Renewables and Energy for Rural Development in Sub-Saharan Africa

Edited by
Maxwell Mapako
Abel Mbewe

Zed Books

About AFREPREN

The African Energy Policy Research Network (AFREPREN) is an African initiative on energy, environment and sustainable development supported by the Swedish International Development Cooperation Agency (SIDA) and the Swedish Agency for Research Cooperation with Developing Countries (SAREC). It brings together 97 African energy researchers and policy makers who have a long-term interest in energy research and the attendant policy-making process. AFREPREN has initiated policy research studies in 19 African countries: Angola, Botswana, Burundi, Eritrea, Ethiopia, Kenya, Lesotho, Malawi, Mauritius, Mozambique, Rwanda, Seychelles, Somalia, South Africa, Sudan, Tanzania, Uganda, Zambia and Zimbabwe. The Network also maintains close collaborative links with energy researchers and policy makers from Côte D'Ivoire, Ghana, Nigeria, Sierra Leone and Senegal. The key objective is to strengthen local research capacity and to harness it in the service of energy policy making and planning. Initiated in 1987, AFREPREN is a collective regional response to the widespread concern over the weak link between energy research and the formulation and implementation of energy policy in Africa. AFREPREN is funded by SIDA.

African Energy Policy Research Series

African Energy: Issues in Planning and Practice
AFREPREN (1990)

Energy Management in Africa
M. R. Bhagavan and S. Karekezi (eds)
(1992)

Rural Electrification in Africa
V. Ranganathan (ed)
(1992)

Energy Options for Africa: Environmentally Sustainable Alternatives
S. Karekezi and G. Mackenzie (eds)
(in association with the UNEP Collaborating Centre on Energy and Environment)
(1994)

Biomass Energy and Coal in Africa
D. O. Hall and Y. S. Mao (eds)
(1994)

Energy Utilities and Institutions in Africa
M. R. Bhagavan (ed)
(1996)

Transport Energy in Africa
M. R. Bhagavan (ed)
(1996)

Renewable Energy Technologies in Africa
S. Karekezi and T. Ranja
(1997)

Biomass Energy Policy in Africa
D. L. Kgathi, D. O. Hall, A. Hategeka, C. V. Mlotshwa & M. B. M. Sekhwela
(1997)

Planning and Management in the African Power Sector
V. Ranganathan (ed)
(1998)

Petroleum Marketing in Africa
M. R. Bhagavan (ed)
(1999)

Reforming the Power Sector in Africa
M. R. Bhagavan (ed)
(1999)

Capacity Building for a Reforming African Power Sector
M. Teferra and S. Karekezi (eds)
(2002)

Renewables and Energy for Rural Development in Sub-Saharan Africa
Maxwell Mapako and Abel Mbewe (eds)
(2004)

Renewables and Energy for Rural Development in Sub-Saharan Africa

Edited by

Maxwell Mapako and Abel Mbewe

Contributing authors

Semere Habtetsion
Stephen Karekezi
Waeni Kithyoma
Maxwell Mapako
Joseph Mbaiwa
Abel Mbewe
Zemenfes Tsighe
Wolde-Ghiorgis Woldemariam

Zed Books Ltd
LONDON & NEW YORK

in association with

African Energy Policy Research Network
(AFREPREN)

Renewables and Energy for Rural Development in Sub-Saharan Africa
was first published in 2004 by
Zed Books Ltd, 7 Cynthia Street, London N1 9JF, UK and
Room 400, 175 Fifth Avenue, New York, NY 10010, USA
www.zedbooks.co.uk

in association with

the African Energy Policy Research Network (AFREPREN),
PO Box 30979, Nairobi, Kenya
www.afrepren.org

Contact: Stephen Karekezi, Director
African Energy Policy Research Network (AFREPREN/FWD)
PO Box 30979, 00100 Nairobi GPO, Kenya
Tel: +254-20-566032 or 571467
Fax: +254-20-561464 or 566231
Email: afrepren@africaonline.co.ke
or
Stephenk@africaonline.co.ke

Cover designed by Sophie Buchet
Typeset by Long House, Cumbria, UK
Printed and bound in Malta by Gutenberg Ltd

Distributed in the USA exclusively by Palgrave Macmillan,
a division of St Martin's Press, LLC.,
175 Fifth Avenue, New York, NY 10010

A catalogue record for this book
is available from the British Library

ISBN Hb 1 84277 518 9

Contents

List of Tables

List of Figures

Box

List of Abbreviations and Glossary

$\mu g/m^3$	Micro grams per cubic metre
ADB	African Development Bank
ADLI	Agriculture Development-Led Industrialization (strategy)
AFC	Agricultural Finance Corporation
AFREPREN	African Energy Policy Research Network
BEMCO	Botswana Earth-Moving Machinery Company
Biofuels	Wood, charcoal, agricultural residues, dung, grass, shrubs, leaves
Biogas	Mixture of methane and carbon dioxide produced from decomposing organic matter under anaerobic conditions
Biomass	Organic wastes, natural forests, energy crops and crop residues
BPS	Barlows Power Systems
Briquette	Compact fuel in the form of a ball made from coal or biomass; has comparable combustion characteristics to charcoal
BTC	Botswana Technology Centre
BUN	Biomass Users Network
CBO	Community-Based organization
CBR	Cost–benefit ratio
CEO	Chief executive officer
CFC	Chlorofluorocarbons
Commercial energy	Electricity, kerosene, liquefied petroleum gas
CONIEL	Compagnia Nazionale Imprese Elettriche
CSA	Central Statistics Authority
DANIDA	Danish International Development Agency
DoE	Department of Energy
DTC	Development Technology Centre
EDM	Electricidade de Mocambique
EEA	Eritrea Electric Authority
EELPA	Ethiopia Electric Light and Power Authority
EEPCO	Ethiopian Electric Power Company
EESRC	Ethiopian Energy Studies and Research Centre
Energy ladder	Refers to a variety of energy carriers. Each rung on the ladder corresponds to a dominant fuel used by a particular income group
EPC	Ethiopian Petroleum Corporation
EPE	Ethiopian Petroleum Enterprise
ERB	Energy Regulation Board
EREP	Expanded Rural Electrification Programme
EREDPC	Ethiopian Rural Energy Development and Promotion Centre
Erisoc	Eritrea Stove Oven and Cylinder plc
ERL	Energy Resource Limited
ERTC	Energy Research and Training Centre
ESCO	Energy service company/Engineering Services Corporation
ESMAP	Energy Sector Management Assistance Programme

GDP	Gross domestic product
GEF	Global Environment Facility
GHG	Green House Gas
GIDD	Gender in Development Division
GWh	Gigawatt-hour
ICS	Interconnected system
IEA	International Energy Agency
IGAD	Intergovernmental Authority for Development
ILO	International Labour Organization
IRR	Internal rate of return
JCL	Jatropha Curcas L
JICA	Japan International Cooperation Agency
kg	Kilogram
kgoe	Kilogram of oil equivalent
kVA	Kilovolt amperes
kW	Kilowatt
kWh	Kilowatt-hour
kWh/MWh/ GWh	Kilowatt hour/ Megawatt hour/ Gigawatt hour
LPG	Liquefied petroleum gas/liquefied propane gas
LRMC	Long-run marginal cost
Mbaula	Traditional wood/charcoal stove
MEWD	Ministry of Energy and Water Development
MFED	Ministry of Finance and Economic Development
MM	Ministry of Mines
MME	Ministry of Mines and Energy
MMEWA	Ministry of Minerals, Energy and Water Affairs
MoA	Ministry of Agriculture
Modern energy	Electricity, kerosene, liquefied petroleum gas, coal, wind, solar, etc.
MRD	Ministry of Rural Development
MSD	Mechanical Services Department
MSMEs	Micro, Small and Medium Enterprises
MT	Metric tonnes
MTA	Motor Trade Association
MTI	Ministry of Trade and Development
MW	Megawatt
MZM	Mozambican Meticals (currency)
NAIS	National Agricultural Information Services
NDP	National Development Plan
NGO	Non-governmental organization
NISIR	National Institute for Scientific and Industrial Research
NOCZIM	National Oil Company of Zimbabwe
NORAD	Norwegian Agency for Development
NPRS	National Poverty Reduction Strategy
NPRSF	National Poverty Reduction Strategic Framework
NRSE	New and Renewable Sources of Energy
NSSA	National Social Security Authority
OAU	Organization for African Unity
ORAP	Organisation of Rural Associations for Progress
PCE	Petroleum Corporation of Eritrea

Peri-urban	Refers to settlements that are close to cities or towns
Poverty	A situation when individuals or households are not able to acquire basic necessities of life
ProBEC	Programme on Biomass Energy Conservation
PV	Photovoltaic
PVP	Photovoltaic pumping
R&D	Research and Development
R&M	Repair and Maintenance
REA	Rural Electrification Agency
REB	Regional Energy Bureau
REF	Rural Electrification Fund
REFA	Rural Electrification Fund Act
REIP	Rural Enterprises Investment Partnership
RETA	Renewable Energy Trade Association
RETs	Renewable Energy Technologies
RIERF	Rural Institutions Electrification Revolving Fund
RIIC	Rural Industries Innovation Centre
rpm	revolutions per minute
Rural electrification	Extension of national electricity grid to country side areas that are not yet electrified
SADCC	Southern African Development Coordination Conference
SCS	Self Contained System
SEDAO	Società Elettrica del'Africa Orientale
SEI	Stockholm Environment Institute
SEIAZ	Solar Energy Industry Association of Zimbabwe
SHS	Solar Home Systems
SIDA	Swedish International Development Agency
SMEs	Small and medium-sized enterprises
Syngas	Mixture of hydrogen and carbon dioxide generated during biomass gasification
TANESCO	Tanzania Electricity Supply Corporation
TDAU	Technology Development Advisory Unit
toe	Tonnes of oil equivalent
TOTEM	Total Energy Module
Traditional fuels	Wood, charcoal, agricultural residues, dung, leaves and waste
TSE	Telecommunications Services of Eritrea
UN	United Nations
UNICEF	United Nations Children Fund
UNDP	United Nations Development Programme
UNIDO	United Nations Industrial Development Organization
UNZA	University of Zambia
WCC	Wankie Colliery Company
ZAW	Zambia Alliance of Women
ZERO	Zimbabwe Environmental Research Organization
ZESA	Zimbabwe Electricity Supply Authority
ZIMPREST	Zimbabwe Programme of Economic and Structural Transformation
ZNCC	Zimbabwe National Chamber of Commerce
ZRA	Zambia Revenue Authority
ZWB	Zimbabwe Women's Bureau

Acknowledgements

The publication of this report has been made possible through the kind support of the Swedish International Development Cooperation Agency (SIDA).

The editors wish to thank the contributors to this volume who are AFREPREN principal researchers in the Renewables and Energy for Rural Development Theme Group. Special thanks also go to Mr. Joseph Mbaiwa, who assisted in editing and reviewing the reports. The quality of the reports was greatly enhanced by reviews provided by a group of external reviewers, namely: Dr. Maria Fernanda Cardossa, Dr. Jim Watson, Dr. Smail Khennas, and Dr. Jonathan Scurlock, and by S. Karekezi, W. Kithyoma at the AFREPREN Secretariat. In addition, the editors wish to thank the following AFREPREN Secretariat staff and interns who assisted in the formatting and cross-checking of energy data and information, and in providing logistical and coordination support to the AFREPREN Renewables and Energy for Rural Development Theme Group: G. Muthee, E. Manyara, A. Boru, R. Wachira, L. Majoro, J. Muthui, J. Kimani, J. Wangeci, A. Maina, P. Musyoki, S. Amenya, M. Gichohi, G. Rubiro, I. Okech, J. Lwimbuli, J. Odero, L. Wambani, F. Muthoni, S. Mwongela, J. Kioko, D. Kedemi, R. Serem, A. Mangea, and T. Ongesa.

Notes on Contributors

The views expressed in this volume are the authors' own and should not be attributed to the institutions and organizations in which they are employed.

Maxwell Mapako holds a BSc. (Hons) in Environmental Studies and Biochemistry from the University of Wales (UK), and a Diploma in Renewable Energy Sources from Urbino, Italy. He has attended various courses on renewable energy technologies and project management and has worked as a senior research officer in the New and Renewable Energy section of the Government's Department of Energy. Currently the Director of the African regional office of the Biomass Users Network, he is the author of numerous publications on biomass energy technologies that have been instrumental in shaping Zimbabwean renewable energy policies and programmes.

Abel Mbewe holds a Bachelor of Engineering in Electronics and Telecommunications from the University of Zambia. Currently on leave of absence from Zambia, he is working as an Energy/Environment Consultant for the Annobil Group. He has attended several courses on energy and environmental issues and his previous appointments include Executive Secretary of the National Energy Council, Zambia.

Joseph Mbaiwa holds an MSc in Environmental Science, a postgraduate Diploma in Education and a BA in Environmental Science and History, all from the University of Botswana. He is the author of various chapters in books and papers, and has participated in a number of national and international meetings and conferences that led to innovative national energy and environmental policies. He has also worked as a research assistant for both government and non-governmental research projects.

Wolde-Ghiorgis Woldemariam holds a PhD from McGill University, Canada, an MSc from Leigh University, USA and a BSc in electrical engineering from the Massachusetts Institute of Technology. He has been involved in energy research since 1981, and has published a wide range of publications on renewable energy use and applied electromagnetic fields. As a member of the Ethiopia Electricity Power Corporation management board, Professor Ghiorgis provides influential technical and policy advice on energy issues to the Ethiopian government.

Semere Habtetsion holds an MSc and a PhD from Sheffield University in the United Kingdom. He also holds a BSc and MSc in Management and Energy Utilization and Conservation from the Technion-Israeli Institute of Technology. He has held several senior positions, including Director of the Planning and Programming Division in Eritrea's Department of Energy and Dean of the College of Science, University of Asmara.

Zemenfes Tsighe holds a PhD from Trieste University in Italy and a BA and MA from Addis Ababa University. He is an Assistant Professor at the University of Asmara and also has professional skills in research administration and consultancy services. An Associate Researcher in AFREPREN's Renewables and Energy for Rural Development theme group, he is the author of numerous publications including conference and professional papers related to development and the environment.

Stephen Karekezi, BSc, MSc, is the Director of the African Energy Policy Research Network (AFREPREN) as well as Executive Secretary of the Foundation for Woodstove Dissemination (FWD) in Nairobi. Having graduated as an engineer, he obtained postgraduate qualifications in management and economics. In 1995 he was appointed to the Scientific and Technical Advisory Panel (STAP) of the Global Environment Facility (GEF) co-managed by the World Bank, UNDP and UNEP. He has written, co-authored and edited some 87 publications, journal articles, papers and reports on sustainable energy development. In 1990 he received the Development Association Award in Stockholm in recognition of his work on the development and dissemination of the Kenya Ceramic Jiko, an energy-efficient cooking stove.

Waeni Kithyoma holds a BA in Economics and German from the University of Nairobi and has undergone further training in research skills, report writing and project management. A programme manager at the AFREPREN Secretariat in Nairobi, she has been involved in research on renewable energy technologies and is the Backstopping Officer for AFREPREN's Renewables and Energy for Rural Development theme group. She has co-authored and co-edited a number of reports and articles on rural and renewable energy in Africa.

Part 1

INTRODUCTION

Maxwell Mapako and Abel Mbewe

Background and rationale

Energy supply is a key factor in economic and social development, but little attention has been given to the needs of rural households, farmers and small businesses. Rural households in sub-Saharan Africa still derive most of their energy from biomass sources. Lack of modern energy services in rural areas constrains efforts to alleviate poverty and improve living standards.

The five country case studies presented in this volume are all part of a common research theme – Renewables and Energy for Rural Development – and constitute the second part of a two-part study. The first, short-term study examined public sector rural energy initiatives that were welfare-focused, while this medium-term study examines the impact of modern energy on income-generating activities.

The countries represented are Botswana, Eritrea, Ethiopia, Zambia and Zimbabwe. The amount of experience with renewables in the countries represented in the theme group varies widely. This is why the country studies focus on different aspects of the theme topic. The Ethiopian and Eritrean studies dwell on seeking to introduce wider utilization of renewables in view of their more limited dissemination in those countries. Zimbabwe has had over 20 years' experience with the dissemination of renewable energy technologies (RETs), and the promise that was seen in renewables has not been realized. The focus of the Zimbabwe study, therefore, is on the lessons learnt and a possible way forward. The Zambia and Botswana country studies fall between these two extremes.

The major objective of these studies was to identify the options for the provision of modern energy services to low-income rural areas, with special emphasis on the productive uses of energy. The study focuses on whether the decentralized approach to energy delivery is better than centralized delivery; on the role of income-generating activities in attracting modern energy to rural areas; and on the barriers to and opportunities for the promotion of renewable energy technologies in rural areas.

The development process in general, and income-generating activities in rural areas in particular, pivot on access to reliable and sustainable modern energy services. However, the interrelationship of modern energy and such factors as (1) the capacity of small and medium enterprises to generate income and employment, (2) gender impacts, and (3) the role of the private sector in energy production and distribution is poorly understood in the region. The study intends to address these and other related issues.

Methodology and approach

Three hypotheses formulated to guide the study were tested after the indicators, data requirements and data sources had been identified. Data gaps were filled through field surveys and interviews with government officials, as well as association leaders and representatives of beneficiaries. Reviews of national, regional and international literature supported the case studies at the heart of the research work.

These case studies were approached from both the rural enterprise side (bottom-up) and the modern energy supply side, which includes the private sector (top-down). The top-down approach examined the current rural energy supply systems with special reference to the following:

- centralized energy delivery systems;
- decentralized energy delivery systems;
- differentiated performance levels.

This broad review of the rural energy supply systems was used to highlight the factors linked to the successes and/or failures of past and ongoing rural energy initiatives. In addition, energy options to overcome observed barriers were identified.

The alternative, bottom-up approach examined rural enterprises from the following points of view:

- energy forms used, energy intensities and their relative importance;
- energy intensities of the various income-generating activities in rural areas;
- the role of enterprises in attracting modern energy;
- structure and ownership (the gender issue).

This was achieved mainly through primary data analysis, involving surveys and interviews in addition to secondary data analysis. Depending on the hypotheses being tackled, either or both of the approaches were used.

In addition to the approaches mentioned above, general principles relating to income and modern energy services were also employed as part of the analytical frameworks. One of these principles is the *energy ladder* concept, which postulates that rural households and rural-based productive and service sector enterprises progress up the energy ladder as income increases. This implies that energy users shift from traditional, inefficient, inconvenient and low-cost biomass sources to more advanced fuels such as modern biofuels, kerosene, diesel and electricity as their income improves. In addition to income, other factors influence progress up the rungs of the ladder: the state of local-area energy infrastructure; awareness of the benefits of bulk purchase of energy supplies; the availability of government subsidies or donor funding; and access to credit facilities to overcome the high up-front cost of modern energy technologies and appliances. Many of these factors tend to work against the low-income rural groups, placing them at a serious disadvantage.

Generally speaking, past initiatives in the dissemination of renewable energy technologies focused on welfare applications, virtually ignoring the productive functions of rural energy such as its use in medium- and large-scale agro-industries. Consequently, opportunities for enterprise development and job generation based on rural energy initiatives have been very limited.

This failure to focus on the income generation potential of promising renewable energy technologies in rural areas has led to increased attention to low-power renewable energy options such as solar electricity. Consequently, rural and renewable energy options for thermal and motive power applications in rural areas are poorly appreciated. The potential for small-scale productive applications of wind pumps for irrigation, small hydro for grain processing, and biofuel-fired crop dryers and industrial boilers has not been exploited and is consequently not well understood. This is unfortunate, since effective dissemination of such technologies could lead to the rapid establishment of important rural-based small- and medium-scale industries that could provide the nuclei for robust rural growth centres.

