spent receiving visitors is 80% higher than the average in communities with electricity.

Endnotes

1 Besides providing electricity access, the REDP programme is notable for its emphasis on community participation and empowerment, including the equitable involvement of women in decision-making. It has also developed parallel activities, such as training on agricultural or productive activities, promotion of adult education classes, forestry management systems, water management practices, and the introduction of improved cooking stoves or toilet-attached biogas plants.

2 In 2001, year of the last census, there were about 23.15 million people, or 4.25 million households, in Nepal.

3 The Tenth Five Year Plan (FY2003-FY2007) ended mid-July 2007.

4 Peace remains fragile, and delivery of tangible benefits such as rural energy services has high returns as a peace dividend.

5 Firewood, agricultural and livestock residues are the major sources of traditional biomass in Nepal.

6 Out of the total energy consumption, petroleum (mainly consumed in urban areas) amounts to 9%, electricity only 2%, and renewable energy 1%.

7 IEA Website, Nepal statistics for 2006: about 99.6% of the electricity production comes from hydro and 0.4% from oil (http://www.iea.org/Textbase/stats/electricitydata.asp?COUNTRY_CODE=NP)

8 A solar tuki set consists of two 0.4W White Light Emitting Diode lamps with batteries, one 2.5-3W solar panel to charge the batteries and a 3-volt outlet for a small radio. The cost of a solar tuki set is Rs3,500, whereas the cost of a solar home system is Rs20,000-35,000. (UNDP Nepal website at http://www.undp.org.np/)

9 The REDP was initiated in August 1996 as a joint programme of the Government of Nepal and UNDP in five remote hill districts. The Alternate Energy Promotion Centre, part of the Ministry of Environment, Science and Technology, is the programme's executing agency. After its initial successes, the programme was expanded to 10 districts in 1998 and 15 districts in 2000. At present, the REDP is operational as a joint programme of the Government of Nepal, UNDP and the World Bank in 25 remote districts. (Neupane M., Sharma B., 2006)

10 Baglung and Kavre were the two districts selected for the survey in this study.

11 Capacity development activities include (1) planning, oversight and monitoring, (2) development of policies and regulations, (3) situational analysis, (4) stakeholder dialogue, communications and community mobilization, (5) setting up and enhancing institutions, (6) training of programme implementers and community members, and (7) implementation and management.

12 The difference between the national estimation (UNDP, AEPC, 2010) and the estimation made on the selected sites is explained by the following: (1) the national estimation assumes 5.4 people per household, while survey results from the current study suggest an average of 6.5 people per household in electrified communities; (2) the national result estimates costs in 2005 constant dollars, while the current study estimates costs in constant dollars; and (3) hard costs, such as transportation costs and civil construction vary from site to site.

13 Hard costs include (1) transportation (in kind and in cash); (2) electro-mechanical (subsidy and cash); (3) local civil construction costs (e.g. digging canal, sloping and preparing forebay, preparing poles cut from trees); and (4) construction supplies, such as cement and tools.

14 Estimates of capacity development costs (per kW) are based on the national assessment made by UNDP and AEPC (2010). Capacity development costs vary from year to year. They tend to decrease over time, and are lower during the expansion phase than in the replication phase.

15 Village Development Committees are the lowest, local-level administrative unit in Nepal.

16 Questions relative to time spent by household members were addressed to senior women.

17 A Village Development Committee (VDC) is the lowest political and administrative unit in Nepal.

18 The distance between non-electrified communities and electrified communities is only a few kilometres.

19 The reduction in expenditures on energy depends on the end-uses and quantity of electricity consumed. While energy costs for lighting generally decline with electricity access, switching from a solid fuel for cooking (e.g. biomass) to electricity as a source of heat may not necessarily translate into reduced expenditures, considering the high power consumption (in kWh) of electric stoves.

20 Annual household incomes larger than $6,000 are considered to be extreme values, and were excluded from the analysis.

21 Income includes different sources of monetary income as well as the monetary value of items produced and consumed by the households. Crops consumed are valued at the average local market prices, as are eggs, milk or milk by-products from livestock.

22 The coefficients of the function f are detailed in Annex 9, Table 49. '(+)' and '(-)' indicate the signs of the coefficient. A '(+)' signifies that an increase in the related independent indicator results in an increase in the dependent indicator (household income). A '(-)' indicates that an increase in the related independent indicator results in a decrease in the dependent indicator.

