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Subhes Bhattacharyya  
Editor

# Rural Electrification Through Decentralised Off-grid Systems in Developing Countries

*Editor*

Subhes Bhattacharyya  
Professor of Energy Economics and Policy  
Institute of Energy and Sustainable Development  
De Montfort University  
Leicester  
UK

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# Preface

This edited book forms part of the dissemination activity of a Research Councils UK funded project on off-grid electrification. The project, called OASYS South Asia (through grant no EP/G063826/1), is led by me as the Principal Investigator and includes four other partner organisations, namely School of Environment and Development, Manchester University, School of Built Environment, Edinburgh Napier University, The Energy and Resources Institute (TERI, India) and TERI University. The consortium has been working on developing suitable business models for off-grid electrification in developing countries since 2009. As part of the research activity, the consortium members have reviewed a huge volume of literature covering various aspects of off-grid project activities. These were initially presented as Working Papers of the project. This edited volume brings together a revised and updated collection of relevant working papers from this activity for wider dissemination.

This volume contains 12 chapters divided into three parts: Part I provides the background information on electricity access, discusses the developmental implications of rural energy infrastructure (or lack of it) and provides a review of alternative technologies used for off-grid electricity delivery. Part II provides detailed review of rural electrification experiences from around the world, with a special emphasis on off-grid electrification. Part III presents the business-related elements—participatory arrangements, financing, regulation and governance. Finally, a concluding chapter summarises the key findings and indicates further research agenda.

The work reported here has been discussed internally and in various workshops organised as part of the research activity. These were held in Edinburgh, Delhi and Dundee between 2010 and 2012. The chapters have thus benefited from the inputs and comments of a large number of participants from the academia as well as those involved in practice with off-grid electrification.

I hope this volume will prove to be a valuable addition to the literature on rural electrification and off-grid electrification and would benefit researchers and other stakeholders involved in policy-making and enhancing electricity access in rural areas of the developing world.

The work related to my contributions to the volume was carried out while I was with the Centre for Energy, Petroleum and Mineral Law and Policy (CEPMLP), University of Dundee. I acknowledge the support I received there. The book manuscript was prepared while I was relocating to the Institute of Energy and Sustainable Development (IESD), De Montfort University, Leicester, UK.

As the editor of the Volume I would like to thank all contributors to this volume for their continued support and hard work. I would like to thank the publisher—Springer for agreeing to publish this volume despite the specialised nature of the work that still faces limited academic attention. We would like to thank Elsevier for allowing us to reuse materials for a few papers that appeared in some form in their journals. We also thank the Energy and Resources Institute (TERI, New Delhi, India) and the National Renewable Energy Laboratory (NREL), Washington D.C. (USA) for allowing us to reuse some of diagrams from their works. Last but not the least, I would like to thank my wife (Debjani) and daughter (Saloni) for their support in completing this work over the summer of 2012 during a very stressful relocation exercise, thereby enduring a double externality (i.e. sacrificing the entire summer holidays for my academic pursuits and shouldering a higher share of the relocating stress).

Leicester

Subhes Bhattacharyya  
IESD, De Montfort University

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# Abbreviations

AC	Alternating Current
ADB	Asian Development Bank
AEPC	Alternate Energy Promotion Centre
AfDB	African Development Bank
AFPRO	Action for Food Production
AGF	Advisory Group on Climate Change Financing
AMC	Annual Maintenance Contract
AMORE	Alliance for Mindanao Off-grid Renewable Energy
ASER	Senegalese Agency for Rural Electrification (French Acronym)
AWEA	American Wind Energy Association
BANPRES	The Presidential Assistance Project (Indonesia)
BPDB	Bangladesh Power Development Board
BPL	Below Poverty Line
BPPT	Agency for Assessment and Application of Technology, Indonesia
CBO	Community-Based Organisation
CDM	Clean Development Mechanism
CEMIG	Decentralised Electrification Programme (Brazil)
CER	Certified emissions reduction (in CDM)
CFL	Compact Fluorescent Lamp
CH <sub>4</sub>	Methane
CHP	Combined Heat and Power
CIF	Climate Investment Funds
CO	Carbon monoxide
CO <sub>2</sub>	Carbon dioxide
CREDA	Chhattisgarh State Renewable Energy, Development Agency (India)
CREE	Community Rural Electrification Entities
CTF	Clean Technology Fund
DC	Direct Current
DfID	Department for International Development (UK)
DG	Distributed Generation