There is some anecdotal evidence that once a *critical mass* of sustainable rural/renewable energy technologies are in place, a self-driven rural energy industry ensues. Current research literature does not provide reliable quantitative targets that would ensure sustainable and self-driven manufacture or assembly of energy end-use products. Using the solar PV and wind pumps example, it appears that the number of manufacturers/ assemblers is a more important indicator of attainment of the critical mass needed for self-sustainable development. The question of the level of subsidy needed to attain the critical mass is still unclear. Once again, inter-country and intra-country comparisons of the levels of dissemination might provide useful insights.

The medium-term hypotheses

The short-term study which preceded this medium-term study was confined to rural energy initiatives managed by government and utility agencies, with a focus on the policy and institutional/organizational aspects of the modern energy delivery system. To complement this study, the medium-term research deals with rural energy initiatives implemented by both public sector and private sector agencies. The aim is to identify those factors that lead to the success/failure of modern energy supply initiatives to rural areas. To that end, the following hypotheses were formulated and evaluated:

1 Decentralized, private sector energy production and distribution have a better rate of success than centralized, public sector initiatives in delivering modern energy for rural households and income-generating activities.

2 Income-generating activities have greater impact than domestic use in promoting the delivery of modern energy to rural areas.

3 Of all existing and potential components for the promotion of RETs geared to income-generating activities in rural areas, some are far more critical than others and therefore need priority attention and action.

Methodology, data and indicators, and sources of data

We shall now outline the methodology used for tackling each of the hypotheses, the data and indicators required, and the sources of the data. Some of the information was collected using questionnaires, interviews and case studies. The technologies and technical options for the generation and distribution of modern energy vary between the country studies. For example, in all case studies there are diesel-powered generation sets (gensets) and other machinery for agricultural applications, grid electricity, solar photovoltaic installations and various designs of cookstoves and ovens.

In the Eritrea study, one micro-hydro plant for electricity generation, wind pumps, and two biogas digesters for cooking and lighting are cited. None of these are still in operation. Operational renewable energy technologies among those cited are solar thermal and photovoltaic equipment. The Botswana study cites grid electrification by the public and private sectors as well as the distribution of other modern fuels such as paraffin, liquefied petroleum gas (LPG), coal, petroleum products and photovoltaic systems. The Zimbabwe study looks at solar photovoltaic systems, biogas, mini- and micro-hydro, woodstoves, gasifiers, wind pumps and gensets. Generally the numbers of renewable energy technologies in the Zimbabwean study are considerably higher than in most of the other country studies because of sustained dissemination in the decade following independence.

We state each hypothesis in turn below, together with associated research issues, before discussing the relevant data and indicators.

(1) Decentralized, private sector energy production and distribution have a better rate of success than centralized, public sector initiatives in delivering modern energy for rural households and income-generating activities.

ASSOCIATED RESEARCH ISSUE: *Analysis of existing decentralized private sector energy production and distribution activities in rural areas.*

Most government and utility rural energy initiatives are centralized in nature, while those of the private sector are largely decentralized in nature. A comparison of both kinds in terms of major attributes of the initiatives is presented below.

Attributes	Decentralized technology option	Centralized technology option
Technical complexity	Simple manufacturing and metal working	Often complex with 'turnkey' installations
Investment	Small investments for individuals or groups	Large and long-term investment by utilities
Foreign exchange requirements	Generally low	Often high
Modularity	Available at desirable size	Often large-scale
Accessibility	High, short lead time	Limited, long lead time
Labour requirement:		
• per plant	Often low	Often high
• per unit energy generated	Often high	Often low

Methodology

The main methodology adapted to test this hypothesis was a comparative one in which the success/failure rate of decentralized private sector and centralized government and/or utility-led rural energy initiatives were evaluated. Whether the decentralized options have greater participation of women than the centralized options has also been analyzed where data were available.

Indicators

- Increased sales of rural energy technologies from private suppliers;
- Increased number of customers and energy sales in the centralized energy system;
- Effectiveness of centralized/decentralized energy delivery mechanism;
- Rate of switch to modern energy fuels.

Data

- Performance of private sector energy production and distribution enterprises;
- Time series data on sales of energy technologies;
- Time series data of utility sales and growth of customers.

Sources of data

Government documents, including reports, policy statements, project files, and annual reports on the production and distribution of modern energy to rural areas;

- National development plans;
- Interviews with utility company managers;
- Private genset distribution companies and their suppliers;
- Department of Energy reports/project documents;
- Private electrical contractors;
- Utility reports and interviews;
- Project evaluation reports;
- Rural energy needs survey reports.

(2) Income-generating activities have greater impact than domestic use in promoting the delivery of modern energy to rural areas.

ASSOCIATED RESEARCH ISSUE: *Comparative analyses of demand for modern energy in rural areas (actually existing and future potential) created by income generation activities and domestic use.*

It may be inferred that the likelihood of using modern energy technologies for income-generating activities in rural areas could be higher than for domestic level activities in rural areas. One can, therefore, assume that rural energy initiatives aimed at income generating are likely to be more effective in the delivery of modern energy services to rural areas. This hypothesis is effectively testing the above assumption.

In the region, most rural household energy and the energy requirement of rural commercial enterprises is biomass-based, the balance being covered by oil products and electricity. This suggests that income-generating activities attract modern energy services better. Testing the above hypothesis required knowledge of the existing income-generating activities in the case study areas as an indicator of demand threshold, and data on energy intensity by type for rural households and enterprises. Existing and potential demand for modern energy carriers by rural household and enterprises was estimated using the proxy variables of household income and enterprise turnover. Yearly expenditure on modern energy and its share in the respective total expenses for households and enterprises was used to indicate the degree of penetration of modern energy services to these users.

INDICATORS

- Typical rural household income and expenditure on traditional or modern energy;
- Number of income-generating enterprises in the case study areas;
- Rural enterprise turnover and expenditure on traditional or modern energy;
- Degree of penetration of modern energy services to rural households and enterprises, functional and in use.

DATA

- Energy demand (existing and potential) by income-generating activities and households;

- Levels of modern energy consumption by income-generating activities and households;
- Energy expenditure of households and enterprises by type of fuel;
- Number and type of rural enterprises.

SOURCES OF DATA
- Department of Energy annual and project reports;
- Department of Industry report;
- Utility billing systems and private genset operators and municipalities;
- Investment promotion office;
- Central Statistics Office bulletins and reports;
- Business Licensing Office reports;
- Chamber of Commerce;
- Socio-economic study reports;
- Pilot and evaluation project reports.

(3) Of all existing and potential components for the promotion of RETs geared to income-generating activities in rural areas, some are far more critical than others and therefore need priority attention and action.

ASSOCIATED RESEARCH ISSUE: *Analysis of components for promoting the production and deployment of RETs by private entrepreneurs in rural areas – for example, market research, financing mechanisms, provision of infrastructure for production, repair and maintenance, training (entrepreneurial, technical, managerial) and technical back-up.*

There are generally very few RET systems introduced for income generation purposes in the country studies. The focus of the study is therefore to varying extents on the general application of RETs for all end uses.

The research issue which gave rise to this hypothesis is the need for analysis of the importance of the project components for the production and deployment of RETs by private entrepreneurs in rural areas. These include market research and the other components listed above, as well as quality control, gender considerations, and policy support. Thus, identification of the most important barriers/promoters in each country's context is an initial step in testing this hypothesis. Case studies of successful and less successful rural energy projects, and the reasons for their failure or success, were analyzed to identify the most important factors that affect the dissemination of RETs for priority attention by policy makers.

INDICATORS
- Availability of technical support services and financial mechanisms;
- Comparative cost/benefit ratio for investment in RETs by enterprises;
- Commercialization efforts such as market research;

- Existence of essential policy support for the promotion of RETs;
- Quality control procedures and standards.

DATA

- Number of institutions and skilled manpower providing technical support;
- Comparative costs of different energy sources and technologies;
- Efficiency levels of different energy technologies;
- Performance reports of RETs projects;
- Government policy on subsidies, customs tax, licences, etcetera, in relation to RETs and other energy sources.

SOURCES OF DATA

- Department of Energy reports and documents, survey results;
- Interviews with the private RET suppliers and users;
- Reports from the Customs Department;
- Rural electrification studies and masterplans;
- national development plans;
- national energy policy.

Summary of findings and policy options of country studies

Numerous common threads running through the country studies can be discerned. In the cases of Eritrea and Ethiopia, the much more limited diffusion of modern energy means that their experiences are more limited when compared with those of Botswana, Zambia and Zimbabwe. This limits the scope for the comparative analyses called for in the hypotheses.

The country studies generally highlight the role of government in the promotion of RETs, and the greater success scored by the private sector in the dissemination of commercial energy. The centralized dissemination of modern energy is found to have an urban focus and to be associated with centralized production of energy. Governmental focus on renewable energy technologies is weak.

Though there is a trend suggesting that income-generating activities have greater impact in promoting the delivery of modern energy, this is not be confirmed in all study countries because of the limited exposure to modern energy in Eritrea and Ethiopia alluded to above. The dissemination components common to most country studies are appropriate financing mechanisms, training and capacity building, maintenance and conducive institutional arrangements. Below, the study country findings are presented in the sequence of the three hypotheses, followed by the recommended policy options in the following subsections.

Botswana

HYPOTHESIS 1: The decentralized private sector is better placed to effect the production and distribution of modern energy in rural areas than the centralized public sector initiatives. The centralized, grid-based rural electrification is currently performing poorly. The decentralized private sector has been successful in distributing fuels such as paraffin, LPG and coal to rural areas. In areas where the private sector was provided with the opportunity to produce and distribute electricity, it has managed to carry out the responsibility successfully.

HYPOTHESIS 2: Income-generating activities have greater impact than domestic use in promoting the delivery of modern energy to rural areas. Domestic use has so far been unable to promote the delivery of modern energy in rural areas, but the introduction of modern energy technologies in rural areas was shown to increase the establishment of commercial enterprises, thereby alleviating poverty.

HYPOTHESIS 3: The dissemination components that were identified as being critical for the promotion of RETs geared towards income-generating activities in rural areas in Botswana are training, capacity building, financing mechanisms, quality control and market research.

KEY POLICY OPTIONS CONSIDERED VIABLE IN BOTSWANA

- The production and distribution of modern energy to rural areas should be decentralized and handed over to the private sector. The role of government should be limited to facilitation and regulatory interventions in the form of policies and acts. Financing schemes should be put in place to enable private energy providers to produce and distribute modern energy in rural areas, and to help rural communities to afford modern energy. Public awareness should be raised through campaigns promoting the decentralized private sector energy initiatives in rural areas.
- Government initiatives that bring energy to rural areas should target small and medium-scale enterprises rather than targeting domestic consumption. Income-generating activities increase the demand for modern energy in rural areas, hence creating a base upon which modern energy, especially electricity, can be extended to households. Government should continue to sponsor research into appropriate energy sources for rural areas. It is the responsibility of government to generate and disseminate information on the modern sources needed in rural areas.
- Government should establish a national PV credit scheme with easier terms of payment and enact a training policy on PV electrification and relevant standards in order to address the current problems of installation, repair and maintenance of PV devices in rural areas.

- An effective policy is needed to ensure that the grid-based and PV rural electrification in Botswana complement rather than compete with each other. Solar water heaters seem to have a wider market in both rural and urban areas. Wind energy for agricultural purposes remains relevant. Consideration should be given to the further development of these two options in the country.

Eritrea

HYPOTHESIS 1: The major focus of the centralized energy delivery system is on the urban-industrial centres while that of the decentralized system is diffuse. The centralized system cannot fully satisfy the demand for modern energy services. The dissemination of LPG is more successful with the participation of the private sector, though failure to target income-generating activities, bad management and inadequate supervision lead to failure.

The government is promoting RETs through several initiatives including public awareness, installations for welfare purposes, assessment of renewable energy sources, research, training, and customs tax reductions on RETs equipment.

HYPOTHESIS 2: Rural enterprises attract rural electrification, which in turn encourages the development of new enterprises. Rural areas with subsistence farming are unable to attract modern energy services cost-effectively and need initial investment from the government and donors to help them to move on from subsistence farming. Rural enterprises shift towards modern energy services faster than the rural domestic sector. Rural households continue to derive 95 per cent of their energy from biomass and spend a larger proportion of their income on energy compared with small and medium-sized enterprises (SMEs). The contribution of biomass to the total energy consumption of rural enterprises decreased from 76 per cent in 1995 to 50 per cent in 1998.

HYPOTHESIS 3: The use of RETs either for domestic or small rural enterprises is still negligible and there is virtually no access to modern energy. The potential for renewable energy sources in Eritrea is good, and could contribute to improving the security, reliability and sustainability of energy supply in the country. The major barriers to diffusion are high initial cost and lack of suitable financing mechanisms, low awareness among stakeholders, minimal infrastructure for installation and maintenance, shortage of foreign currency, and cultural and gender issues.

KEY POLICY OPTIONS CONSIDERED VIABLE IN ERITREA

- Some Eritrea Electric Authority services have to be decentralized, and government should continue to expand modern energy infrastructure, particularly where the private sector is not prepared to invest. A more conducive investment climate in the energy sector will enable the private sector to complement government efforts.

- The development of rural enterprises should be promoted, using both local and modern energy sources to encourage the transition from subsistence farming and reduce the drudgery imposed by traditional energy usage on women. Subsidies for energy prices or any cross-subsidies amongst energy fuels should be shifted towards the capital costs of first-time use of modern energy in rural areas, particularly for income generation. This will improve the eligibility of rural entrepreneurs for financing.
- The capacity of the Energy Research and Training Centre needs to be enhanced to facilitate resource assessment and the training of RET technicians.

Ethiopia

HYPOTHESIS 1: Continued use of fuelwood has depleted forest coverage in the country from 40 per cent in the 1900s to 3 per cent of the land surface by 2002. Productive activities are dependent on human and animal power. Few modern energy services found in rural areas are dependent on energy supplied by the electric utility in its centralized and decentralized systems. Decentralized and private supply options have been tried, but on lesser scales in comparison with those provided by the public sector. The impacts of both centralized and decentralized rural energy options on gender-related issues are not seen as significant.

Attempts have been made to provide rural energy supply options to rural towns and semi-rural settlements by a decentralized public electric system using diesel generation. Distribution of kerosene supplies from private centralized depots has been reaching rural areas by private and decentralized distributors. Private suppliers/producers continue to be engaged in decentralized electricity supply patterns for isolated/remote rural settlements, but at significantly higher prices.

HYPOTHESIS 2: The link between the demand for modern energy services in rural areas and the creation of income-generating activities (such as the marketing of modern fuels) has not been addressed. In most rural households, the only source of modern energy supply will continue to be kerosene. Use of kerosene in rural areas is extremely low, however, and limited to lighting with very small lamps.

HYPOTHESIS 3: Prioritization of RETs for modernizing productive activities in rural areas has occurred mainly in key agricultural-industrial productive activities – although RETs have yet to be promoted in rural areas for upgrading traditional farming methods and indigenous productive activities, or creating off-farm activities.

KEY POLICY OPTIONS CONSIDERED VIABLE IN ETHIOPIA

- Rural energy supplies, including modern energy, will need to be promoted and provided widely to rural areas in Ethiopia. Public and private sectors will need to be actively involved through both decentralized and centralized supply options. The aim will be to alleviate poverty and to initiate sustainable development.
- It will be important to learn from the experiences of other developing countries, and income-generating activities in rural areas need to be emphasized over domestic use in the rural areas of Ethiopia in promoting modern energy services and supplies such as mini-hydro, wind generators, photovoltaic systems and biogas plants. A policy on incentives and opportunities will facilitate assembly of major components of renewable energy technologies within the country.

Zambia

HYPOTHESIS 1: Centralized public energy delivery systems like electrification through grid extension are expensive and require large investments in infrastructure. Private sector decentralized energy distribution offers a better alternative.

HYPOTHESIS 2: The impact of modern energy is higher in income-generating activities than households, and SMEs are willing to switch to modern energy forms if technologies and financing are made available.

HYPOTHESIS 3: The most critical components that need priority attention in rural energy programmes are financing, market research, training and capacity building.

KEY POLICY OPTIONS CONSIDERED VIABLE IN ZAMBIA

- Private sector participation in the delivery of rural energy services and mobilization of financial and human resources should be encouraged.
- Financing mechanisms for energy projects should be developed, and a critical mass of skilled human resources will be necessary for successful implementation of the rural energy strategy.
- Stakeholder awareness of energy technologies, and promotion of the wider use of energy technologies that have been developed locally, should be included in rural energy programmes.

Zimbabwe

HYPOTHESIS 1: The private sector is almost entirely involved in income-generating rural energy initiatives and has been successful in this. There is some synergy between public sector initiatives and private sector success. The public sector can successfully raise awareness and demonstrate, preparing the ground for private sector enterprises.

HYPOTHESIS 2: Modern energy services open up more opportunities for income generation than traditional energy sources. Some of the opportunities are impossible without modern energy services. It is likely that rural livelihoods will be uplifted through the provision of modern energy services, since these provide an enabling environment for the establishment and growth of income-generating activities.

The average amount of energy consumed by income-generating activities is greater than that for households because income-generating activities target customer bases larger than the typical family size and often rely on processes like welding, soldering, sawing and grinding, which are not encountered in households. The existence of income-generating activities therefore raises the potential market for modern energy services. This is due to the need to improve existing income-generating activities, which can almost always expand production once they have access to modern energy services.

HYPOTHESIS 3: Institutional arrangements that are supportive of energy initiatives, availability of appropriate financing mechanisms, and maintenance were found to be the most important dissemination components for modern energy.

KEY POLICY OPTIONS CONSIDERED VIABLE IN ZIMBABWE

The following recommendations are generally feasible in the medium to long term. Prevailing economic and political difficulties in Zimbabwe constrain short-term prospects for recommendations requiring government and donor funds.

- Policy needs to be sensitive to the needs of smaller income-generating activities, which are mostly owned by the rural poor, and are often home-based. In addition, development of local design and maintenance capacity needs to be given higher priority than dissemination of more new systems. Government demonstration and private sector dissemination have worked relatively well for modern energy sources. A more deliberate approach is warranted where demonstrations are planned with the private sector role and handover mechanisms integrated.
- Modern energy initiatives in rural areas should have a bias towards income-generating activities, and should cover the needs of micro-enterprises (small home-based income-generating activities). In addition, the promotion and dissemination of modern energy services needs to be integrated to enhance support for income-generating activities.
- There is a need to maintain clarity on the roles of government depart-

ments and other stakeholders, especially at this time when restructuring is leading to profound changes in the role of government. Government should require inclusion of maintenance policies in new projects and make this a condition for endorsement or approval.

Part II

AN OVERVIEW

Stephen Karekezi and Waeni Kithyoma

REGIONAL PROFILE

Sub-Saharan Africa

(excluding South Africa):

SELECTED INDICATORS

- Population (million): 631.3 (2001)
- Rural population (million): 421.7 (2001)
- Rural population growth rate (%): 1.8 (average 2001)
- Area (km^2): 22,405,000 (2001)
- GNP *per capita* (US$): 300 (2001)
- Poverty levels: Below one dollar a day (%): 50 (1998)
  Below two dollars a day (%): 81 (1998)
- Commercial energy consumption *per capita* (Kgoe): 669 (2000)
- Biomass contribution to total energy consumption (%): (40–90)
- Electricity consumption *per capita* (kWh): 432 (2000)

Sources: World Bank 2000a; World Bank 2001; AFREPREN/FWD 2001

1

Renewables and Rural Energy in Sub-Saharan Africa

Introduction

In spite of the rapid urban growth experienced by sub-Saharan Africa over the last 20 years, the majority of sub-Saharan Africans still live in rural areas. Although this distribution is likely to change in the not-too-distant future, rural sub-Saharan Africa continues to be home to the majority of Africans (Figure 1.1). It is estimated that 68 per cent of the inhabitants of sub-Saharan Africa live in rural areas (World Bank, 2000a).