23 Table 49 (Annex 9) provides detailed results of the regression model; it indicates that the coefficient associated to electricity access equals 0.086.

24 Approximate calculations, as we assume E[income/electricity=1]=exp(0.086)*E[income/electricity=0]. That formula indicates that the expected income of household with electricity (electricity=1) equals about 1.1 -or exp(0.086)- times the expected income of households without electricity (electricity=0).

25 The average annual income of non-electrified households is about $1,213. An increase of 1.1 times means $1,334. Therefore, the average increase attributable to electricity access is around $121 annually. This represents about 8 per cent of $1,530, the average annual income of electrified households.

26 This methodology is used in the USAID, NRECA report on 'Economic and Social Impact Evaluation Study of Rural Electrification Programme in Bangladesh'. In that report, the income determination model estimates that 13.7 per cent of the annual net income of electrified households can be attributed to electricity. Income of non-electrified households would be expected to increase by 1.27 times if they had had electricity access.

27 Information from other publications (e.g. Pokharel, 2006) is used to illustrate that statement, because of the lack of data regarding productive uses in non-electrified communities in the survey.

28 The comparison between electrified and non-electrified enterprises is not presented, because of a lack of observations regarding non-electrified enterprises.

29 Estimation based on additional project information from selected areas (2010).

30 Businesses operating before MHS installation: 2 water mills, 1 bee-keeping and 1 mill for agro-processing (which is now using electricity).

31 REDP experiences showed the importance of entrepreneurial capacity development activities, which were not systematically implemented during the first phase of the project. Therefore, some training activities were only performed some years after the MHS installation, which can explain in part the trend in Figure 4. See the Introduction for more information on REDP activities in Baglung and Kavre.

32 This definition is based on the 'Nepal Living Standards Survey (NLSS) 2003/2004' (Central Bureau of Statistics of Nepal, 2004), which defines an 'agricultural household' as an economic unit of agricultural production under single management comprising all livestock and poultry kept, and all land used wholly or partly for agricultural production, without regard to title, legal form or size. Agricultural holdings are grouped into two categories: land holdings and holdings with no land. Holdings with land are those cultivating at least 0.013 hectares (1,458 sq ft or 8 *dhur*) in the case of Tarai, and at least 0.0127 hectares (1,369 sq ft or 4 *ana*) in the hills and mountains, during an agricultural year. Holdings with no land, on the other hand, are those with two or more cattle (or the equivalent of other livestock and poultry) and operating less than 0.013 hectares of land for agricultural purposes.

33 Excluding energy for cooking and heating, as electricity is not used to meet those needs.

34 The coefficients of the function f are detailed in Annex 9, Table 50. '(+)' and '(-)' indicate the signs of the coefficient. A '(+)' signifies that an increase of the related independent indicator result in an increase of the dependent indicator (energy expenditures). A '(-)' indicates that an increase of the related independent indicator results in a decrease of the dependent indicator.

35 Table 50 (Annex 9) provides detailed results of the regression model; it indicates that the coefficient associated with electricity access equals -0.904.

36 Approximate calculations, as we assume E[energy_expenses/electricity=1]=exp(-0.904)*E[energy_expenses/electricity=0]. That formula indicates that the expected energy expenditures of household with electricity (electricity=1) equals about 0.4 -or exp(-0.904)- times the expected energy expenditures of households without electricity (electricity=0).

37 Energy expenditures of non-electrified households average $42 per year (based on the survey data). Applying the regression model, and with other variables being constant, the estimated average expenditures for electrified households are $17, which would represent an average decrease attributable to electricity access of around $25 per year.

38 If we assume that electrical mills consume 5 kWh at a price of Rs6.57 per kWh, i.e. the average power purchase rate paid in Nepal in 2008-2009 (Nepal Electricity Authority, 2009), then the cost of electricity to run the mill for five hours per day, 300 days per year, would be about Rs49,275 (or $657), which is about 45 per cent less than the price of diesel for the same service.

39 Assuming the price of diesel to be $0.80 per litre, and motors consuming 1 litre of diesel per hour, then the average cost of diesel for the same activities would be $2,095 for agro-processing activities, and $2,044 for sawmill activities.