DoE	Department of Energy
DTBP	Di- <i>tert</i> -Butyl Peroxide
EC	Electricity Co-operatives
ECS	Electricity Consumer Societies (Sri Lanka)
EdC	Electricite du Cambodge
ERB	Energy Regulation Board (Zambia)
ESAP	Energy Sector Assistance Program
ESMAP	Energy Sector Management Assistance Program
ETS	Emissions Trading System
EVN	Electricity of Vietnam (Electricity Utility)
EWEA	European Wind Energy Association
FDI	Foreign Direct Investment
GDP	Gross Domestic Product
GEDAP	Ghana Energy Development and Access Project
GEF	Global Environment Facility
GFCF	Gross Fixed Capital Formation
GGC model	Gobar Gas and Agricultural Equipment Development Company Model
GNESD	Global Network on Energy for Sustainable Development
GNI	Gross National Income
GSS	Ghana Statistical Society
GTZ	German Technical Cooperation (now called GIZ)
HAWT	Horizontal Axis Wind Turbines
HDI	Human Development Index
HPS	Husk Power Systems (India)
IBF	Input-based Franchisee
IDA	International Development Agency (World Bank)
IDCOL	Infrastructure Development Company Limited
IEA	International Energy Agency
IEC	International Electro-technical Commission
IFC	International Finance Corporation
INEP	Integrated National Electrification Program (South Africa)
ITSL	Intermediate Technology Sri Lanka
KUD	Village Co-operatives (Indonesia)
KVIC model	Khadi and Village Industries Commission Model
kW	Kilo watts
LaBL	Lighting a Billion Lives
LDC	Least Developed Countries
LED	Light Emitting Diodes
LnC	Light in the Countryside (Brazil)
LpT	Light for all (Brazil)
MCDA	Multi-criteria Decision Analysis
MFI	Micro-Finance Institution
MHP	Micro-hydro power
MNRE	Ministry of New and Renewable Energy (India)

MPPU	Multi-Purpose Project Unit
NEA	Nepal Electricity Authority
NEA	National Energy Administration (China)
NEA	National Electrification Administration (the Philippines)
NECEUN	National Association of Community Electricity Users-Nepal
NES	National Electrification Scheme
NGO	Non-Governmental Organisation
NIS	National Interconnected System (Colombia)
NIZ	Non-interconnected Zones (Colombia)
NRECA	National Rural Electric Cooperative Association
NTPC	National Thermal Power Corporation (India)
O&M	Operation and Maintenance
OBA	Output-based Aid
ODF	Official Development Assistance
OECD	Organisation for Economic Co-operation and Development
PBS	Palli Bidyut Samiti
PCU	Power Conditioning Unit
PDN	Power Distribution Network
PEA	Provincial Electricity Authority (Thailand)
PERMER	Project for Renewable Energy in Rural Markets
PGSEP	Philippines German Solar Energy Project
PLF	Plant Load Factor
PLN	Indonesian Electricity Utility (Perusahaan Listrik Negara)
PO	Partner Organisation
PoA	Program of Activities
PPP	Purchasing Power Parity
PPP	Public-Private Partnership
PRODEEM	The Brazilian Programme for Rural Electrification
PV	Photo-Voltaic
QTP	Qualified Third Parties (Philippines)
REA	Rural Electrification Agency (Ghana)
REB	Rural Electrification Board
REC	Rural Electricity Co-operative
RECS	Rural Electrification Collective Scheme
REDP	Rural Energy Development Program
REE	Rural Electricity Entrepreneurs
REF	Rural Electrification Fund
REP	Rural Energy Policy
REP	Rural Electrification Program (Kenya)
REPP	Renewable Energy Power program (Philippines)
REREDP	Renewable Energy for Rural Economic Development
REST	Rural Electricity Supply Technology
RET	Renewable Energy Technology
RGVY	Rajiv Gandhi Grameen Vidyut Yojana (Rajiv Gandhi Rural Electrification Programme)

RGR	Global Reversal Reserve (Brazil)
RVEP	Remote Village Electrification Programme
SCADA	Supervisory Control and Data Acquisition system
SCF	Strategic Climate Fund
SCS	Solar Battery Charging Station
SDPC	State Development Planning Commission (China)
SELCO	Solar Electric Light Company (India)
SEP	Special Energy Program
SETC	State Economic and Trading Commission (China)
SHS	Solar Home Systems
SIDA	Swedish International Development Agency
SPC	State Planning Commission (China)
SPPS	Single Point Power Supply
SPUG	Small Power Utilities Group (Philippines)
SPV	Solar Photo-Voltaic
SREP	Scaling-up of Renewable Energy in low-income countries
SWT	Small Wind Turbine
TEDAP	Tanzania Energy Development and Access Project
TERI	The Energy and Resources Institute, New Delhi, India
TVE	Town and Village Enterprise
UNDP	United Nations Development Programme
USAID	United States Agency for International Development
USD	United States Dollar
VAWT	Vertical Axis Wind Turbines
VDC	Village Development Committee
VEC	Village Electricity Committee
VESP	Village Energy Security Programme
WBREDA	West Bengal Renewable Energy Development Agency
WEC	World Energy Council
WHO	World Health Organisation
WHS	Wind home systems