The bulk of rural inhabitants are poor, with irregular income flows. Poverty levels in rural Africa range from 50 to 77 per cent if one uses national poverty references (Table 1.1).

The high levels of poverty are reflected in the consumption pattern of modern energy. *Per capita* consumption of modern energy in sub-Saharan African countries is very low when compared to other regions. The low levels of modern energy consumption prevalent in sub-Saharan

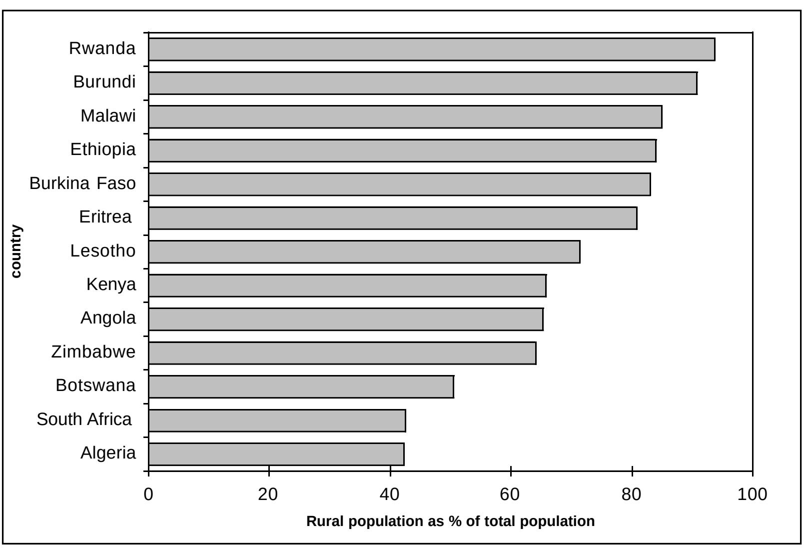


Figure 1.1 Percentage of population in rural areas (1998)
Source: UNDP, 2000

Table 1.1 Rural poverty levels in selected African countries

Country	% of rural population under national poverty line
Djibouti	86.5
Zambia	83.1
Madagascar	76.7
Mozambique	71.3
Ethiopia	61.3
Mauritania	61.2
Gambia	61.0
Uganda	59.4
Tanzania	57.0
Lesotho	53.9
Kenya	52.9
Zimbabwe	48.0
Nigeria	45.1

Source: AFREPREN/FWD, 2002; IDA and IMF, 2000; Word Bank, 2003b

Africa are especially low in rural areas, which are characterized by high levels of traditional biomass energy use (Table 1.2).

The provision of modern energy services to this large segment of sub-Saharan Africa's population is expected to assist greatly in reversing the high poverty levels found in the continent's rural areas.

This chapter provides an overview of the rural energy sector in Africa, with specific emphasis on sub-Saharan Africa. A review of energy use patterns in rural areas is provided in the next section under three broad categories: household energy use; energy for agriculture; and energy use in SMEs. In the third section we review major trends and patterns in the

Table 1.2 Traditional energy consumption as a percentage of the total consumption – selected sub-Saharan African countries (1999)

Country	Traditional energy as % of total energy consumption
Tanzania	95.2
Ethiopia	93.4
Mozambique	93.0
Zambia	78.0
Kenya	77.8
Congo	74.7
Côte d'Ivoire	68.6
Eritrea	66.6
Ghana	67.2
Togo	62.3
Zimbabwe	59.5

Source: IEA, 2002

region's rural energy sector, before offering recommendations in the concluding section on the way forward for providing improved energy services to the rural population and especially the poor.

Energy use in rural sub-Saharan Africa

Biomass energy is the dominant energy form for most African countries. Figures for sub-Saharan African countries indicate that a high proportion of total national energy supply is derived from biomass energy (Figure 1.2). The term 'biomass energy' refers to a wide range of natural organic fuels such as wood, charcoal, agricultural residues and animal waste. Biomass is currently used largely in its traditional and unprocessed form. The bulk of the biomass energy is used for household cooking purposes. Other important end uses of biomass energy in the rural areas include small-scale charcoal production, agro-processing and beer brewing.

As shown in Table 1.3, in the household sector, which is the major consumer of energy, rural households consume higher amounts of energy (Kgoe) than urban households. This is attributable, however, to the high amount of biomass used in rural areas, mostly inefficiently.

Sub-Saharan Africa is the least electrified region of the world, with

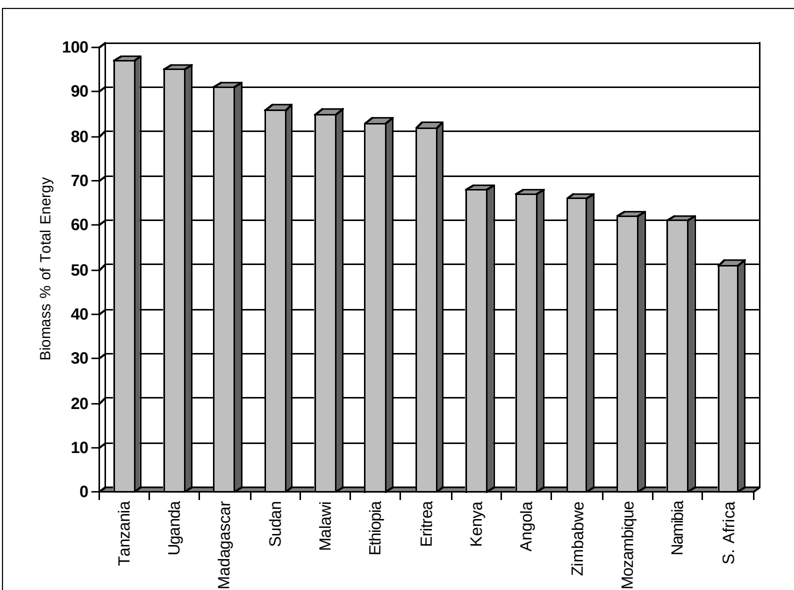


Figure 1.2 Biomass energy as a percentage of total energy for selected Eastern and Southern African countries (2001)

Source: AFREPREN/FWD, 2003

Table 1.3 *Per capita* energy consumption of urban and rural households (Kgoe)

Country	Urban	Rural
Kenya	60	220
Zimbabwe	150	300
Botswana	166	390
Zambia	180	200
Senegal	120	170

Source: African Development Bank, 1996

rural electrifications levels that are routinely below 5 per cent (see Table 1.4). Given that a significant proportion of the rural population is poor, Table 1.4 clearly demonstrates that the rural poor do not have access to electricity in most countries in the region.

Quantitatively, fossil fuels and conventional energy sources such as

Table 1.4 Rural electrification in selected sub-Saharan African countries

Country	% of total population living below the poverty line (majority of whom reside in rural areas)	Rural electrification level
Ethiopia	76.4	0.70
Malawi	54.0	0.05
Mozambique	78.4	0.70
Uganda	55.0	1.00
Tanzania	51.1	1.00
Zambia	86.0	2.00
Kenya	47.0	2.00
Eritrea	Not available	2.00
Botswana	33.0	8.00
Zimbabwe	41.0	18.00

Source: AFREPREN/FWD, 2003; World Bank, 2000a

electricity play a minor role in rural energy supply, as is demonstrated by the low electrification levels. However, the contribution of these energy forms is valuable because of their numerous productive functions. Diesel is used in small agro-processing activities such as grain milling and in rural transport. These are important rural economic activities and may often represent the only major source of income outside the sale of agricultural produce. Similarly, electricity may be used to power equipment repairs and tractors. It is also widely used in small-scale commercial establishments such as restaurants, shops and guesthouses. In addition, electricity is often vital for proper operation of key rural institutions such as schools, dispensaries and hospitals.

With the bulk of the region's poor residents in dispersed rural settlements, conventional grid electrification is considered too costly for most of rural Africa. The dispersion problem is more acute in Eastern and Southern Africa, where, in contrast to the village settlement patterns of West Africa, the majority of the rural population live in dispersed homesteads. The transmission and distribution costs of extending grid electricity to dispersed homesteads is high, thus creating an ideal market for decentralized energy technologies that better match the dispersed nature of sub-Saharan Africa's rural population. As a result, the region is perceived to be the ideal place for the deployment of new and innovative electrification technologies that will be not only cost-effective but also environmentally sound. Renewables are often recommended as the most appropriate energy technology choice for much of rural Africa.

Although the total number of RETs in use is below expectation, substantial numbers have been disseminated in the region. Numerous improved stoves have been introduced in the region with positive results. Wind pumps for water pumping have been disseminated in areas with sufficient wind potential (3 m/s), while pico and micro hydropower have shown potential (Karekezi and Ranja, 1997).

In general, energy use in rural areas can be subdivided into the following three broad categories:

- household energy;
- energy for agriculture;
- energy for small and micro enterprises (SMcEs).

We shall review energy use patterns in each of these categories. Energy use in medium-scale and large rural enterprises – such as sugar, tea and coffee estates – is not addressed because of its indirect link to poverty.

Household energy

The bulk of energy consumed in rural areas is used in households. Households require energy mainly for cooking, lighting and space heating. Cooking accounts for between 90 and 100 per cent of energy consumption. The rest of the energy consumed is for lighting, provided either by woodfuel (cooking fire), kerosene lamps or candles. Space heating is required in areas with cold climates, and is often catered for by energy used for cooking (WEC/FAO, 1999).

Household energy consumption levels and the types of energy used depend on a variety of factors, such as the availability and costs of energy sources. Table 1.5 shows that, as incomes increase, the use of modern energy becomes more prevalent in rural households. For instance, while low-income rural households rely mainly on biomass fuels for cooking, high-income households use modern fuels such as kerosene and LPG.

Firewood remains the most common fuel for cooking in most African countries. As shown in Table 1.6, Botswana, South Africa and Djibouti are exceptions in that although a substantial part of their rural populations use firewood, the use of modern fuels such as kerosene, LPG and electricity is fairly high (World Bank, 2000a).

The predominance of firewood as the dominant source of cooking energy, despite its inefficiency and harmful impact on human health, could be attributed to its availability as a 'free' source of energy.[1] In most cases, firewood is collected and not purchased.

Studies have shown that there are links between biomass combustion

Table 1.5 Rural energy use patterns in sub-Saharan African countries by end uses

End use	Rural household income		
	Low	Medium	High
Cooking	Dung, residues, wood	Dung, residues, wood, kerosene and coal	Wood, kerosene, coal, LPG and biogas
Lighting	Kerosene. candles	Kerosene, candles and batteries	Kerosene, LPG, electricity
Space heating	Dung, residues, wood	Dung, residues, wood, kerosene and coal	Dung, residues, wood, kerosene and coal
Other appliances	None	Grid or genset-based electricity and batteries	Grid or genset-based electricity and batteries

Source: Karekezi and Kithyoma, 2002

Table 1.6 Fuels used for cooking in rural households for selected African countries (% of fuel used)

Country	Firewood	Gas, Kerosene	Charcoal	Electricity	Other
Central African Republic	100	0	0	0	0
Guinea	99	0	1	0	0
Gambia	97	1	1	0	1
Mali	97	0	0	0	2
Tanzania	96	0	3	0	0
Madagascar	94	0	5	0	0
Uganda	94	2	4	0	0
Kenya	93	2	4	0	0
Burkina Faso	91	1	1	0	7
Niger	90	1	0	0	9
Côte d'Ivoire	89	1	2	0	8
Zambia	89	0	9	1	1
Botswana	86	14	0	0	0
Senegal	84	2	12	0	2
South Africa	49	23	5	21	2
Djibouti	44	48	5	1	2

Source: World Bank, 2000a.

and respiratory illnesses in women and children (Karekezi and Ranja, 1997). Women and children are more likely to be adversely affected by particle emissions from biofuel smoke because they spend much of their time near biomass-based cooking fires. Approximately 4–5 million children in developing countries die annually due to acute respiratory infections. A recent study in a rural area in Kenya found that women, who undertook most of the cooking at household level, were exposed to twice as much particulate emission as their male counterparts, and were on average twice as likely to suffer from respiratory infections (Schirnding, 2001).

As shown in Figure 1.3, particulate emissions from the use of fuelwood are significantly higher than the recommended average. In a recent study of indoor air pollution levels, the recommended level concentration of particulates below 10 microns in diameter was set at 150 μg/m^3. The concentration in most homes using biofuels in developing countries, including sub-Saharan Africa, averages 200 to 5,000 μg/m^3 (Ezatti and Kammen, 2002).

The link between rural household biomass energy use and women is one that is often ignored; yet its importance cannot be overstated. The relationship between biomass energy and women's work and well-being is evident in women's role as users of energy sources, producers of

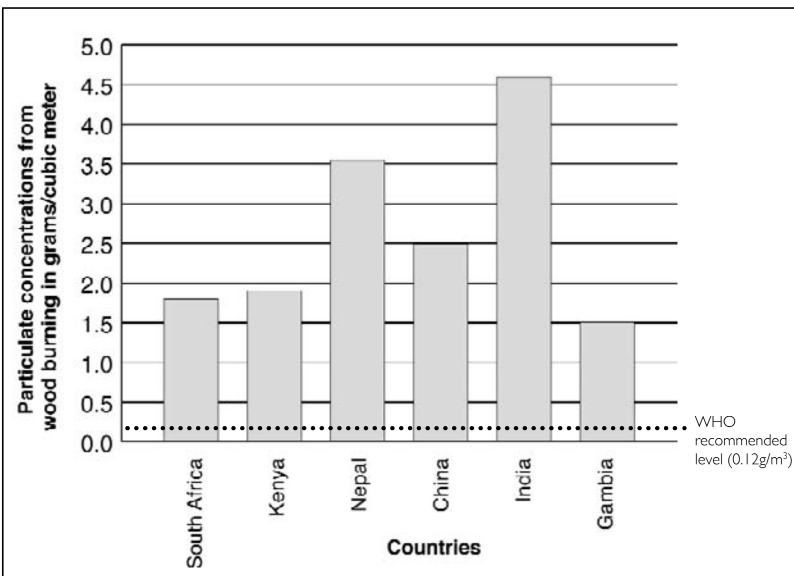


Figure 1.3 Indoor levels of particulates emitted from wood in developing countries

Source: Karekezi *et al*., 1995

traditional biomass fuels, and educators on the collection, management and use of fuels. In addition, women and children are the most vulnerable group in terms of energy scarcity and adverse environmental impacts associated with biomass energy production and use (WEC/FAO, 1999).

Kerosene is the most widely used modern energy source for lighting in rural areas, as in the examples of Botswana and Uganda (Table 1.7). The use of kerosene implies that rural households are willing to incur the relatively high cost of kerosene lamps (wick and pressure) and fuel. Firewood is another important fuel for lighting, and it does not require additional investment. For high-income rural households, electricity (either from the grid or gensets) is an option. Owing to its high up-front costs, electricity is not an important option for low-income households for lighting.

In the recent past, solar PV has been promoted in rural areas for meeting household lighting needs. In Kenya between 1998 and 2001, for example, the PV industry undertook more than US$10 million worth of business (Hankins, 2001). Assuming that most of the PV systems were sold in rural areas, this substantial amount of investment does not seem to have had a significant impact on the level of rural electrification, which is roughly 3.8 per cent (Kamfor, 2002).

Energy for agriculture

The agricultural sector accounts for a substantial proportion of the region's GDP: over 20 per cent in most countries (World Bank, 2000b). Agricultural commodities such as coffee, tea and tobacco often dominate the export sector of most sub-Saharan African countries. For the foreseeable future, heavy dependence on agriculture is likely to continue being the norm rather than the exception for most countries in the region. This is, however, not the case for countries with large mining and oil industries.

In spite of abundant energy resources, available estimates of Africa's energy consumption indicate limited use of modern energy resources in the agricultural sector. The continued low consumption of modern

Table 1. 7 Main source of fuel for lighting in rural areas, Botswana and Uganda, 1994

Type of fuel	Percentage of households using	
	Botswana	Uganda
Paraffin/kerosene	75.76	85.77
Wood/charcoal	11.26	11.37
Candle	8.65	–
Electricity	2.68	1.50
Gas	1.00	0.13
Others	0.64	1.23

Source: Central Statistics Office, Botswana, 1995a; Ministry of Finance and Economic Planning, Uganda, 1995 energy is a source of concern. This could be an indication that the agricultural sector is not getting adequate attention from policy makers in the region in terms of provision of high-grade energy services.

The energy needs of agricultural production in rural areas range from intensive power use in transport, water lifting and pumping, land preparation, and primary and seedbed cultivation, to lighter power requirements for weed control, planting, transplanting and harvesting. Limited use of mechanized agricultural practices in Africa means that human labour continues to be an important source of power for agricultural activities in the continent (FAO/ADB, 1995).

Human power, however, has limited output compared to mechanized power sources. Humans are nevertheless flexible and skilled, and can make sophisticated judgements and adjustments as they work. Table 1.8 estimates animate power requirements for various agricultural activities.

Table 1.8 Human power consumption for various farming activities

Activity	Gross power needed (watts)	KWh consumed (assume 7-hour working day)
Clearing bush and scrub	400–600	2.8–4.2
Felling trees	600	4.2
Hoeing	300–500	2.1–3.5
Ridging, deep digging	400–1000	2.8–7.0
Planting	200–300	1.4–2.1
Ploughing with draught animals	350–550	2.45–3.850

Source: WEC/FAO, 1999; National Energy Foundation, 1995, and Balbach, 2000

An important view to consider when estimating the amount of human energy available for agricultural activities in rural areas is the amount of calories contained in food intake. In many countries in the region, daily *per capita* calorie supply is below 2,000 calories (2.32 kWh), as compared to the recommended daily average calorie intake of 2,200 calories (2.55 kWh) (National Energy Foundation, 1995). For low-income rural inhabitants in sub-Saharan Africa, the typical daily calorie intake is significantly less than 2,000 calories. The daily *per capita* calorie intake needs to be used with caution because it includes allocations for children, who may not be fully involved in agricultural activities, and is partly based on an average *per capita* calorie intake figure that includes urban and higher income groups.

It would appear that the daily *per capita* calorie intake in rural areas is insufficient for a full day's agricultural work (Table 1.8). If one factors in the debilitating impacts of frequent food shortages, famine, disease, drought and floods, it is most likely that few in rural sub-Saharan Africa have access to an adequate calorie intake.

Another potentially important source of power for agriculture found in rural areas of the region is animal traction. Cattle and donkeys can provide transport, pull implements, lift water and be used in agro-processing activities such as cane crushing and threshing. In contrast to much of Asia, use of animal power is underdeveloped in much of sub-Saharan Africa. Reasons for this state of affairs vary; the prevalence of animal diseases such as trypanosomiasis is often mentioned as an important barrier to wider use of animal power (FAO/ADB, 1995).

Semi-mechanized technologies include basic hand tools (hoes, slashers), semi-mechanized hand tools (hand-driven threshers) and animal-drawn tools (ox ploughs). Reliance on hand tools has generally been the norm throughout the region (FAO/ADB, 1995), with limited use of semi-mechanized hand tools and animal-drawn tools. Mechanized technologies such as tractors are not widely used in the region. The stock of tractors in Africa was estimated to be about 540,000 in 1994. Over half these tractors were in three countries: Algeria, Egypt and South Africa. This is less than half the total number used in Latin America, which stood at 1,214,093 tractors in 1994 (WRI, 1998).