40 The coefficients of the function f are detailed in Annex 9, Table 51. '(+)' and '(-)' indicate the signs of the coefficient. A '(-)' indicates that an increase of the related independent indicator results in a decrease of the dependent indicator (no. of students per primary school teacher).

41 Table 51 (Annex 9) provides detailed results of the regression model; it indicates that the coefficient associated to electricity access equals -12.126.

42 The net enrolment rate is defined as the ratio of the total number of students in the correct-age group and enrolled in school at a given level of education to the total number of children in the age group specified for that level of education. The specified age group is 6-10 years for primary level, 11-14 years for lower secondary, and 15-16 years for higher secondary level.

43 In Nepal, school grade levels go from 1 to 10, with 1 being the lowest grade of primary school. Secondary school starts at grade 6. More recently, the government has encouraged existing high schools to add two additional years of school (10+2).

44 For the purpose of this analysis, school grade levels were grouped into five categories (i.e., 0-1, 2-3, 4-5, 6-7, and 8+).

45 The coefficients of the function f are detailed in Annex 9, Table 52. '(+)' and '(-)' indicate the signs of the coefficient. A '(+)' signifies that an increase of the related independent indicator result in an increase of the dependent indicator (school grade levels). A '(-)' indicates that an increase of the related independent indicator results in a decrease of the dependent indicator.

46 Table 52 (Annex 9) provides detailed results of the regression model; it indicates for example that the coefficient associated to electricity access equals 1.002 for school grade levels 4 to 5. The ratio of the relative risk of being in class 4-5 over being in class 1 or less for household with electricity equals exp(1.002)=2.723, which means an increase by 1.7.

47 In statistical analysis, 'odds' refers the ration of two probabilities—that is, the probability of an event of interest divided by the probability that the event will not occur.

48 Annual schools expenditures higher than $700 are considered as extreme values and not included in the analysis.

49 School expenses include registration fees, school supplies, clothes, etc.

50 The coefficients of the function f are detailed in Annex 9, Table 53. '(+)' and '(-)' indicate the signs of the coefficient. A '(+)' signifies that an increase

of the related independent indicator result in an increase of the dependent indicator (household expenditures for education). A '(-)' indicates that an increase of the related independent indicator results in a decrease of the dependent indicator.

51 Table 53 (Annex 9) provides detailed results of the regression model; it indicates that the coefficient associated to electricity access equals 0.435.

52 Approximate calculations, as we assume E[school_expenses/electricity=1]=exp(0.435)* E[school_expenses/electricity=0]. That formula indicates that the expected school expenditures of household with electricity (electricity=1) equals about 1.54 -or exp(0.435)- times the expected school expenditures of households without electricity (electricity=0).

53 The average school expenditures for non-electrified households are $79 per year. An increase of 1.54 times gives $122. Therefore, the average increase attributable to electricity access is $43 annually. This increase represents about 26 per cent of the average school expenditures of electrified households reported in the survey results (with average expenses of $164).

54 Details of inferential analyses are provided in Annex 8.

55 In Nepal, school grade levels go from 1 to 10, with 1 being the lowest grade of primary school. Secondary school starts at grade 6.

56 This study categorizes school grade levels into five categories for analysis (i.e., 0-1, 2-3, 4-5, 6-7, and 8+).

57 The coefficients of the function f are detailed in Annex 9, Table 54. '(+)' and '(-)' indicate the signs of the coefficient. A '(+)' signifies that an increase of the related independent indicator result in an increase of the dependent indicator (school grade levels). A '(-)' indicates that an increase of the related independent indicator results in a decrease of the dependent indicator.

58 Table 54 (Annex 9) provides detailed results of the regression model; it indicates for example that the coefficient associated with electricity access equals 1.171 for school grade levels 4 to 5. The ratio of the relative risk of being in class 4-5 over being in class 1 or less for girls living in household with electricity equals exp(1.171)=3.226, which means an increase by 2.2.

59 See Figure 22.

60 See Table 10.

61 See the following section on "Time allocation".

62 While the difference in time spent reading is not significant between women with and without electricity access, a difference is observed when only readers are taken into account. This means that electricity does not encourage women that did not read previously to start reading, but it does allow women with established reading habits to spend more time reading.