Table 1.9 Renewable energy technologies: applications in agriculture

RET	Selected agricultural process
Photovoltaic technologies	Pumping, lighting, cooling, crop processing
Solar water heaters	Dairy processing and heat energy for poultry
Wind pumps	Irrigation, crop processing
Biogas plants	Production of fertilizer
Biofuel cookstoves	Milk pasteurization, heat energy for poultry, crop drying, crop processing

Source: AFREPREN/FWD, 1999

A number of RETs have demonstrated an encouraging level of success in meeting the demand for energy for agriculture in rural Africa (Table 1.9). The following technologies have shown promise: small hydro plants for shaft power and electricity generation; biogas plants, which provide sludge for use as fertilizer; and solar crop dryers.

One technology that could have considerable impact in the region's agricultural sector is wind-driven machines for water pumping and for irrigation. Most countries in the region have wind energy potentials that are sufficient for water pumping (3 m/s). Positive results have already been registered in the Ala Plains of Eritrea, where this technology is in use (Habtetsion and Tsighe, 2001). However, as shown in Table 1.10, with the exception of South Africa and Namibia, this potential has not been exploited fully in most countries (Karekezi and Ranja, 1997), mainly because of the high initial costs: US$1,000–7,000 (AFREPREN/FWD, 2003).

Table 1.10 Wind energy potential and number of wind pumps in selected sub-Saharan African countries

Country	Potential (m/s)	Number of wind pumps
South Africa	7.2–9.7	280,000
Namibia	–	30,000
Kenya	3.0	360
Botswana	3.0	250
Zambia	2.5	100
Tanzania	–	58
Uganda	4.0	13
Sudan	3.0	12
Burundi	2.5	1
Cape Verde	9–10	–
Lesotho	5.0	–
Seychelles	3.62–6.34	–
Mozambique	0.7–2.6	–

Source: Karekezi and Ranja, 1997; AFREPREN/FWD, 2002

Energy use in small and micro rural enterprises

A wide range of SMcEs can be found in rural areas. The term refers to entities that largely rely on family/household members, with limited use of non-household members. Most of these enterprises are based in the informal sector, and can be categorized into commercial/service enterprises and production enterprises. Commercial/service enterprises include small shops, rural guesthouses, beerhalls and battery recharging centres. Production enterprises are largely agro-based or forest-based activities, and include saw milling, grain milling and pottery making.

Table 1.11 Examples of rural income-generating activities

Country	Activities
Ethiopia	Pottery, weaving, dairy processing, local beer brewing, leather treatment, grain milling, small-scale mining, edible oil processing, bakeries, guest houses, shops, candle wax manufacture, honey processing, mechanical and electrical repair workshops
Zambia	Pottery, weaving, dairy processing, local beer brewing, grain milling, small-scale mining, edible oil processing, bakeries, guest houses, shops, candle wax manufacture, welding, tinsmiths, soap making, mechanical and electrical repair workshops
Zimbabwe	Pottery, weaving, dairy processing, local beer brewing, grain milling, small-scale mining, edible oil processing, bakeries, guest houses, shops, candle wax manufacture, welding, battery charging, tinsmiths, blacksmiths, soap making, mechanical and electrical repair workshops

Source: AFREPREN/FWD, 2000

The various small and micro enterprises in different rural areas of the region share similar characteristics, such as reliance on family labour. However, the types may vary depending on cultural and socio-economic conditions. Table 1.11 presents an inventory of rural micro-enterprises in three Eastern and Southern African countries.

Biomass consumption is still dominant in many rural SMcEs. Examples of enterprises that largely rely on biomass include beer brewing, fish smoking, baking and tobacco curing. For example, tobacco curing uses 23 per cent of total fuelwood consumption in Malawi (Kgathi and Mlotshwa, 1997; McCall, 2001), while beer brewing consumes 25 per cent of total fuelwood annually in Zambia (ZERO, 1998). Lighting, motive and shaft power needs of SMcEs are invariably met using modern energy sources, for example, electricity from the grid or from gensets, kerosene or solar PV. Other renewables that have shown potential for meeting energy needs of SMcEs are shown in Table 1.12.

Table 1.12 Renewable energy technologies for small and micro rural enterprises

	Production enterprises	Commercial & service enterprises
Solar drying	Processing of tobacco, timber, coffee, tea, wood and fruits	
Solar water heaters	Crop processing	Clinics, schools
Animal-driven vehicles	Transport	Transport, water pumping
Cookstoves*	Beer brewing	Food kiosks, food preparation for clinics, hospitals and schools
Photovoltaics	Dairy processing	Electrification of small shops, bars, food kiosks, and powering of mobile communication devices
Charcoal kilns*	Production of charcoal for sale in rural and urban areas	

Source: Adopted from Best, 1992a, 1992b

* Only renewable if the source of wood is from planned forests that are regularly replanted.

Estimated power requirements for small industries in rural areas are significantly higher than those of typical rural households. As shown in Table 1.13, these range from 2,000 W (power mills) to 163,000 W (oil mills) (WEC, 1992).

Diesel generators are preferred for applications requiring 3 kWp and above. Micro and pico hydropower is also used to provide motive and shaft power in some countries. Wind pumps and wind generators can be

Table 1.13 Power requirements for agro-processing and power outputs of small-scale PV systems

Agro-processing needs	Average effective mechanical power of small industries (watts)
Power mills	2,200
Saw mills	13,000
Rice mills/groundnut shellers	14,000
Cotton gin mills	33,000
Flour mills	73,000
Oil mills	163,000

Source: Best, 1992a, 1992b

instrumental in the provision of energy to small and micro enterprises. Table 1.14 shows the typical uses of different sizes of wind generators – though the dissemination of wind turbines in the sub-Saharan African region has been very limited. This is partly attributable to low wind speeds and high costs (Karekezi and Ranja, 1997).

Table 1.14 Typical applications of wind generators

Rotor diameter (m)	Typical rated power in 12 m/s wind	Typical use
1	50 W	Battery charging for lighting and communications in remote locations
2	1 kW	Multi-battery charging and communications
6	10 kW	Heating and multi-electrical uses, probably with some battery storage
14	50 kW	Stand-alone electricity generation for communities (small villages)
20	100 kW	Grid connection, export and sale of output to grid company

Source: Karekezi and Ranja, 1997

Emerging trends and patterns

Despite past efforts to accelerate improved energy use in rural areas, traditional biomass energy has continued to dominate rural energy statistics in sub-Saharan Africa. Access to improved energy services in rural areas has not registered significant growth in most countries in the region. The following section briefly discusses emerging trends in the rural energy sector of the country.

Renewables and rural energy – limited policy support

Experience in the region shows that the success of any major national/regional level energy initiative is, to a large extent, dependent on the existing government policy. Government policies are an important factor in terms of their ability to create an enabling environment for the successful implementation of rural energy initiatives.

As mentioned earlier, renewables are often recommended as the most appropriate energy technologies for rural sub-Saharan Africa. As a result, most rural energy initiatives are renewables-based, with the exception of grid rural electrification. Policy support for rural energy is, therefore, often reflected in a country's renewable energy policy.

Most governments do not have a clear-cut policy on the development and promotion of RETs, which continue to be undertaken within an energy planning and policy vacuum (Table 1.15). This is in contrast to the conventional energy sector (electricity and petroleum), which has well-elaborated policy documents and development plans. RETs and rural energy policies are often subsumed in energy policy documents. As a result, rural energy development follows an *ad hoc* path, with little

Table 1.15 Rural energy policies in sub-Saharan Africa

Country	Dedicated rural energy/renewables policy	Coverage of rural energy/ renewables in main energy policy
Botswana	None	• Emphasis on solar energy development
Eritrea	None	• Broad support for the development of renewables without specific targets or interventions
Ethiopia	None	• Broad support for harnessing of renewables, with no specific targets or interventions
South Africa	None	• Specific policies on biomass subsector • Broad support for harnessing of renewables, with no specific targets or interventions
Zambia	None	• Specific polices on biomass sub-sector • Specific support to awareness creation on other RETs
Zimbabwe	None	• Specific policies on biomass sub-sector • Broad support for the economic harnessing of other renewables

Source: Compiled by authors

recourse to national energy plans, which are rarely available or else out of date and inadequate (Karekezi, 1988).

Most of the early policy initiatives on renewables in the region were driven by the oil crises of the early and late 1970s. In response to the crises, governments established either an autonomous Ministry of Energy or a department dedicated to the promotion of sound energy policies, including the development of RETs. For example, Zambia responded by outlining policy proposals in its Third National Development Plan (1979-83) to develop alternative forms of energy as partial substitutes for conventional energy resources. Unfortunately, once the energy crisis subsided, government support for energy development and RET activities diminished significantly. Currently, most of the remaining support is at rhetorical level.

A survey carried out in Botswana revealed that about 57 per cent of the respondents had no knowledge of government policies designed to promote the use of RETs (Mosimonyane, 1995). In Malawi, the policy vacuum has meant that the majority of RET dissemination efforts have not only been *ad hoc*, but have operated largely as informal sector activities outside the framework of government machinery, thus failing to mobilize the fiscal support of the central government and its major donors (Kafumba, 1994). A study on wind energy undertaken in Kenya showed that Dutch aid officials would have been interested in financing wind projects if there was an official wind energy policy strongly supported by the government of the day (Karekezi and Ranja, 1997).

In addition to the lack of dedicated policy documents on renewables and rural energy, independent rural energy agencies are virtually non-existent in the region. In comparison to the conventional energy sector, which has well-established institutions and agencies, very few countries in the region have dedicated rural energy institutions. In cases where these institutions exist, their focus is on conventional grid electrification, with little attention paid to other rural energy technologies.

Limited policy support for renewables and rural energy is further demonstrated by the low budgetary allocations to renewables in most countries. Most countries place more emphasis on the petroleum and power sectors, which supply a small portion of the population, than on renewables (especially biomass), which supply a large portion of the population.

Energy investment patterns and energy use in the region are shown in Figure 1.4. The large-scale conventional energy sector serves a smaller proportion of the population, but receives the bulk of energy investments in most sub-Saharan African countries.

Very little expenditure is allocated to small and medium-scale RETs as compared to the conventional energy sector. For example, investment trends in Ethiopia's energy sector reveal heavy investments in the electricity and petroleum subsectors. As shown in Figure 1.5, investments in petroleum quadrupled from 1990–2000, while investments

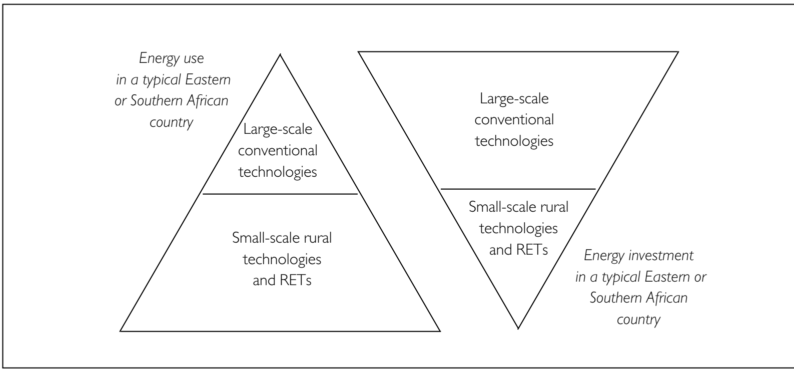
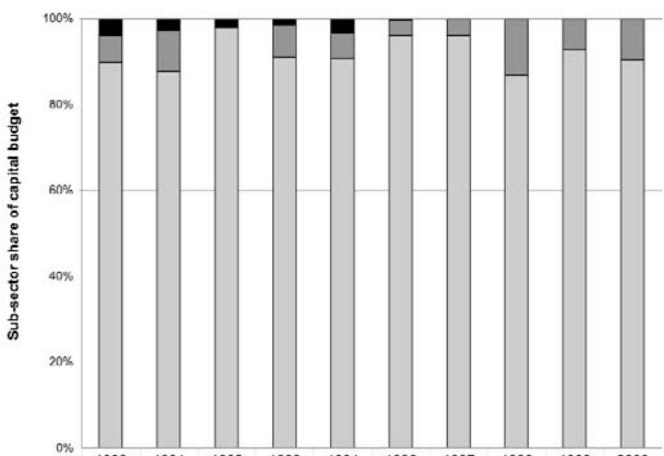


Figure 1.4 Energy use vs energy expenditure in a typical sub-Saharan African country

in electricity almost tripled in the same period. In contrast, expenditure on traditional and alternative energy (which includes RETs) has steadily decreased from about 1 per cent of total expenditure in 1990, to 0.1 per cent of total expenditure in the year 2000 (Wolde-Ghiorgis, 2002).

Only 2.9 per cent of total forecast expenditure for the energy sector in Kenya was allocated to renewable energy, as shown in Table 1.16 (Ministry of Energy, 1987). In addition, the public investment plan indicates that only 1 per cent of priority project investment for the energy



	1990	1991	1992	1993	1994	1996	1997	1998	1999	2000
■ Traditional and alternative	14.2	5.9	4.0	4.1	10.5	0.7	0.5	0.5	0.4	0.5
▪ Petroleum	21.8	19.8		20.1	16.9	5.5	36.1	81.0	93.2	94.3
□ Electricity	314.0	182.0	187.0	240.0	267.0	145.0	861.0	539.0	1,209.0	886.0

Figure 1.5 Energy sector capital budget shares (%) and total budget shares (million Birr) for Ethiopia, 1990–2000

Source: Wolde-Ghiorgis, 2002

Table 1.16 Gross expenditure forecast for the energy sector, Kenya (1987–2000)

Subsectors	Total (Thousand Kenyan pounds)
Administration services	11,515
Planning services	6,677
Solar and wind energy	4,423
Woodfuel resources	74,321
Other biomass resources	2,057
Petroleum exploration	32,118
Electric power generation	1,985,210
Transmission lines/substations	141,158
Distribution	178,550
Geothermal exploration	80,200
Rural electrification	224,081
Total gross expenditures	2,740,311

Source: Ministry of Energy, 1987

sector was allocated to small and medium scale RETs in 1999/2000 (Ministry of Finance and Planning, 1998).

The Public Investments Plan for Uganda, which highlights priority projects for funding by government, indicates that RETs were not considered priority investment projects in the energy sector portfolio. Out of 12 priority projects in 1994/5–1996/7, only two were RET projects, accounting for only 0.3 per cent of total estimated budget for that period (Ministry of Finance and Economic Planning, 1994).

Although the expenditure on renewable energy has been increasing over the years in Botswana, the bulk of expenditure is allocated to rural

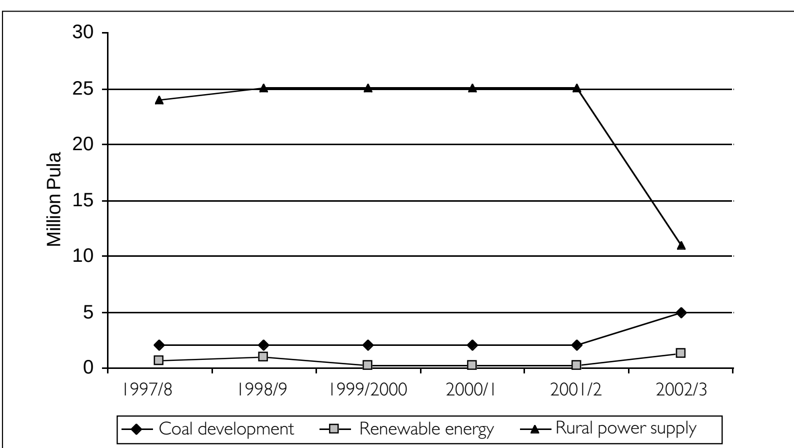


Figure 1.6 Energy sector development expenditure in Botswana (1997–8)

Source: Ministry of Finance and Development Planning, 1997 power supplies, which mainly involves the extension of the grid to rural areas. Figure 1.6 provides trend data on expenditure in the energy sector in Botswana.

The planned disbursement for the energy sector in Zambia indicates a heavy emphasis on electrification (mainly grid extension). Only about 2.5 per cent of planned investments in the public investment plan are allocated to RETs, namely micro-hydropower (1.5 per cent), woodfuel efficiency (0.2 per cent), and solar PV (0.8 per cent) (Ministry of Finance and National Planning, 2002).

Rural energy programmes in Africa are unlikely to register significant development and dissemination without supportive government policies, which are backed by the requisite budgetary allocations.

Rural electrification

As the region with the lowest electrification levels in the world, sub-Saharan Africa has had a number of initiatives aimed at increasing access to electrification. External observers and experts react with a great deal of concern when shown data indicating that in a typical sub-Saharan African country, less than 5 per cent of the rural population have access to electricity. Since most of the experts come from countries with almost universal electricity access, any form of development without electricity is to them unthinkable. Consequently, numerous electrification programmes have been launched in the region. However, rural electrification levels in the region have continued to be woefully low (Table 1.17), with the exception of South Africa and Mauritius.

Almost every country in the region has a rural electrification programme. In most cases, the programme is financed by a levy imposed on electricity consumers. Although funding for rural electrification programmes has increased over the years in most countries, this has not been matched by increased access to electrification.

For example in Kenya, the Rural Electrification Programme (REP) has seen its revenue grow steadily from close to Ksh 200 million in 1993 to over Ksh 1 billion in 2001. Yet the number of new customers added to the programme each year has fluctuated but not improved. Strangely enough, the number of new connections in 1993, when revenue was about Ksh 200 million, was the same as in 2001, when the Rural Electrification Fund (REF) obtained about Ksh 1 billion, a staggering 5-fold increase in revenue. Looking at the scenario in another way, in 1993 the cost per connection was about Ksh 38.431, while in 2001 it cost the REF Ksh 226.030 to connect a new customer. This shows that, although increased funding is going into the programme, there does not seem to be a commensurate effort at increasing the number of customers added to the programme each year (Karekezi, Kimani and Mutiga, 2003).

As shown in Figure 1.7, the reform of the electricity sector through the enactment of an electricity act seems not to have had any significant impact on rural electrification levels.

Table 1.17 Rural electrification levels in selected sub-Saharan African countries

Country	Rural electrification levels % (2001)
Ethiopia	0.20
Malawi	0.05
Mozambique	0.70
Tanzania	1.00
Uganda	1.00
Kenya	2.00
Eritrea	2.00
Zambia	2.00
Swaziland	5.00
Botswana	8.00
Namibia	15.00
Zimbabwe	19.00
South Africa	50.00
Mauritius	100.00

Sources: AFREPREN/FWD, 2001; Karekezi and Kimani, 2002; Teferra, 2000; Mapako, 2001; Kayo, 2001; Mbewe, 2000; Chiwaya, 2001; Dube, 2001; Nyoike, 2000; Mogotsi, 2000; Mandhlazi, 2000; Chandi. 2000; Katyega, 2001; World Bank, 1996; NER, 2001

In cases where electricity is provided in rural areas, it is often unaffordable to the poor, who therefore cannot access it. In the foreseeable future, it is unlikely that rural electrification levels in most countries in the region will substantially increase. There is need to rethink the design and implementation of rural electrification programmes carefully.