63 According to the Nepal Demographic and Health Survey 2006, (Ministry of Health and Population, 2007) only 0.1 per cent of the people use electricity for cooking, all of them in urban areas. In rural areas, about 94 per cent of the people use solid fuels for cooking and 5 per cent use gas.

64 Details of inferential analyses are provided in Annex 8.

65 There are four health posts in the area surveyed, as well as three sub-health posts. Health posts cover an average of 12,000 people, while sub-health posts cover an average of 5,000 people.

66 While 100 per cent of health centres have been interviewed in the selected sites, the sample only counts seven observations. The figures must therefore be interpreted with care.

67 According to Pokharel (2006), used dry-cell batteries in rural Nepal are simply thrown in the garden or in open space—sometimes even thrown where animal dung is collected for fertilizer.

68 Although the chi-square test indicates an association between the amount of fuelwood consumed and electricity access, the t-test shows that the difference in average consumption is not significant.

69 Details of inferential analyses are provided in Annex 8.

70 On average households consume 8.8 bhari of fuelwood per month; i.e. 9 bhari for electrified households and 8.7 for non-electrified households (1 bhari = 8 kg). While the consumption level is similar, expenses vary greatly: households in communities with electricity access spend on average $25 per year for fuelwood, but non-electrified households spend less than $10. There are multiple factors to explain the difference

in expenditures on fuelwood in electrified and non-electrified communities. Indeed, fuelwood is free in some areas, while people have to pay for it in other places, and its price depends on local availability. Where community forestry programmes have been developed (mostly in REDP communities), the price of the fuelwood is fixed by the community forestry group and can be higher. Better-off households might choose to buy fuelwood instead of collecting it themselves.

71 For more information on community forestry programmes in Nepal, see Adhikari et al., 2004.

72 In order to run the multinomial logistic regression, the consumption of dry-cell batteries is categorized into four groups (no consumption, less than 2 batteries per month, between 2 and 4 batteries, and more than 4 batteries per month).

73 The coefficients of the function f are detailed in Annex 9, Table 55. '(+)' and '(-)' indicate the signs of the coefficient. A '(+)' signifies that an increase of the related independent indicator result in an increase of the dependent indicator (dry-cell batteries consumption). A '(-)' indicates that an increase of the related independent indicator results in a decrease of the dependent indicator.

74 Table 55 (Annex 9) provides detailed results of the regression model; it indicates for example that the coefficient associated to electricity access equals -2.094 when 2 or less batteries are consumed each month. The ratio of the relative risk of consuming 2 or less batteries over not consuming any for household with electricity equals exp(-2.094)=0.12, which means a decrease by 88 per cent.

75 In order to run the multinomial logistic regression, the consumption of kerosene is categorized into four groups (no consumption, less than one litre per month, between one and two litres, and more than two litres per month).

76 The coefficients of the function f are detailed in Annex 9, Table 56. '(+)' and '(-)' indicate the signs of the coefficient. A '(+)' signifies that an increase of the related independent indicator result in an increase of the dependent indicator (kerosene consumption). A '(-)' indicates that an increase of the related independent indicator results in a decrease of the dependent indicator.

77 Table 56 (Annex 9) provides detailed results of the regression model; it indicates for example that the coefficient associated to electricity access equals -1.787 when less than 1 litre of kerosene is consumed each month. The ratio of the relative risk of consuming less than 1 litre of kerosene over not consuming any for household with electricity equals exp(-1.787)=0.168, which means a decrease by about 83 per cent.

78 Details of the estimation are presented in Annex 11.

79 More details on carbon markets and assumptions on price of carbon dioxide per ton can be found in World Bank reports such as States and Trends of the Carbon Market annual reports.

80 Details of inferential analyses are provided in Annex 8.

81 Although the chi-square test indicates a relationship between the time spent on cleaning, cooking and electricity access, the t-test shows that the difference in average time spent is not significant.

82 For more details refer to the section on agricultural production under MDG 1 section.

83 On average, households surveyed produce about 580 kg of rice, 655 kg of maize, 160 kg of wheat and 164 kg of millet. Manual agro-processing of that production requires about 260 hours (i.e. adding 196 hours/year for manual grinder to 64.5 hours/year for manual husker), while the use of electrical mills reduces the agro-processing time to about 11 to 21 hours (Table 19).