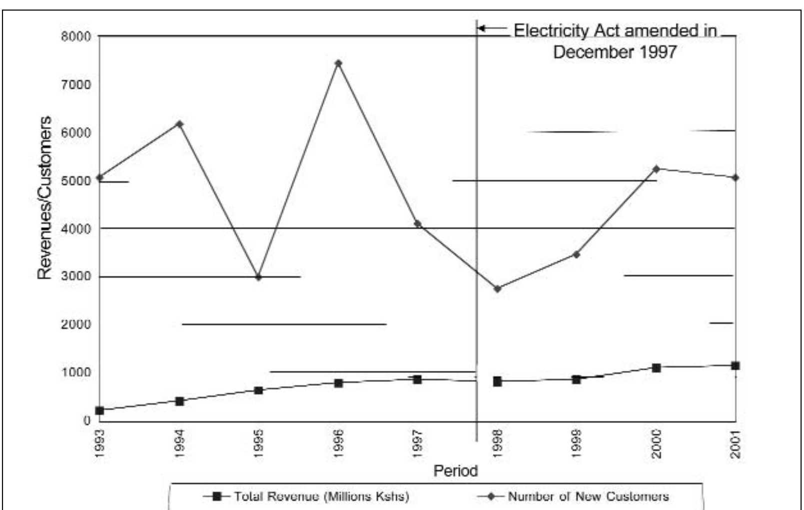


Figure 1.7 Rural electrification revenue and number of new rural customers, Kenya

Source: KPLC, 1997, 2001/2; Republic of Kenya, 2003

In particular, the emphasis on grid electrification is one that needs detailed assessment.

In the absence of the grid, conventional wisdom on how to increase modern energy use in rural sub-Saharan Africa often perceives solar PV as the most attractive option. It is argued that PV is ideal for the dispersed rural households and enterprises of Africa and is, in the long-term, a cheaper option than grid-based electricity. Many national renewable and rural energy strategies give priority to the dissemination of PV technology.

Almost every country in the region has had a solar PV project. This substantial investment and emphasis on solar PV, however, has not been matched by increased access to modern energy, especially in rural areas. This is evident in the very low rural electrification levels common in the region.

In spite of high expectations and significant investment levels, the dissemination levels of PV technology in sub-Saharan Africa continue to disappoint. The expectation that millions of rural homes would install PV systems has failed to materialize (Mapako 2003; Mulugetta *et al.*, 2000; AFREPREN/FWD, 2002).

High cost is one of the most important barriers to greater dissemination of PV technology in sub-Saharan Africa. The cost of a typical low-end PV household system is several times higher than the GNP *per capita* of most sub-Saharan African countries (Table 1.18). This comparison actually underestimates the relative high cost of the PV systems because the GNP *per capita* figure overestimates rural incomes by including the high-income urban residents. Rural inhabitants of sub-Saharan Africa are poorer than their urban counterparts and their income flows are often less regular.

Table 1.18 GNP *per capita* and cost of 40–50 Wp solar PV system

Country	GNP per capita (1999)	Estimated cost of solar PV system (40–50 Wp) US$	% of estimated cost of solar PV system per GNP *per capita*
Zambia	330	1200	363.63
Uganda	310	1037	334.52
Eritrea	200	600	300.00
Kenya	350	620	177.14
Lesotho	570	1000	175.44
Zimbabwe	610	800	131.15

Source: World Bank, 2001; AFREPREN/FWD, 2001; Peters and Kijek, 1992

Another way of looking at Table 1.18 is to divide the cost of a typical low-power PV system by the GNP *per capita*. It translates the expenditure on the PV systems to an outlay of between 131 and 364 per cent of the prevailing GNP *per capita*. This averages to about 200 per cent of the GNP

Table 1.19 GNP per household and cost of 40–50 Wp PV system

Country	GNP *per capita* (1999)	Estimated household income (GNP x 6)	Estimated cost of solar PV system (40–50 Wp) US$	% of estimated cost of the PV system per estimated household income
Zambia	330	1,980	1200	60.61
Uganda	310	1,860	1037	55.75
Eritrea	200	1,200	600	50.00
Kenya	350	2,100	620	29.52
Lesotho	570	3,420	1000	29.24
Zimbabwe	610	3,660	800	21.86

Source: World Bank, 2001; AFREPREN/FWD, 2001; Kijek *et al.*, 1994

per capita, and, applied to the USA or a typical European country, would translate as an expenditure of over US$50,000, or almost twice the cost of a medium-range saloon vehicle. It is unlikely that anyone in the USA or Europe would be willing to make such an investment for a device that delivers some light and powers a radio and perhaps a black and white TV. On the other hand, it is quite feasible to expect a typical small-scale entrepreneur in the USA or Europe to start a business with such a sum. The most successful renewable technologies in rural Africa are likely to be the ones that can generate income and facilitate the start-up of small or micro enterprises. PV is generally unsuitable for powering rural enterprises.

One could argue that the use of the GNP *per capita* figure is misleading, as it does not represent household income. The typical size of a rural household is about six persons. Multiplying GNP *per capita* by six should provide a more realistic figure of income. But, as shown in Table 1.19, the cost of a typical PV system is still prohibitive: between 22 and 61 per cent of GNP per household.

An even more realistic assessment would be to compare the cost of a typical PV system with estimated rural household incomes as shown in Table 1.20. The comparison still indicates that the cost of a PV system is too expensive for most poor rural households – it is equivalent to between 100 and 200 per cent of the annual income of a rural household.

Table 1.20 Annual rural household incomes for selected countries

Country	Annual rural household income (US$ in year 2000)
Eritrea	372
Ethiopia	528
Zambia	768

Source: AFREPREN/FWD, 2001

Even when one considers smaller PV systems, their costs are still beyond the reach of majority of the population (Table 1.21). Investment in a PV system would imply allocating a significant proportion (88–125 per cent) of income on an energy technology for lighting. At the household level, electricity from PV has little impact on cooking in rural households, which is the highest end use of household energy.

Table 1.21 Cost of smaller PV systems in Kenya vs *per capita* income

PV system size	Cost of system US$	*Per capita* income	% of estimated cost of solar PV system per GNP *per capita*
10 W	310	350	88%
15 W	335	350	95%
20 W	440	350	125%

Source: AFREPREN/FWD, 2001

For many rural households, the capital required to purchase a PV system represents a huge investment. For example, in Kenya, the typical cost of a PV system can purchase up to three cows, which can transform the lives of a typical rural family. Alternatively, the household may prefer to purchase four or five bicycles (more if procured on the second-hand market), which can be leased and provide the family a steady stream of income. In some parts of sub-Saharan Africa, the investment cost of a typical PV system could build a new house for the family. Additional comparative costs of rural energy devices that could significantly improve rural household income are given in Table 1.22.

Studies in Kenya and Namibia confirm that most poor rural households cannot afford even the low-end 18 Wp PV solar systems. This assessment is further bolstered by the fact that the largest number of installations is found in the richer African countries such as South Africa and Namibia. The GDP *per capita* levels of these two countries are 6 to 10 times higher than the typical GNP *per capita* of most sub-Saharan African countries (World Bank, 2001).

It is often argued that the removal of duty and import taxes, combined with the introduction of credit systems, would make PV systems more affordable to the rural poor households. This argument would also apply to alternative investments. Might it be more useful to remove duties and taxes and institute credit systems on energy technologies that would generate income and create micro enterprises in rural areas?

Substantial financing in the form of grants and credit has been provided to various initiatives disseminating PV technologies in rural Africa. Experience to date, however, has fallen below expectations. For instance, the UNDP/GEF project in Zimbabwe, with funding of US$7 million, installed just over 10,000 systems over six years (Hankins, 2001; Mulugetta *et al.*, 2000). However, about 63 per cent of systems are not

Table 1.22 Comparative costs of solar panels and other rural energy devices

Prices of solar PV panels in Kenya in 2001	
Sizes of panels	Cost of panel only (in US$)
10 W	72
15 W	89
20 W	137
40 W	210
50 W	261
60 W	350
110 W	529
120 W	580

Comparative costs	
Improved firewood stove	2
Kerosene stove	5
Solar dryer	10
300 W micro-hydropower generator	30
Manual grinder	56
Manual water pump	63
Animal-drawn cart	70
Animal-drawn plough	100
Sewing machine	115

Source: AFREPREN/FWD, 2001

fully operational (Mapako, 2003). Despite the substantial growth of companies in the PV sector during the implementation of the project (from a handful to 60 by late 1997), only 15 companies existed by the year 2000. In addition, affluent rural households purchased most of the systems, since over 80 per cent of the rural population could not afford the smallest systems even at the cheapest rates. Stringent requirements for loan applications excluded the majority of the rural population from qualifying (Mulugetta, *et al.*, 2000; Mapako, 2001). In another study on the viability of PV in Manicaland, Zimbabwe, 65 per cent of the rural population could not afford to pay the solar service fee (the lowest cost possible for providing PV-based electricity), while 91.5 per cent could not afford a credit scheme (Cloin, 1998).

The less visible but equally important drawback of PV technology is its high reliance on imported components. Well over 50 per cent of the cost of PV technology consists of the panel and solar battery, which are often imported: as a result, the potential of PV technology in local job creation is severely reduced.

The high import content of PV technology adds an additional load to the foreign exchange reserves of sub-Saharan African countries, which are often miniscule and perennially close to exhaustion. With diminishing revenue from unprocessed commodities, the export earnings of most countries have been on a downward trend with little prospect of better world prices in the foreseeable future. For example, sub-Saharan African countries that largely rely on coffee as their main export have seen world prices of coffee fall by two thirds in the last few years. Promoting a technology such as PV with high import content in countries facing a massive fall in export earnings is not good macroeconomic practice.

It is, therefore, evident that future renewable energy strategies in sub-Saharan Africa should de-emphasize PV and give greater prominence to a wider range of renewables that offer more attractive opportunities for income generation and job creation.

The way forward

In the near to medium-term future, greater emphasis on electrification of rural households is unlikely to succeed and would not address the needs of the rural poor in sub-Saharan Africa. What are urgently needed are technologies that can quickly increase incomes to the rural poor in sub-Saharan Africa, while providing improved energy services to the rural areas. Energy technologies that are primarily designed to generate electricity are unlikely to be the best candidates, primarily for reasons of cost.

The reality of the rural energy sector is that biomass energy use is bound to continue being dominant. While biomass energy is often perceived in a somewhat negative light, there are attractive opportunities for using biomass energy in more modern, efficient and environmentally attractive ways (Karekezi and Ranja, 1997).

At the household level, improved rural woodstoves, which are designed to reduce heat loss, increase combustion efficiency and attain a higher heat transfer, would be appropriate for dissemination. However, despite these obvious benefits, improved rural stoves have continued to display low penetration rates when compared to urban stoves, as shown in Table 1.23. Increased dissemination of these stoves in rural areas of the region therefore needs to be aggressively pursued.

Other benefits that could accrue from increased use of improved biomass technologies include the alleviation of the burden placed on women in fuel collection, freeing up more time for women to engage in other activities, especially income-generating activities. The production and dissemination of improved stoves in rural areas is also likely to benefit women. An example is the Maendeleo/Upesi stove, which was produced and disseminated in Kenya under the Women and Energy Project.

Improved biofuel institutional stoves have also been disseminated in several countries within Eastern and Southern Africa, and would be ideal for rural institutions such as schools and hospitals. These stoves are designed to reduce running expenditure for institutions through reduced woodfuel consumption (Karekezi and Ranja, 1997).

Table 1.23 Dissemination of improved biofuel stoves in selected sub-Saharan African countries

Country	Improved household stoves disseminated
Botswana	1,500
Malawi	3,700
Zimbabwe	20,880
Sudan	28,000
Ethiopia	45,000
Eritrea	50,000
Uganda	52,000
Tanzania	54,000
South Africa	1,250,000
Kenya	1,450,000

Source: AFREPREN/FWD, 2002

At small and micro enterprise level, biomass energy is an attractive fuel for small-scale industrial boilers found in many rural agro-industries. In addition, there are technologies that can improve the efficiency of biomass in traditional energy-intensive rural productive activities such as charcoal production, crop drying, fish drying and beer brewing.

Small and medium-scale renewables and other rural technologies are important options for poverty alleviation, and should be given greater priority in rural energy initiatives. This is particularly true of renewable energy technologies that are locally made and operate on the basis of solar, thermal and animate power. These sets of renewable energy technologies are not only affordable to the very poor but can be a source of jobs, employment and enterprise creation for the rural poor in Africa. A model example of this is the treadle water pump promoted by Approtec in Kenya. About 24,000 of the low-cost micro-irrigation pumps, dubbed 'money-maker', are in use in Kenya. The pumps have had direct impact on poverty alleviation. Small-scale and subsistence farmers have experienced up to ten-fold increases in income. About 16,000 jobs have been created, and four manufacturers of the pumps are operational in Nairobi, Kenya and Arusha, Tanzania (Approtec, 2001).

Another example is the solar dryer, which is easy to construct and affordable and can result in significant improvement of rural incomes. Solar dryers allow rural farmers to store their produce over a longer period of time. Farmers are able to sell the produce during low season, thus realizing higher prices. In Uganda, for instance, solar dryers were introduced as a way of curbing post-harvest losses and improving food security in one rural area. Over time residents of the area became more interested in solar dryers for income generation rather than for food security. A company was formed to provide solar dryers to rural groups.

The rural groups would invest US$100, and would be provided with a solar dryer and become suppliers of dried fruit. In 1995, about 40 tonnes of dried fruits were exported from the area. This project resulted in benefits to the rural communities. For example, one women's group that became a supplier of dried fruits using solar dryers recorded incomes of about US$75 for each woman. The use of solar dryers has resulted in increased food security and the generation of employment and incomes in the rural area (Okalebo and Hankins, 1997).

The Upesi Stove Project in Western Kenya, mentioned earlier, provides an additional example of the impact of small-scale improved energy technologies in rural areas. The Women and Energy Project of the Ministry of Energy in Kenya initially spearheaded the production and dissemination of the Upesi stove. The project had the overall objective of improving the living conditions of Kenya's rural population by reducing fuelwood requirements and improving fuelwood availability (Muriithi, 1995).

Given the difficulty faced in disseminating the Maendeleo stove in rural areas, the Intermediate Technology Development Group (ITDG) renamed the stove 'Upesi' and promoted its commercial production in west Kenya. ITDG focused on benefits to the producers and the development of a commercial market for the stoves.

Women were the main implementers of the ITDG project, and 19 women's groups were trained on the manufacture of the stove. To date, ten of these groups have been recognized as producers of the stove. This has had a positive impact on the recognition of women's status in Kenyan society and their right to control household budgets.

The project developed a participatory approach to ensure that the producer groups controlled the extent of their involvement in the project and the nature and pace of their training. The aim is to ensure that only the most motivated and best-organized groups continue with the training and production. This competitive aspect has had a positive impact on the quantity as well as the quality of stoves produced.

Overall, the project has achieved significant results. Annual production is over 12,000 Upesi stoves and 2,500 liners for the Kenya Ceramic Jiko. The total profit generated by the production of the stoves is estimated to be between 217,500 and 397,500 Kenya shillings (US$2,788–5,096) (Khennas *et al.*, 1995). The project provided the opportunity for women to engage in income-generating activities, and has undoubtedly improved their livelihood and welfare.

Other technologies that offer a greater range of income generation benefits at relatively low cost, and should therefore be promoted in rural areas of sub-Saharan Africa, include:

- Low-cost efficient hand tools and animal-drawn implements, which would increase the agricultural productivity of rural Africa;
- Low-cost and more efficient biomass-based combustion technologies

(improved cookstoves, efficient charcoal kilns, brick-making kilns, fish smokers, tea dryers and wood dryers);
- Pico and micro hydropower for shaft power that can be used to process agricultural produce and increase its value (IN-SHP, 1999);
- Ram pumps for irrigation, which increase agricultural outputs and thus generate income for the farmer (Hislop, 1992);
- Solar water pasteurizers that provide clean potable water and reduce water-borne diseases: the longer-term result is increased availability of labour and, thus, greater agricultural output and income (Torres and Salas, 2001).

A renewable energy strategy that relies on a wider range of renewable technologies (such as those mentioned above) can ensure that the poor select the technology that best fits their comparative advantage as well as their incomes. For example, if a rural farmer is near a river or stream, pico/micro hydro might be appropriate. If the farmer happens to live near a ready supply of wood from planted forests, or near a sawmill with plenty of wood waste available, biofuel technologies might be the best option. Rural energy programmes should be redesigned to encompass other non-electrical, mechanized and animate technologies. These technologies are more affordable to the rural poor, and can be used in income generation.

Sub-Saharan African countries need to develop rural energy technology strategies that rely on a diverse set of technologies that are not confined to PV electrification and that reflect their national natural endowment profiles as well as the incomes of the poor, who constitute the majority of rural sub-Saharan Africa inhabitants. If a proportion of the funds for rural electrification were allocated to the promotion of non-electrical technologies, this would result, given their low cost, in the significant dissemination of these technologies.

In the near term, the ideal institutional solution would be to transform current rural electrification programmes and agencies into rural energy agencies that are given the mandate to disseminate the rural energy technologies mentioned above. This institutional innovation would allow a portion of the very substantial rural electrification levies and funds to be used to disseminate and promote non-electrical renewable and rural energy technologies. In many sub-Saharan African countries, this change could result in a massive increase in funds available for renewables and rural energy technologies, and, at a stroke, transform the renewables and rural energy subsector.

Proactive and long-term renewable and rural energy policy and institutional innovations such as this, aimed at senior decision makers in both government and the private sector, should be promoted. The policy programmes should be designed to demonstrate the economic and environmental benefits of renewables technologies to sub-Saharan Africa's poor; and they should propose short- and medium-term policy initiatives that would engender large-scale dissemination of renewables.

Priority should be given to highlighting the real and tangible economic benefits (such as job creation and income generation) that renewable and rural energy programmes can deliver to the region at both the micro and macro levels. For example, renewable and rural energy technologies are generally more labour-intensive than conventional and centralized energy projects and can help to address problems of employment of the urban and rural poor. Empirical data and information on this would possibly result in higher budgetary allocations to the development of renewables and other rural energy technologies, and result in improved energy services for the rural poor.

References and Select Bibliography

AFREPREN/FWD 1999. *Renewables and Energy for Rural Development Theme Group: Data and Statistics and Methodology Handbook*. Nairobi: AFREPREN/FWD Secretariat.

—— 2000a. 'Renewables and Energy for Rural Development Theme Group Proposal'. Nairobi: AFREPREN/FWD Secretariat.

—— 2000b. 'RETSCAP Newspaper Cuttings'. Nairobi: AFREPREN/FWD Secretariat.

—— 2001. Master Energy Database. Nairobi: AFREPREN/FWD Secretariat.

—— 2002. *African Energy Data and Terminology Handbook*. Occasional Paper No. 13. Nairobi: AFREPREN/FWD.

—— 2003. *Updated Energy Data Handbook*. Nairobi: AFREPREN/FWD Secretariat.

African Development Bank 1996. *Household Energy Consumption Pattern in Africa*. Abidjan: African Development Bank Group.

Approtec, 2001. 'Micro-Irrigation Technologies'. www.approtec.org/tech_irrigate. shtml. site, accessed 3 May 2003.

Balbach 2000. 'How Many Calories Am I Using to Exercise?' World Wide Web.

Best, Gustavo 1992a. 'Energy, Environment and Sustainable Rural Development'. *World Energy Council Journal*, December 1992. London: WEC.

—— 1992b. 'The Role of Renewable Energy Technologies in Rural Development', in M. R. Bhagavan and S. Karekezi (eds), *Energy for Rural Development*. London: Zed Books.

Dube, I. 2001. 'Energy Services for the Urban Poor in Zimbabwe: Second Draft Report'. Nairobi: AFREPREN/FWD Secretariat.