84 On average, households surveyed produce about 580 kg of rice, 655 kg of maize, 160 kg of wheat and 164 kg of millet. Agro-processing of that production using traditional ghattas to grind grains requires about 113 hours (i.e. adding 64.5 hours/year for husking rise to 49 hours/year for using traditional watermill), while the use of electrical mills reduces the agro-processing time to about 11 to 21 hours (Table 19).

85 Households are using traditional ghattas for agro-processing or doing manually as it takes times to switch to new technology. It also depends on the quality and quantity of the agricultural products. For large quantities, they often opt for power milling.

86 It was not possible to use data of time spent on agro-processing activities by households in this section, as it is not clear from the survey which technologies non-electrified households use to process crops. Moreover, in many cases, households might also benefit from electrical mills available in neighbouring villages.

87 Estimation made assuming that the time saved by an average sample household using electrical mills is 240 hours annually.

88 Those estimations are based on average wage rates per hour in the surveyed areas, i.e. Rs16 for men and Rs9.30 for women.

89 The absence of productive activities in non-electrified communities did not allow econometric modeling; therefore the impact of socio-economic or geographic factors on that additional income could not be included in the analysis.

90 According to 2010 information from selected areas, about 3.4 per cent of households have developed a new activity after electrification.

91 This is the case in Nepal, where seed capital now exists.

92 The hedonic pricing method seeks to find a relationship between the characteristics of a good and the prices of marketed goods. It is most commonly applied in real estate economics or consumer price index calculations.

93 The travel cost method estimates economic use values associated with ecosystems or sites by using time and travel cost expenses, such as prices to access a specific site.

94 Energy value of lighting is measured by lumens: for example, a candle emits around 12 lumens, a kerosene lamp from 30 to 80 lumens, and a 60-watt light bulb 730 lumens.

95 Load controllers are installed in REDP projects if the communities required it, which was not the case in the sites selected for the survey. So, the surveyed communities have no metering systems and electricity consumers (domestic and non-domestic) are charged on a flat-tariff basis. Tariffs are decided by the communities and are different at each site.

96 The terai ('moist land') is the country's southern belt of fertile, alluvial plains, consisting largely of marshy grasslands, savannas and forests.

97 End 2006, 44 MHSs for a total of 451 kW have been installed in Baglung and 16 MHSs for a total of 235 kW have been installed in Kavre. (AEPC, REDP, 2007)

98 A hypothesis is a precise statement relating to the research question to be tested.

99 The type of scale helps to determine which type of statistical analysis is appropriate. Parametric statistical tests (e.g. t-tests, z-tests) use interval or ratio scale of measurement. For data with ordinal or nominal scale, non-parametric tests are used (e.g. chi-square tests).

100 In the chi-square test, the null hypothesis assumes no relationship or association between the variables, while the alternative hypothesis assumes that a relationship does exist. In the t-test, the null hypothesis states that there is no difference between the mean of the two variables, while the alternative hypothesis states a difference between them.

101 The significance level is determined by the p-value, the probability of an observed result happening by chance under the null hypothesis. A probability of .05 or less is commonly interpreted by social scientists as justification for rejecting the null hypothesis that one variable is unrelated (that is, only randomly related) to the other variable. Therefore a 'statistically significant' result implies that the probability of obtaining the observed data (or more extreme) under the null hypothesis, is small – typically less than 0.05.

102 For comparison, according to the Project Design Document prepared to request registration of the MHP project as a small scale CDM project, the average lighting tariff is $0.09/kWh, the tariff for productive uses is $0.10/kWh.

103 For comparison, according to the Project Design Document prepared to request registration of the MHP project as a small scale CDM project 'average household electricity consumption is estimated to be 27 kWh/month, out of which 18kWh is used for lighting and 9 kWh, for productive uses.'

104 Some average estimations have been made using data found in the literature to estimate lumens generate by traditional and electric lights: incandescent bulbs: 12 lumen/W; low consumption bulbs: 55 lumen/W; fluorescent tubes: 60 lumen/W; kerosene lamps: 40 lumen and candles: 12 lumen.

105 When the distinction between the different bulbs was not clear in the survey data, it has been assumed that bulbs with a power of 20W or less were low consumption bulbs.