Chandi, L. H. 2000. 'Renewables and Energy for Rural Development with a Gender Perspective: First Draft Research Report'. Lusaka.

Cloin, J. 1998. *PV on Thatch: a Search for Opportunities of Sustainable Implementation of PV in Manicaland, Zimbabwe*. Netherlands: Einhoven University of Technology.

Chiwaya, A. 2001. *Energy Sector Reform Theme Group: Data and Statistics Compilation – Malawi*. Nairobi: AFREPREN/ FWD.

Ezzati, M. and Kammen, D. 2002. 'Household Energy, Indoor Air Pollution and Health in Developing Countries: Knowledge Base for Effective Interventions'. *Annual Review of Energy and the Environment*, 27. USA: Annual Reviews.

FAO/ADB 1995. *Future Energy Requirements for Africa's Agriculture*. Rome: Food and Agriculture Organization.

Habtetsion, Semere 2001. *Energy for Rural Development in Eritrea – Proceedings of a National Policy Seminar*. Nairobi: AFREPREN/FWD.

Habtetsion, Semere, and Tsighe, Zemenfes 2001. 'Current Energy Utilisation Patterns in Rural Eritrea'. Unpublished research report. AFREPREN/FWD.

Hankins, M. 2001. 'Commercial Breaks – Building the Market for PV in Africa'. *Renewable Energy World*, July–August, 2001. London: James & James Science Publishers Ltd.

Hislop, D. 1992 *Energy Options: an Introduction to Small-scale Renewable Energy Technologies*. London: ITDG.

IDA and IMF, 2000. UGANDA: *Poverty Reduction Strategy Paper and Joint World Bank–IMF Staff Assessment of the PRSP, IDA and IMF*, Kampala, Uganda.

IEA 2002. *Energy Statistics and Balances of Non-OECD Countries*. Paris: Organization for Economic Cooperation and Development (OECD)/International Energy Agency.

IN-SHP 1999. *Small Hydro Power News*, 3. Hangzhou, China: International Network for Small

Hydro Power.
Kafumba, C.R., 1994. 'The Status of Renewable Energy Technologies In Malawi', paper presented during the first Regional AFREPREN Workshop on Renewable Energy Technology Dissemination, Naivasha, Kenya, 30 May–1 June, AFREPREN, Nairobi.
Kamfor 2002. 'Study on Kenya's Energy Demand, Supply and Policy Strategy for Households, Small-Scale Industries and Service Establishments. Kenya: Ministry of Energy.
Karekezi, Stephen, 1988. *Renewable Energy Technologies in Africa*, AFREPREN Working Paper Series, AFREPREN, Nairobi.
Karekezi, S. and Kimani, J., 2002. 'Status of Power Sector in Africa: Impact on the Poor', *Energy Policy Journal*, Special Issue Vol 30, Oxford: Elsevier Science Limited.
Karekezi, S., Kimani, J. and Mutiga, A., 2003. 'Energy Services for the poor in Eastern Africa: Sub-Regional "Energy Access" study of East Africa', unpublished report, AFREPREN, Nairobi.
Karekezi, Stephen and Kithyoma, Waeni, 2002. 'Renewable Energy Strategies for Rural Africa: Is a PV-led Renewable Energy Strategy the Right Approach for Providing Modern Energy to the Rural Poor of sub-Saharan Africa?' *Energy Policy*, 30, 11–12, (Special Issue – 'Africa: Improving Modern Energy Services for the Poor'). Oxford: Elsevier Science Ltd.
Karekezi, S., Majoro, L. and Kithyoma, W. (eds) 2002. *Renewable Energy Technologies in Africa – an Energy Training Course Handbook*. Occasional Paper No. 10. Nairobi: AFREPREN/FWD.
Karekezi, S. and Ranja, T. 1997. *Renewable Energy Technologies in Africa*. London: AFREPREN/FWD/SEI/Zed Books.
Karekezi, S., Turyareeba, P. and Musumba, C. 1995. *Household Energy, Indoor Air Pollution and the Impact on Health in Africa*. Nairobi: FWD.
Katyega, M. J. 2001 'Energy Services for the Urban Poor in Tanzania: Second Draft Report'. Nairobi: AFREPREN/FWD Secretariat.
Kayo, D. 2001. *Power Sector Reforms in Zimbabwe: Implications for Private Sector Participation*. Nairobi: AFREPREN/FWD.
Kenya Power and Lightening Company (KPLC) 1997. *Report and Accounts for the Year Ended 30th June 1999*. Nairobi: Kenya Power & Lighting Company Limited.
—— 2001/2002. *Annual Report and Accounts 2001/2002*. KPLC, Nairobi.
Kgathi, D. L. and Mlotshwa, C. V. 1997. 'Fuelwood Procurement, Consumption and Substitution in Selected areas of Botswana: Implications of Theory and Policy', in D. Kgathi, D. O. Hall, A. Hategeka, C. V. Mloshwa and M. B. M. Sekwhela (eds), *Biomass Energy Policy in Africa*. London: Zed Books.
Khennas, S. *et al*. 1995. *Rural Energy Services*. London: Intermediate Technology Publications.
Kyokutamba, J. 2001. 'Energy Services for the Urban Poor: the Case of Uganda. Second Draft Report.' Nairobi: AFREPREN/FWD Secretariat.
Mandhlazi, W. 2000. 'South Africa Country Proposal for Renewables and Energy for Rural Development Theme Group'. Pretoria.
Mapako, M. 2001. 'Renewables and Energy for Rural Development in Zimbabwe'. Unpublished Research Report. AFREPREN/FWD.
—— 2003. 'The Socio-Economic Impact Assessment of Three Decades of Solar Electrification in Zimbabwe'. Masters thesis, University of Cape Town, South Africa.
Mbewe, A. 2000. *Country Validation Data: Data and Statistics Submissions – Zambia. Renewables Energy Technologies and Energy for Rural Development*, Nairobi: AFREPREN.
McCall, Mike 2001. 'Brewing Rural Beer Should be a Hotter Issue'. *Boiling Point*, 47. Rugby: ITDG.
McNelis, B. Derrick, A. and Starr, M. 1992. S*olar-Powered Electricity: a Survey of Photovoltaic Power in Developing Countries*. London: IT Publications/UNESCO.
Ministry of Energy and Regional Development, 1987. *National Energy Policy and Investment Plan*. Nairobi: Ministry of Energy and Regional Development.
Ministry of Finance and Development Planning, Botswana 1995a. *Living Conditions in Botswana: 1986 to 1993/94*. Gaborone: Central Statistics Office.
—— 1995b. *Household and Income Expenditure Survey: 1993/94*. Gaborone: Central Statistics Office.
Ministry of Finance and Economic Planning, 1994. *Public Investment Plan 1994/95 – 1996/97: Priority Project*s. Kampala: Ministry of Finance and Economic Planning.
Ministry of Finance and Economic Planning, Uganda 1995. *The 1991 Population and Housing Census: Analytical Report*. Entebbe: Statistics Department.
Ministry of Finance and National Planning, 2002. *Public Investment Programme 2001– 2003*. Lusaka, Zambia: Ministry of Finance and National Planning.
Mogotsi, B. 2000. 'Data and Statistics Compilation'. Nairobi: AFREPREN/FWD.

Mogotsi, B. and Bok, S. D. 2001. *Energy for Rural Development in Botswana*. Occasional Paper Number 3. Nairobi: AFREPREN/FWD.
Mosimanyane, M.T., Zhou, P.P. and Kgathi, D.L., 1995. 'Renewable Energy Technologies in Botswana – The Case of Wind Energy for Water Pumping', draft report, SEI/AFREPREN/FWD, Nairobi.
Mulugetta, Y., Nhete, T. and Jackson, T. 2000. 'Photovoltaics in Zimbabwe: Lessons from the GEF Solar Project'. *Energy Policy*, 28. London: Elsevier Science Ltd.
Muriithi, J., 1995. 'Women and Energy Project, Kenya: An Impact Study', *Boiling Point*, No 35, ITDG/GTZ, January, Nairobi.
National Energy Foundation 1995. 'Understanding Energy'. CD ROM. Essex: Anglia Multimedia.
NER 2001. *National Electricity Regulator Annual Report 2000/2001*. Sandton: National Electricity Regulator.
Nyoike, P. 2001. Personal communication.
Okalebo, J. and Hankins, M. 1997. 'Why Women Adopt Solar Dryers'. *Energia News*, 3. Netherlands: Energia.
Peters, R. and Kijek, F. 1992. *Study of NRSE pricing in the SADCC Region*. Luanda: Energy Technical Services Fund.
Reddy, A., Williams, R. H. and Johansson, T. B. 1997. *Energy After Rio: Prospects and Challenges.* New York: UNDP.
Schirnding, Y. 2001. 'Gender Differences in the Impact of Biomass Fuel on Health'. *Energia News*, 4, 4. ENERGIA, The Netherlands: Energia.
Teferra, M. 2000. *Energy Sector Reform Theme Group: Data and Statistics Compilation – Ethiopia*. Nairobi: AFREPREN/FWD.
Torres, R. X. and Salas, C. A. 2001. 'Solar Disinfection of Water in Latin America Benefits Women and their Families'. *Energia News*, 4, 4. Netherlands: Energia.
UNDP (United Nations Development Programme) 2000. *Human Development Report 2000.* New York: Oxford University Press.
WEC 1992. *World Energy Council Journal*, December 1992. London: World Energy Council.
WEC/FAO 1999. *The Challenge of Rural Energy Poverty in Developing Countries*. London: World Energy Council and Food and Agriculture Organization.
Wolde-Ghiorgis W. 2002. 'Renewable Energy for Rural Development in Ethiopia: the Case for New Energy Policies and Institutional Reform'. *Energy Policy*, 30, 11–12 (Special Issue – 'Africa: Improving Modern Energy Services for the Poor'). Oxford: Elsevier Science Ltd.
World Bank 1996. *Rural Energy and Development: Improving Energy Supplies for Two Billion People*. Washington, DC: World Bank.
—— 1999. *World Development Indicators*. Washington, DC: World Bank.
—— 2000a. *African Development Indicators 2000*. Washington, DC: World Bank.
—— 2000b. *Entering the 21st Century: World Development Report 1999/2000.* Washington, DC: World Bank.
—— 2001. *World Development Report 2001/2002*. Washington, DC: World Bank.
—— 2003. *African Development Indicators 2003*. Washington, DC: World Bank.
—— 2003b. *World Development Indicators 2003*. World Bank, Washington DC.WRI (World Resources Institute) 1998. *World Resources: a Guide to the Global Environment*. New York: Oxford University Press.
ZERO 1998. *Energy and Sustainable Rural Industries*. Harare: Zimbabwe Environmental Research Organization.

Note

1 Although wood can be nominally 'free' it is sometimes illegally procured from state-protected forest reserves, thus contributing to some level of devegetation. Available studies nevertheless indicate that the bulk of woodfuel used in rural households is tertiary in nature – that is, dead branches and wood from trees cleared to allow for agriculture.

Part III

ZIMBABWE

Maxwell Mapako

COUNTRY PROFILE

Zimbabwe

SELECTED INDICATORS

Population (millions): 12.82 (2001)
Rural population as a percentage of the
total (%): 64 (2001)
Land area (km2): 391,000
Capital city: Harare
GDP growth rate (%): –8.4 (2001)
GNP *per capita* (US$): 480 (2001)
Official exchange rate: Z$116.2 = US$1 (June 2003)
Economic activities: Agriculture, manufacturing, mining, commerce, forestry
Energy sources: Biomass, imported petroleum, hydro, solar, coal
Installed capacity (MW): 1,961 (2001)
Electricity consumption per capita (kWh): 710 (2001)
Electricity generation (GWh): 11,972 (2001)
System losses (%): 15 (2002)
Electrification levels (%): (2001) National: 40
Urban: 84
Rural: 19
Biomass consumption as a percentage of total energy (%): 62.78 (2000)
Poverty levels
(%) population living below US$1 a day: 36.0 (1990–1)
(%) population living below US$2 a day: 64.2 (1990–1)

Sources: Kayo, 2002; Mapako, 2002; Dube, 2000; AFREPREN, 2003; EIU, 2003; World Bank, 2003a; World Bank, 2003b; IEA, 2002

Acknowledgements

The publication of Part III of this book was made possible through the kind assistance of the Swedish International Cooperation Development Agency (SIDA). The author also gratefully acknowledges the support and advice provided by the AFREPREN Secretariat, in particular Stephen Karekezi, the Director of AFREPREN/FWD, theme group backstopping officer Waeni Kithyoma, and Abel Mbewe who edited Part III in manuscript.

2

Introduction

Situated in Southern Africa, Zimbabwe has an area of 390,757 square kilometres. According to the preliminary results of the 2002 census, Zimbabwe has a population of about 11.63 million persons (CSO, 2003). The 1997 population was reported to be about 12.3 million (CSO, 1998a), which means the population has declined by more than 5 per cent. The latest preliminary census population figures sparked a debate in the media in early 2003, with suggestions that AIDS and migration caused by the present economic difficulties were to blame.

The average sex ratio in 1997 was of 93.8 males per 100 females (CSO, 1998a). The sex ratio varies considerably between the ten provinces. The average population density in 1997 was 30 persons per square kilometre, up from 27 at the time of the 1992 census. The average household size was 4.4 in 2002 (CSO, 2003).

Nearly 35 per cent of the population is in urban areas because of gainful employment opportunities in industry, commerce and mining. Small and medium-scale enterprises (SMEs) are pervasive, ranging from small household enterprises to cooperatives and small companies in both urban and rural areas.

Wood is the main cooking fuel in rural areas while electricity and paraffin are the main cooking energy sources in urban households. This pattern is shown in Table 2.1. The use of liquefied petroleum gas (LPG) and coal can be seen to be negligible. Grid electricity is provided to 84 per cent of urban and 7 per cent of rural households.

The Department of Energy in the Ministry of Mines and Energy has overall responsibility for energy matters. There is however a certain amount of fragmentation, with the Ministry of Environment and Tourism being responsible for forests.

Table 2.1 Main cooking fuels in the urban and rural areas of Zimbabwe (%)

Area category	Wood	Paraffin	Electric	Gas	Coal	Other
Urban areas average	7.2	31.1	61.0	0.6	0.1	0.0
Rural areas average	94.7	2.9	2.2	0.1	0.0	0.1
National average	66.02	14.05	19.08	0.28	0.42	0.12

Source: Based on CSO, Intercensal Demographic Survey, 1997

Because Zimbabwe has had nearly twenty years' experience with the dissemination of renewable energy technologies, it has become apparent that the promise that was seen in renewables has not been realized. However, since there is no clear way forward, many agencies have continued to disseminate renewables in the same way as before. This study will attempt to show why many known barriers have not been addressed, and to assess the actual and/or potential impact of rural energy and renewables on income-generating business opportunities.

The amount of experience with renewables in the other African countries represented in the theme group varies widely. This is why the country studies focus on different aspects of the theme topic. The Ethiopian and Eritrean studies tend to dwell on seeking the best way to introduce wider utilization of renewables in view of their more limited dissemination in those countries. The Botswana study also has a similar thrust. It would appear, however, that Botswana has had more experience with community biogas initiatives than all other countries in the region (Mapako, 1993).

Clearly these studies are tackling different aspects of the same broad problem. They will highlight common issues experienced in several countries, and also allow for exchange of ideas in those cases where for example one country is pushing wider dissemination while another is pausing to examine barriers and their removal after a period of active dissemination of a range of renewable options.

Rationale of the medium-term study

The major reasons for the medium-term study in Zimbabwe are:

- The short-term study has been completed and was concerned with rural energy initiatives that were implemented by public sector agencies, mostly the government and parastatals. The medium-term study will complement the earlier study by considering both the private and public sector players in the promotion of renewables and energy for rural development.
- There is an opportunity to influence energy policy, which is not finalized, and in any case may be reviewed every two years. Important early steps in this direction are the National Energy Policy Seminars hosted by the Biomass Users Network (BUN) and AFREPREN in September 2000, September 2001 and October 2002. Also, two important strategies are being developed by the Department of Energy, the national Biomass Energy Strategy and the Energy for Rural Development Strategy. These have not been finalized and may be interrupted by the upgrading of the Department of Energy to full ministry status (Ministry of Power and Energy Development) in 2003.
- There is limited information available on rural income-generating activities and their energy needs. In Zimbabwe, as in most developing

countries, the informal sector is a major employer, particularly in rural areas, and is therefore important.

- To understand the status of energy technologies and practices in rural areas of Zimbabwe, with particular emphasis on rural SMEs.
- There is a disappointing level of uptake of RETs in Zimbabwe's rural areas, despite the concerted efforts of government, NGOs and church-based organizations. A review of its own past activities by the Department of Energy in 1997 showed usage levels of RETs already installed to be low. Only 5–10 per cent of installed improved woodstoves and biogas digesters were functional and in use (DoE/GTZ, 1997). In view of this, it is necessary to look carefully at which RETs should be disseminated and how this should be done in future. An understanding of which components are critical will be enhanced by this study.

For historical reasons, rural energy issues were largely neglected before independence in 1980. With the coming of independence, vigorous efforts were made to develop many sectors of the economy, principally education and health, but also rural energy, as a way to achieve a high degree of autonomy. The government directly funded and participated in the implementation of most renewable energy initiatives, with the result that Zimbabwe has one of the highest totals of installed renewable energy systems in the region. Despite these efforts, it is clear some twenty years later that the impact of all that effort is much less than what might have been expected, and that much of the momentum has waned.

Summary of major findings from the short-term study

The short-term study explored such factors as political will, the impact of welfare and income-generating approaches, the economic soundness of rural energy initiatives and the suitability of the implementing agencies in an attempt to highlight the factors that may have led to success or failure of initiatives. Unless such reflection is undertaken periodically, future initiatives will inevitably repeat the mistakes of the past. The necessary data were mostly compiled from interviews and observations at rural service centres, the BUN/AFREPREN National Energy Policy Seminar (21–22 September 2000), discussions with energy specialists and with industry, and from recent literature, particularly the 1997 review of the past energy programmes of the Department of Energy (DoE/GTZ, 1997) and more recent interviews in 2000.

Biogas

The short-term study showed that to date, over 200 biogas plants have been installed in Zimbabwe, mainly through the efforts of the Department of Energy. The Appropriate Technology Section of Silveira House (a church-based organization) and Biomass Users Network (BUN) also actively promoted the use of biogas in rural areas, but without subsidies. This activity has slowed down considerably, discouraged by the poor performance of biogas digesters.

In the mid 1980s numerous donor organizations provided funds for training and for the construction of biogas digesters. The UNDP sponsored the training in China of a builder/promoter in biogas plant construction. On his return he was engaged as a biogas promoter to work in the rural areas building digesters and training local builders. Silveira House assisted with loans for bulk purchase of cement by intending owners of biogas digesters. The period when the biogas promoter was active saw the highest rate of digester construction ever achieved in Zimbabwe (DoE, *Energy Bulletin*, August 1992).

Poor construction of rural household biogas digesters, especially at the beginning of the programme, and poor maintenance by users resulted in many of the digesters falling into disuse. Lack of suitable transport for rural trips curtailed the monitoring of projects by the Department of Energy. Lessons were therefore not learned as the programme progressed. Some biogas digesters were never completed.

Large-scale modern biogas digesters have been tried briefly. The Italian government donated a modern turnkey biogas plant of the TOTEM (Total Energy Module) type with a capacity of 80 cubic metres for use at Kushinga Phikelela Agricultural Training Institute. This was meant to generate electricity for the Institute’s dairy project in the early 1980s. In the early 1990s a portable pilot biogas plant was installed at a food-processing factory (Cairns Foods) in Harare by a United Nations Industrial Organization (UNIDO)/Department of Energy/Cairns Foods pilot project. The purpose of this project was to demonstrate the potential of using agro-industrial wastes (potato and coffee) for generation of biogas and stabilizing organic waste. The project did not convince industry to attempt full-scale implementation.

The fact that biogas digesters demand considerable management input has led to wholesale abandonment, especially by families. This frequently comes about because of normal changes over time, as children leave home and ageing parents find the maintenance of the digester increasingly onerous. The result is reduced feeding frequency, leading to reduced gas output, which in turn produces discontentment, a downward spiral that culminates in complete neglect of the biogas digester.

The majority of biogas digesters were *welfare* type installations, with an insignificant minority of owners paying the full price for their installations. In addition, with the exception of well under 10 per cent of all cases, the installations were not for *income generation* purposes.

Small hydros

A handful of mini- and micro-hydro sites are in existence, predominantly in the eastern highlands of Zimbabwe.

1 *Claremont* hydro plant is in Manicaland Province, at Claremont Orchards. With a capacity of 250 kW, it is used for electricity generation.

2 *Mutsikira* hydro plant is also in the Manicaland Province, near Nyabadza Business Centre off the Rusape–Nyanga road. The capacity is 3 kW. It is used to drive a hammer mill, to pump irrigation water, to drive a timber sawmill, and to power a grinder for sharpening tools.

3 *Kuenda* Cooperative Farm is in the Mashonaland Central Province near Mount Darwin. The power plant is on the Ruya River and has a capacity of 74 kW. The equipment has not worked since about 1986.

4 *Aberfoyle* hydro plant is in the Manicaland Province on the Aberfoyle tea estate in the Honde Valley. It is located on the Nyakombe River, a tributary of the Pungwe River. Its capacity is 25 kW and it provides electricity for the farm's clubhouse complex, which includes guest-houses.

5 *Svinurai* Cooperative Scheme is located at Cashel on a tributary of Umvumvumvu River. It has a capacity of 10 kW. It drives a hammer mill and a 20 kW DC generator, but not at the same time.

6 *Rusitu* hydropower station is at the confluence of the Rusitu and the Nyahode rivers, and is owned by the Rusitu Power Corporation, a joint venture between the NGO Energy and Development Activities – Zimbabwe (ENDA–Zimbabwe) and the Zimbabwe Power Corporation, a small-scale power subsidiary of the Zimbabwe Electricity Supply Authority (ZESA). The generation station has a rating of 750 kW, and was installed in 1997.

7 *Nyafaru* hydropower station, completed by ITDG in 1996, is on the Nyafaru River, also in the Eastern Highlands. Capacity is 20 kW. This supplies a community with electricity and has administrative complications often associated with community projects, including abuse of administrative power, use of unauthorized appliances, and disagreements over tariffs.

Solar

Solar PV technology has taken root in Zimbabwe, driven by the efforts of both public and private sectors. Institutional systems have predominantly been part of programmes funded by international donors. Most have experienced problems of maintenance and spares once the project support ended. The majority of systems in the field may be those procured and installed through informal channels by the owners, usually on a do-it-yourself basis or by hiring local electricians of varying skill levels. Some energy service companies have been started and are continuing. PV water pumping has been demonstrated through several initiatives, notably one that involved the Department of Energy, GTZ and the Department of

Water: some 16 pumping stations were installed, which have been handed over to the Department of Water.

Woodstoves

The woodstove project started in 1982 with trial designs to establish the best design for fuel conservation in Seke Communal Lands. A pilot phase was then carried out in the Hurungwe and Guruve areas. The improved stove is a mud, cement and brick structure usually with one to three cooking places, a hotplate and a chimney fitted with a damper. It has undergone a lot of change since the project started. A number of reasons were found to be responsible for the disappointing level of adoption of the 'improved' stoves in Zimbabwe, among them inappropriate positioning in the kitchen, limited functionality and non-portability of the stove, inability to control stove heat output, inability to use slower-burning larger logs, and discomfort due to heat retention by the stove in hot weather (Department of Energy/GTZ, 1997; Corvinus and Mapako, 2000).

Gasification

Gasification of crop residues was tried experimentally by the Department of Energy but not followed up with full-scale trials. Commercial gasification has existed since the late 1970s and has worked well, using coke and charcoal as fuels.

The short-term study concluded that, in view of the prevailing political and economic uncertainty in Zimbabwe, government is clearly constrained and in the short-term will be preoccupied with political and economic issues. The shortcomings of government departmental structures in implementing projects have been brought out, and it was felt necessary to bring energy planning under the rural development umbrella in order to better integrate service delivery to rural areas. The large number of unsatisfactorily completed renewable energy projects will make it difficult for end users to take RETs seriously in future and corrective action needs to be taken where this is still feasible. Having noted the relative success of initiatives that were not welfare-focused, it is recommended *to focus on initiatives with an income-generating focus*. In this regard the current role of certain conventional energy options like diesel gensets in the rural energy sector is clear and acknowledged. Of these recommendations, the issue of rehabilitation is seen as being more difficult in the absence of the necessary resources, particularly for biogas digesters.

Link between the short-term and medium-term studies

The short-term hypotheses investigate the impact of government and utilities policies and programmes on the provision of modern energy to rural areas for domestic use and for income-generating activities. The focus of the short-term study was on public sector (government and utility) programmes in rural areas. The medium-term study examined decentralized private sector initiatives and compared them to centralized public sector initiatives studied in the short-term study. Data collected in the short-term study provided the essential comparative basis for the examination of the role of the private sector in rural energy development in the medium-term study.

The second hypothesis in the medium-term study assesses the impact of income-generating activities on modern energy dissemination. It is based on the findings of the first hypothesis in the short-term study, which asserted that past rural energy initiatives failed because they lacked an enterprise focus.

The third hypothesis in the medium-term study is linked to the second hypothesis in the short-term study. For successful dissemination and promotion of RETs for income generation to occur (an issue tackled in the medium-term study), there should exist a *conducive institutional framework* (an issue tackled in the short-term study).

3

Study Findings and Conclusions

The findings, and conclusions presented in this chapter are drawn from experiences with renewable energy initiatives in Zimbabwe and other countries. In terms of experiences, Zimbabwe has considerably more than neighbouring countries following vigorous efforts by government in the post-independence decade. Mini-surveys in Kadoma district provided recent data that have been used to support the analysis in this study.

Hypothesis 1: Decentralized private sector vs centralized public sector energy initiatives

The short-term study touched on issues of welfare and economic energy project initiatives, and in many cases those project examples can be used to examine the differences in success rate between decentralized private sector initiatives and centralized public sector initiatives. Some of the characteristics of the two categories of initiatives are compared in Table 3.1.

The characteristics tabulated do not apply to all initiatives. For example, the issue of quality of installation came through well in the solar home systems (SHS) survey conducted in Sanyati, Zimbabwe in July 2001. The building up of an SHS allows the owner to procure components from different sources and put these together into a working system. Without some technical knowledge to enable the owner to do the necessary load and charge calculations, the system design is unlikely to be optimized. The commonest result of this is that battery life is shortened through incomplete charging, and deep discharging of automotive batteries, which are not designed for deep cycling.

Table 3.2 presents a summary of most significant RET initiatives in Zimbabwe, highlights their links to income generation, and classifies them to show which are public sector and which are private sector initiatives. A number of project initiatives will be discussed, and each case ends with a conclusion relevant to the initiative under discussion.

Gensets

There is no accurate census of the number of gensets in Zimbabwe. Based on the numbers – mostly used for grinding – at government institutions

Table 3.1 Selected characteristics of decentralized private and centralized public rural energy initiatives

Decentralized private sector initiatives	Centralized public sector initiatives
Generally better targeted owing to the role of the user in deciding what is needed, and demanding it from supplier, i.e., a bottom-up process	Targeting often difficult owing to the frequent omission of user input in project design and implementation, which is usually top-down, sometimes with token end-user input
Installed quality can be variable in the case of DIY installations because of different levels of technical competence among users	Installed quality easier to manage through project structures using qualified staff
User tends to be more hands-on in looking after the installation	User tends to be dependent on the project and may regard the installation as belonging to the installing institution
Overall unit cost tends to be lower due to higher efficiencies and more careful matching of demand	Overall unit cost can be quite high especially due to overheads of the installing institution
User has the option to purchase components when funds permit – i.e., build-up of system can be flexible, which means payment schedule is flexible	User subject to rigid project timelines, e.g., time window when equipment is available on favourable terms
Approach likely to be more responsive to gender issues because it responds to the needs of the specific client	Gender sensitivity can easily be compromised in the design of the project, or misdirected due to lack of consultation or awareness
Generally this is not a ‘project’ with a definite start and stop date. Open-ended, with competing suppliers	Initiatives are specific projects with targets and deadlines for the participating stakeholders

such as schools, hospitals and clinics, on farms, and in the rural areas, the Energy Sector Management Assistance Programme (ESMAP) estimated that there were about 3,000 diesel-powered grinding mills in Zimbabwe in 2000. There are another several thousand gensets in other applications like water pumping and back-up power generation. The total rural generating capacity has been estimated at 50 MW in Zimbabwe for 1998, which includes mines, commercial farms, ranches and other commercial enterprises (ESMAP, 2000).

These are not part of any government promotion or demonstration projects, but rather the result of purely private sector marketing. There are therefore no welfare installations except in cases like health institutions, where the gensets may not have been paid for by the institution. Even in such cases, however, government has passed on costs of running and

Table 3.2 Summary of past initiatives in Zimbabwe and their links to income generation

Initiative	Installed	Functional status	Income-generating significance	Private or public sector
Biogas	Over 200 units nationwide, approx five for income generation	Approximately 10–15 units in use at least occasionally in 1997. Overall failure	Majority public sector installations not used for income generation. The few private sector initiatives were for income generation	Predominantly public sector contribution
Mini/micro hydro	Eight sites, mostly in the Eastern Highlands of Zimbabwe	Seven out of eight units are operational in 2000. Successful	Income-generating objective in all cases. Tariffs to communities have presented some challenges	Private sector and NGO involvement
Solar PV	Approx. 85,000 systems	60% to 80% of systems partly operational in 2002 owing to lack of maintenance support and spares	Power level not suited to be prime mover in income generation, but can contribute to income generation as shown by survey	Dominated numerically by private initiatives
PV water pumping	16 sites nationwide	Most sites functional in 1997. Local trained maintenance is in place. Successful	Not generating power for use in income-generating uses, but can contribute. Sale of pumped water can provide income	Predominantly public sector project initiatives
Wood/coal stoves	Approximately 14,000+ coal and wood stoves. Coalstoves<1%	Most in working order but over 95% abandoned by 1997. Failure	Can produce sufficient energy to provide for income generation. Size of stoves limits the scale of such operations however	Dissemination dominated by public sector projects
Gasification	About six units, of which two were govt. research trials	Four commercial units operational 1997. Government test units abandoned 1993. Successful	All operational units are for income generation and capable of producing enough energy for large scale industrial applications	Dominated by commercial units in industrial use for direct heating applications
Wind pumps	650 units, all privately installed	Most expected to be functional in 1997. Successful	Income-generating uses on farms for water pumping, especially livestock watering	Fully private sector driven
Gensets	Thousands. Approx. 3,000 diesel grinding mills in all	Most expected to be functional in 2000. Successful	Capable of producing flexible levels of energy for commercial applications. Predominantly used for small enterprises	Fully private sector driven

Source: DoE Biogas and Stove Project records; BUN Solar Project records; ESMAP, 2000 maintaining equipment because of ongoing economic transformation. The major difference with household PV installations, typically employing 50 Watt modules, is that gensets are typically rated at several tens of kVA and are capable of providing power at levels that open up the possibility of powering important SME activities like welding, oil pressing, and grinding. There is flexibility in using either direct shaft power, or generating electricity first.

It can be concluded that, in the case of gensets, the hypotheses holds true in view of the business opportunities that are opened up for both manufacturers of gensets and ancillary equipment, and rural enterprises of all sizes. The flexibility in matching supply to demand using off-the-shelf technology is a definite plus. In addition, the power level of gensets is capable of coping with most, if not all the power requirements of the rural enterprises, including welding, pumping, power back-up, and grinding. A significant amount of decentralized generation capacity of about 50 MW has been disseminated through private sector marketing of gensets.

Biogas

In terms of numbers disseminated, the number of biogas digesters installed through public sector initiatives overwhelms the number of digesters installed through private sector initiatives. This is mainly because of vigorous promotion of the technology by government. In time the private sector became convinced of the viability of the technology *in specific niches* and this led to a handful of installations tailored to service the needs of income-generating activities.

The private sector installations have owners who paid considerable amounts of money for their installations and have a clear idea of what they need from the digesters. Because the digesters play a specific role in the income generation process, the incentive to maintain them in working order is strong and the owner is even willing to pay for maintenance. On the other hand, the public sector installations were installed free or for token costs and did not often have a defined need that they were filling for the user. The result was that the user tended to neglect the biogas digester since it made little or no difference in his income strategy, and in some cases was an added burden. This failure of public sector initiatives to target the correct users and address needs felt by the user is a major contributing factor to the widespread abandonment of biogas digesters installed through this approach. On the other hand, as shown in Table 3.3, the private sector installations were all found to be working when visited at different times.

Even though some of the public sector installations worked at the outset, almost all had failed for one reason or another in less than four years. The few business biogas digesters that were built at the behest of the user, who paid all costs and in some cases undertook the building, are still operational and in active use up to ten years later. The existence of

Table 3.3 Biogas: selected cases with time series data, 1991–6

Digester	1991/2	1995	1996
Centralized public sector Installations			
A. Chikazhe (Chesa Purchase Area; Mt Darwin). Builder: Kunonga	Worked well from the start	Operating. Outlet pit not being emptied regularly	Operating. Feeding variable. Only used for quick boiling – e.g., morning tea
Chirara (Pabvebango, Mt Darwin). Builder: Kasukuvere	Structural defect. Dome faulty, inlet outlet levels wrong	Not rectified	Not rectified
Dhokwani (Mt Darwin). Builder: Kunonga	Working well	Formed thick scum and stopped. Misfed. Corrective action by DoE	Not working
Matiya (Madziwa CL) Builder: Kunonga	Working well	Not working	Not working
J. Kasukuvere Builder: Kasukuvere	Incomplete	Incomplete. Outlet filled with soil	Incomplete. Outlet filled with soil
Private sector decentralized installations			
Malwatte (near Marondera on Mutare Rd)	Installed by Alternative Technologies Pvt. Ltd.	Working well	Working well
Mapanga (off Murewa Rd)	Self-built by businessman enthusiast	Working well	Working well
Monte Cassino Mission School, Macheke, Mutare Rd	Not yet in place	Working well	Working well

Source: Department of Energy/GTZ (1997)

clear demand for the business installations is typified by cases where the businessmen actually built the biogas digesters after collecting the necessary information. Mr Mapanga is typical of this for biogas, while Mr Mutsikira provides a similar example for small hydro.

It is thus apparent that, in the case of biogas, public sector efforts to promote and disseminate biogas technology succeeded in bringing it to the attention of the public, eventually resulting in the private sector adopting the technology for special application about a decade after the public sector efforts at promotion started. As far as dissemination and utilization goes, the public sector installations generally failed after a few years for a number of reasons, some of which have been mentioned above.

Generally, the private sector initiatives have worked much better, partly as a result of learning from the public sector. Credit goes to the public sector for the introduction of the technology, but the success of the private sector must be recognized in installing biogas digesters that were used sustainably. This suggests that the public sector can play the role of promoting and assisting the introduction of potentially useful rural energy options, while the private sector can successfully disseminate those options that show promise in fulfilling the needs of end users. This conclusion confirms the hypothesis, but goes further to show the respective roles of the private and public sectors in rural energy provision.

Solar PV projects

PUBLIC AND PRIVATE SECTOR DECENTRALIZED DISTRIBUTION

Solar PV technology has taken root in Zimbabwe owing to the activities of both the public and private sectors. Institutional systems have predominantly been part of programmes funded by international donors. Most have experienced problems of maintenance and spares once the project support ended.

With the *UNDP/GEF Solar Project*, Zimbabwe was awarded a US$7 million solar photovoltaic project, which was intended to provide more than 9,000 PV home systems. Intended beneficiaries were rural households, small rural businesses, community establishments (churches, schools, clinics, cooperatives, district councils) and commercial farms (workers' housing units).

The project was intended to address the issue of global warming and greenhouse gas emission by providing a sustainable model of solar electricity dissemination in Zimbabwe's rural areas in order to supplement grid electricity extension where it is not economically feasible. This objective is clearly debatable as far as the extent of the impact of such a project on global warming is concerned.

The main delivery modes were the national utility (ZESA), private enterprises and non-governmental organizations. Over the five-year period over 9,000 45-watt-equivalent systems were delivered under subsidized conditions. The subsidies were in the form of duty waiver on imported components and a low interest rate of 15 per cent per annum for clients purchasing systems under the project. About 50 companies and a few NGOs were active in the solar energy field by the time the project ended. One of the NGOs, Biomass Users Network, completed its quota of 200 systems at the end of 1998 and shared its experiences at a presentation on

29 September 1999 at the Department of Energy. Some of the lessons highlighted were:

- Smaller systems may not sell to the poorest, who have more basic priorities;
- Scattered systems were proving costly to maintain;
- Poor user awareness will lead to abuse and higher incidence of need for repair;
- Local maintenance ability was found to be necessary.

ESCO model solar PV projects

SME DECENTRALIZED DISTRIBUTION

The Department of Energy and the Japanese International Cooperation Agency (JICA) decided, as part of the elaboration of an electrification master plan in Zimbabwe, to run a pilot ESCO (energy service company) solar home system project. Two clusters of 50 households were selected in Kadoma district after extensive consultation with stakeholders, and local companies were hired to install systems. A local NGO, the Biomass Users Network, was contracted to act as the energy service company and maintain the systems for a fee to be paid by each client to cover the cost of maintenance plus a contribution to a fund that would enable replacement of key system components when they failed, particularly the batteries, and, less frequently, charge controllers. Most installations were completed in 1998 and four BUN maintenance technicians were trained at Kwekwe Technical College. Two of the trainees who did well at college (one of them a woman) were contracted. The technicians were provided with bicycles and toolboxes and required to visit every installation monthly, complete data sheets, and attend to any problems. This is ongoing.

The project has been running for four years, with most clients, who are farmers, paying their maintenance fees annually after harvesting and selling produce. Monthly payments are not practicable with such clients, given their income patterns. The majority of clients in this project are households, though there are several business premises where systems are used for extending operating hours of shops or bottle stores selling beer and playing music for clients.

A major risk factor is the variation in agricultural yields, which depends on the weather. Farmers can fall into arrears when rainfall is poor, and if this happens successively then catching up with payments becomes difficult. Major and mutually reinforcing advantages of this approach are (1) that clients are assured of a high level of system maintenance by the close proximity of the technician; and (2) that ESCO is dependent on the payments, which will not be forthcoming if systems are not working.

Operational problems revolve around the need to ensure that clients adhere to the stipulated operation procedures and avoid overloading or tampering with systems. Precautions taken include placing the battery and charge controller in a box that is locked, the keys being kept by a technician who visits clients regularly or when a fault is reported between such visits. Despite this, there were cases of clients tampering with the keys to gain access to the battery to use it for other purposes or to disconnect it to charge a flat car battery, for example.

The total installed PV capacity in Zimbabwe has been estimated at up to about 1.68 MWp, which is far below the 50 MW achieved by the gensets (ESMAP, 2000).