106 IEG, 2008. In many cases the linear demand curve overestimates the amount of consumer surplus. An alternative functional form is a constant elasticity (log linear) demand curve.

107 With a linear demand curve, estimation of the consumer surplus would be overestimated and it would amount to about Rs705 ($9.40) per month, which is more than twice the consumer's surplus assuming a non-linear demand curve.

108 If the chi-square test statistic has an associated probability <0.05, the difference between the groups is statistically significant, which means that at 5% level of significance, the null hypothesis (assuming no relationship) can be rejected.

109 If the p value is lower than 0.05, then the difference between the two groups is statistically significantly different from zero at the 5% level of significance.

110 If the chi-square test statistic has an associated probability <0.05, the difference between the groups is statistically significant, which means that at 5% level of significance, the null hypothesis (assuming no relationship) can be rejected.

111 If the p value is <0.05, the difference between the two groups is statistically significantly different from zero at the 5% level of significance.

112 If the chi-square test statistic has an associated probability of <0.05, the difference between the groups is statistically significant, which means that at 5% level of significance, the null hypothesis (assuming no relationship) can be rejected.

113 If the p value is <0.05, the difference between the two groups is statistically significantly different from zero at the 5% level of significance.

114 If the chi-square test statistic has an associated probability of <0.05, the difference between the groups is statistically significant, which means that at 5% level of significance, the null hypothesis (assuming no relationship) can be rejected.

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117 If the chi-square test statistic has an associated probability of <0.05, the difference between the groups is statistically significant, which means that at 5% level of significance, the null hypothesis (assuming no relationship) can be rejected.

118 If the p value is lower than 0.05, the difference between the two groups is statistically significantly different from zero at the 5% level of significance.

119 CDM-SSC-PDD (version 02) – Micro-hydro Promotion by Alternative Energy Promotion Centre (AEPC).

120 According to the Project Designed Document, 'Average electricity consumption per household per month in three different rural areas of the mountain district of Kavre in central Nepal, is found to be 21.64 kWh, 18.90 kWh and 20.26 kWh according to data made available by the Nepal Electricity Authority. A similar study in rural areas of Lamjung district in western Nepal shows that the average monthly electricity consumption per household is only about 18.15 kWh. The average of all these values is 19.72 kWh per household per month. Another study shows that the average monthly consumption per household in the domestic sector ranges from 15 kWh to 150 kWh and the weighted average of these is 27 kWh per household per month. It has also been mentioned based on field experiences that the monthly consumption of a 5 ampere meter holder (min. tariff block) increases to 20 kWh and then remains stagnant at that level. Giving due considerations to all these sources, a conservative monthly consumption value of 18 kWh per household (i.e., 216 kWh per year) has been used for baseline calculations. In addition to this, a study based on actual field findings from 13 agro-processing units in rural areas of Nepal found that an average household requires about 9 kWh per month for milling purposes. Thus, the average monthly electricity consumption per household would then be the addition of 18 kWh and 9 kWh, which gives a value of 27 kWh (i.e., 324 kWh per year).'

121 Data were estimated according to households' use of electricity, because there is no meter reading in the selected MHP sites.

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Decentralized Energy Access and the **Millennium Development Goals**

Decentralized, off-grid power supplies such as micro hydropower can be perceived as expensive investments by poor countries like Nepal. Can these investments be justified by the benefits that electricity brings to villages in remote mountainous regions? This book describes research into the development gains brought to such villages, measured in terms of progress towards achieving the millennium development goals. Indicators relating to income, education, gender equality, maternal and child health and environmental impact were measured in villages benefiting from micro hydropower, compared with neighbouring villages without an electricity supply.

The cumulative development advantages were found to far outweigh the investment costs of a micro-hydropower system. The household income benefits and cost savings associated with an electricity supply were found to be considerable, and to outweigh the investment costs of micro hydropower over the lifetime of an installation. Where businesses that exploited the new energy supply had been started, the income gains were even more marked. In addition, there were other significant development benefits in terms of education, gender equality and health.

Decentralized Energy Access and the Millennium Development Goals provides conclusive evidence of these transformative benefits and recommends that Nepal, and countries like it, scale up investments in its micro-hydropower programme.

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