In order to get some necessary data on income generation in the use of SHS, the issues of maintenance and attitude of users who have had exposure to SHS and the attendant problems, a small sample survey of 40 households was undertaken in July 2001 in Sanyati, Kadoma district, Zimbabwe. In this area it is possible to find ESCO, GEF, private owner-installed SHS and battery-only installations. The survey specifically excluded the ESCO installations as these have access to intensive maintenance and more is known about them than the other installations. A service technician who is resident in the area and normally works on the ESCO installations carried out the survey. He also interacts with the other SHS owners and helps them out with advice.

The survey found that the private installations took advantage of the prevailing reasonable cost of components and were fuelled by the outreach and advertising efforts of the GEF project. The issue of variable technical quality of installation can be seen from a general lack of correlation between battery size and module capacity as shown in Figure 3.1.

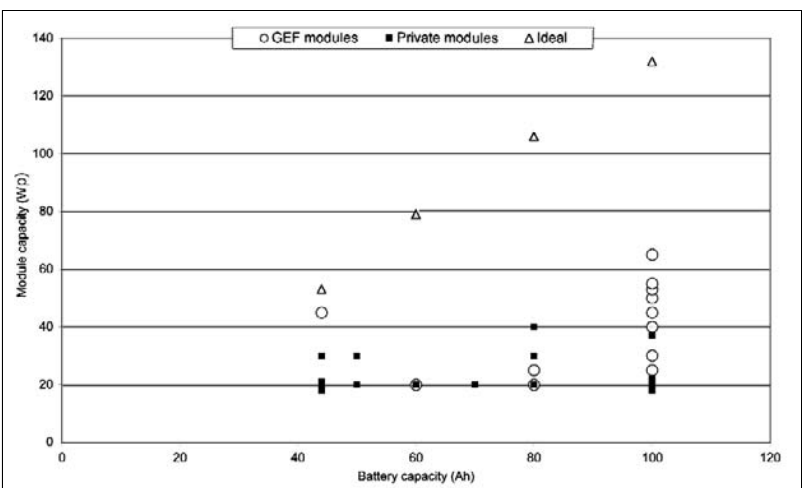


Figure 3.1 Matching of module to battery sizes. Calculated ideal case vs survey cases

Source: Produced from Kadoma district survey data

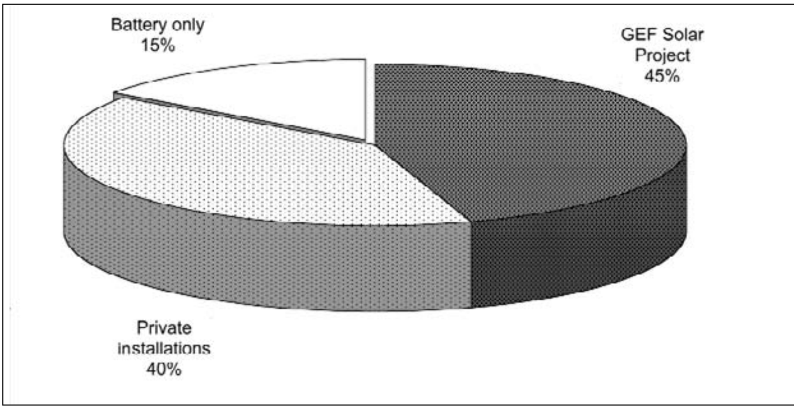


Figure 3.2 Solar home systems encountered in the survey by installing project

Source: Produced from Kadoma district survey data

(A simple way to size a basic solar home system is given in Appendix III.1, p. 99.) The expected pattern would be an increase in module capacity with increasing battery size in order to maintain battery-charging capacity. As it is, some large batteries are matched with very small modules, which implies that these batteries may never be fully charged. This, coupled with the lack of charge controllers in the majority of the systems, means that batteries are generally facing serious abuse.

The average age of batteries when they fail is found to be 2.1 years for all the systems. For the GEF (public sector) installations alone, the average age at failure of battery is 2.4 years while for the private systems the average age at battery failure is only 1.4 years. It is worth noting that the GEF project brought in sealed deep cycle batteries, which may be one reason the project batteries lasted well. No similar replacement batteries are available on the local market, however. The majority of systems encountered were installed through the GEF and related initiatives, as shown in Figure 3.2.

A number of maintenance issues were raised with the interviewees for comparing the experiences of public sector initiatives with corresponding private initiatives:

- Whether a manual was provided with the equipment;
- Whether the user was trained in how to use and look after the equipment;
- Whether the user carries out any maintenance tasks like cleaning the module or topping up battery water;
- Whether the user is happy with the maintenance arrangements and services available;
- Whether the user would buy an SHS given the benefit of hindsight.

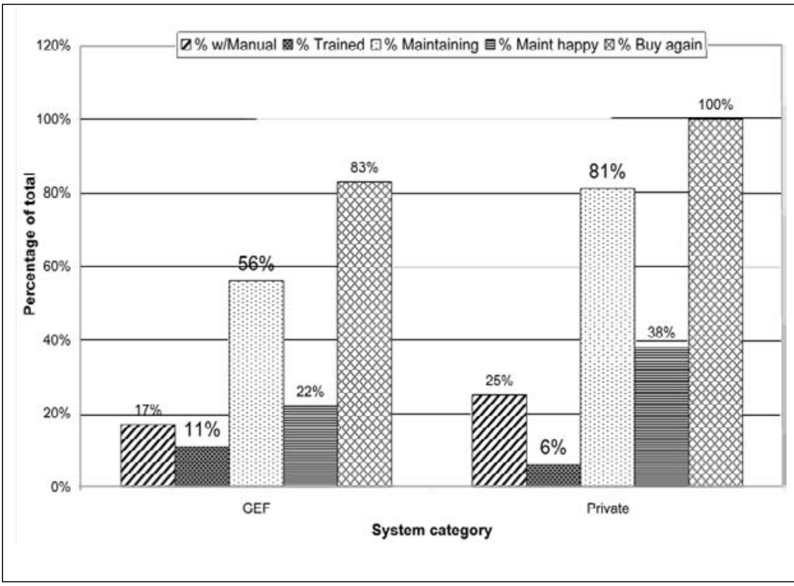


Figure 3.3 Maintenance issues summary from survey results

Source: Produced from Kadoma district survey

It was worrying to note that three users in the private category were adding *acid* (not distilled water) to their batteries when topping up. The most practised maintenance activity was found to be topping up battery water, followed by cleaning of the module. More than three times as many interviewees were unhappy, citing 'component failures'.

Despite the dismay over maintenance, most respondents would buy SHS again even with the benefit of hindsight, citing the higher cost of dry cells, the good quality light, perceived health benefits from paraffin fume elimination, and convenient power for radios. Figure 3.3 shows these issues graphically, separated into public and private sector categories for comparison.

More private sector installations were supplied with manuals, but less were given training. This group was happier overall with their systems in terms of maintenance, and are more enthusiastic about buying again. More in the private sector initiative group undertake maintenance of their systems, but this may not be surprising since they accepted this eventuality when they chose this method of acquiring their systems. (In this case 'private' refers not to a group of projects, but more to individual initiatives to purchase components and assemble systems.)

To conclude, it is clear that many more insights are to be derived from the survey results, including questions that would need to be answered in a more representative survey to provide a national picture.

As far as the hypothesis is concerned, once again it would seem that the roles of the public and private sectors are complementary. The public sector can catalyze awareness of selected technologies, but it would seem that the private initiatives tend to meet user needs more adequately, leading to more contented users overall – as suggested by the results presented here, which are not yet completely analysed or fully reported.

Hypothesis 2: Income-generating activities vs domestic energy use

The extent of the dependence on traditional and modern energy shows a pronounced tendency towards more traditional energy use in rural areas at the national level in Zimbabwe. This is shown clearly when the national average figures for the use of different cooking energy sources are compared. The dominance of wood in rural areas is in sharp contrast with paraffin and electricity in urban areas. The strong dependence on wood in rural domestic applications shown in Table 3.4 is to be expected, and follows logically from the foregoing national overview of energy sources and rural/urban contrasts.

This trend would continue if the other towns and cities including Gweru, Mutare, Masvingo, Kadoma and Kwekwe were also excluded. The figure for paraffin consumption shows the opposite trend very strongly, because this fuel is used predominantly for lighting in rural areas and cooking in lower-income urban households.

Table 3.4 Energy sources most used for household cooking in Zimbabwe

Province	Wood	Paraffin	Electric	Gas	Coal	Other	No. of households
Manicaland	87.0	8.4	4.6	0.1	0	-	391,896
Mash Central	84.0	5.9	9.3	-	-	0.8	209,827
Mash East	87.6	7.5	4.7	0.1	-	0.1	249,381
Mash West	72.8	11.2	16.0	0	-	0	260,977
Mat North	74.5	4.7	20.4	0.1	0.4	-	125,080
Mat South	85.1	2.2	12.4	0.2	-	-	123,453
Midlands	71.9	9.9	18.2	0.1	-	-	284,247
Masvingo	88.3	4.3	6.9	0	-	-	250,231
Harare	2.8	39.7	56.5	0.9	0.1	0	453,037
Bulawayo	2.5	8.5	88.1	0.9	-	-	162,281
Urban areas	7.2	31.1	61.0	0.6	0.1	0.0	926,210
Rural areas	94.7	2.9	2.2	0.1	0.0	0.1	1,584,200
National average	66.02	14.05	19.08	0.28	0.42	0.12	2,510,410 (Total)

Source: CSO, Intercensal Demographic Survey, 1997

Table 3.5 Activities and their predominant energy sources

Rural activity	Predominant energy source
Domestic	
Cooking	Traditional (wood)
Baking	Traditional (wood)
Space heating	Traditional (wood)
Lighting	Modern (paraffin); traditional (wood)
Entertainment (TV, radio, social functions)	Modern (batteries, PV); traditional (wood)
Income-generating	
Cooking	Traditional (wood)
Lighting	Modern (PV, grid)
Entertainment	Modern (PV, grid)
Radio/TV repair	Modern (PV, grid)
Battery charging	Modern (PV, grid)
Grinding	Modern (diesel, grid)
Welding	Modern (diesel, grid)
Metalwork	Modern (grid)
Carpentry	Modern (grid), traditional (manual)
Car repair	Modern (grid)
Spray-painting	Modern (grid)
Brick making	Traditional (wood)

Source: Based on theme group proposal, amended for Zimbabwe

An important difference between domestic energy use and income-generating activity energy use is the scale on which energy is used. Cooking a family meal targets the family members, whereas cooking food for sale aims at supplying many more persons, necessitating more powerful devices. The structure of such devices may also be adapted, for example to handle the weight of larger cooking pots. Similarly, household lighting may be adequately provided by a wick lamp or candle, but this is totally inadequate for the needs of a bar owner wishing to provide light for, say, 50 clients.

For this reason, the energy sources chosen for similar functions in households and in income-generating activities often differ. The greater power requirement of activities such as grinding grain, welding, and spray-painting means that modern energy sources become essential. Even small-scale income-generating uses such as radio and television repairs, which are common at rural service centres, require electricity for soldering and testing. Table 3.5 shows the importance of modern energy services to a wide variety of income-generating activities.

Table 3.6 shows a different perspective, by looking at selected rural energy initiatives and comparing the relevance they hold for domestic applications, on one hand, and income-generating end uses on the other. Not only do the income-generating activities reflect a wider range of end

Table 3.6 Domestic and income-generating initiatives

Initiative	Domestic application	Income-generating application
PV pumping	N/a	Water pumping
PV (home system)	Lighting, TV and radio	Lighting, soldering, testing
Improved stoves	Cooking	Institutional cooking, baking
Biogas digesters	Cooking	Refrigeration, cooking, waste treatment
Coal stoves	Cooking	Institutional cooking
Gensets	N/a	Grinding, water pumping, electricity generation for power tools, welding, air compression, and lighting.
Grid extension	Lighting, cooking, refrigeration	Irrigation, welding, lighting, power tools, air compressors, grinding, fabrication

Source: Kadoma district survey and theme group proposal, amended for Zimbabwe

uses for a given energy initiative, but in some instances there may not be any direct application to households at all. Examples of such a situation are gensets and PV pumping, where it is not possible for rural households to own such equipment, though they may benefit from projects running the equipment.

An important determinant of who can own certain energy sources is income. One series of surveys in 1994 (UZ/DOE, 1994) put the average rural annual income at US$238 and US$263 for resettlement areas and deforested communal areas near cities, respectively. Urban household incomes at the same time were found to average US$625–1,000 in different towns. The poorest rural households were found to spend 25 per cent of their income on energy, this figure tapering down to 5 per cent for the wealthiest rural households. The annual fuelwood consumption was found to be 5–5.6 tonnes per household per annum on the basis of numerous surveys that have been undertaken in the past in Zimbabwe. Paraffin consumption (predominantly for lighting) was estimated at 25–50 litres per household per annum, and 65–100 candles per household per annum.

Traditional beer brewing was found to require an average 2.8 kg fuelwood per litre of beer brewed (ZERO, 1991). A single brewer producing 100 litres of beer per month would use 280 kg of fuelwood each time, or 3.36 tonnes per annum. A six-member brick-making group producing 120,000 bricks per annum would use up 38.4 tonnes of fuelwood. This means 6.4 tonnes *per capita* per year. For bread baking, a 13-member group used about 313 tonnes of wood per year to produce 136,080 loaves of bread, or 24 tonnes *per capita* per annum! For those involved in these income-generating activities, the level of energy consumption can be much higher than the annual household consumption figures, which are below 6 tonnes *per capita*. On a national level, these rural income-generating activities have been estimated to add 1 tonne *per capita* on average to the annual fuelwood consumption (UZ/DOE, 1994).

The impact of the initiatives has been discussed under Hypothesis 1: it was demonstrated that initiatives such as gensets, PV pumping and biogas for income-generating activities have fared much better than initiatives targeting households, such as improved stoves and household biogas digesters. The comparison should not simply consider numbers disseminated. It is more important to know how many of the disseminated units were in use.

Modern energy sources with an ancillary role in income-generating activities

Because they demand specialized energy sources and higher power levels, income-generating activities clearly provide a better entry point for modern energy sources into rural areas. Table 3.7 presents some of the data from the survey in Sanyati. One interesting point that comes out of the data is the fact that modern energy sources can contribute to income-generating activities *without being the prime power source*. In all the cases cited, the contribution of solar home systems is to facilitate the operation of the income-generating activity.

It would be reasonable to assume that neighbours who are able to afford solar home systems would be encouraged to acquire them through seeing the contribution that having these systems makes to the income-generating activities being undertaken next door. This would be of particular relevance to households already engaged in income-generating activities. For these households, the opportunity to increase the hours of operation of the income-generating activities beyond nightfall would be attractive. This ability to work after dark frees people to engage in other important activities like agriculture during the day. It is important to underscore that the contribution of solar home systems is quite limited owing to the low power capacity of these systems.

The subject of primary and ancillary energy services is explored further in Table 3.8. The survey found that many household-level income-generating activities can be operated without modern energy services. The majority of the income-generating activities listed in Table 3.8 can be carried out using manual tools in operations other than those intrinsically dependent on electricity, like soldering, welding and battery charging.

These activities are normally carried out at rural service centres where the grid is often available. Many income-generating activities will exist in the absence of modern energy services. Differences due to modern energy can be summed up as:

- Reduction of manual drudgery and fatigue. For example, the labour-intensive cutting, planing and sanding of timber in carpentry can all be carried out with electrical machinery in a range of sizes from individual DIY to large industrial models.

Table 3.7 Summary of income-generating activities related to solar home systems encountered in the survey

Category	Details of income-generating activity	Nature of SHS contribution
Handicrafts	Husband makes artificial flowers (for sale) in evenings. Is a teacher during the day.	Good light makes production of handicrafts in evening possible.
	Wife takes school orders for jerseys. Knits by hand in the evenings.	Producing quality garments for sale is easier with good lighting.
	Wife sews garments in the evenings. These are for sale or being mended for a fee.	
	Wife sews and knits baby sets for local sale. She works in the fields during the day.	
Services	Manual peanut butter production. Clients leave peanut packets, which are labelled by children throughout the day. Father grinds peanuts on manual machine at night; clients collect peanut butter next day.	Father works peanut butter machine under SHS light. Free for other work during the day.
	Repair of radios and SHS charge/discharge controllers with electric soldering iron.	Soldering iron powered by SHS or battery via inverter. Workshop light powered by SHS or battery.
	Barber, using electric hair clipper.	Hair clipper powered by SHS or battery via inverter.
	Wife bakes scones and other confectionery for sale to primary school children. Day/night baking shifts.	Night baking shift requires good light, which SHS provides. Quality control easier if product is clearly visible.
	Shop/bottlestore lighting and radio.	Powering lights and entertainment from SHS.
	Husband is a teacher who gives supplementary lessons in the evening and charges for them.	Teaching at night would not be possible without good light.
Farming-related	Two wives involved in gardening. Grading and packing of tomatoes, and bundling of greenleaf vegetables carried out at night.	Grading and packing for sale next day facilitated by good light.
	Raising poultry for sale.	SHS-powered light at night allows poultry to continue feeding and grow faster.

Source: Kadoma district survey

Table 3.8 Common rural income-generating activities and prime/ancillary energy sources

Income-generating activity	Main energy-demanding functions	Typical prime energy source in rural areas	Additional energy service needs
Radio/TV repair	Soldering, drilling, testing, inspection of inaccessible areas (torch)	Manual labour Dry batteries	Good light in cases of manual tools and dry battery usage
Supplementary evening lessons	Good visibility in large room	Solar PV	
Sewing and knitting	Driving sewing machine Good visibility	Manual labour Candle/wick lamp Grid	Better light in cases of manual machines
Baking	Mixing, blending, baking, warming	Manual labour Wood	Good light Power for small utensils (blenders, mixers)
Handicrafts	Cutting, carving	Manual labour	Good light Power for hand tools
Battery charging and hiring	Hiring out charged batteries	Solar PV Grid	Good light (for evening transactions)
Metal fabrication	Cutting, welding, drilling, soldering, shaping, spray painting	Manual labour Genset Grid	Light where grid / genset absent
Carpentry	Cutting, planning, sanding, spray painting	Manual labour Grid	Light where grid absent
Car repair/panel beating	Welding, cutting, sanding, spray-painting, tyre changing/mending	Manual labour Genset Grid	Light where grid absent

- Speed can be increased dramatically, allowing greater production over the same period. An electric sewing machine will produce garments much faster than a manual machine. It is possible to retrofit a hand-operated sewing machine for electrical operation.
- The hours of operation can be extended through the provision of good light. Teachers in Sanyati can work their normal daylight hours and then provide supplementary lessons in the evening for students needing extra tuition for a fee. Similarly, home-based income-generating

activities can operate in the evenings provided that good light is available.

- The working environment for income-generating activities is healthier through the elimination of smoke and fumes caused by the use of kerosene or even wood for lighting.

Any rural operator of an income-generating activity readily appreciates the benefits listed above. It can be argued that where modern energy services are available and affordable, rural entrepreneurs will adopt them. In this way, the existence of income-generating activities clearly has the effect of creating greater demand for modern energy sources. Indeed, the income-generating activities will attract sources which households alone would not attract as readily. Some of the income-generating activities can be singled out to illustrate this point.

- The ownership of radios is high in some areas in Zimbabwe: in 1999 some 73.4 per cent of urban households and 38.5 per cent of rural households owned radios (CSO and Macro International Inc., 2000). Television ownership was put at 52.1 per cent and 7.6 per cent for the same year for urban and rural households respectively. It is common to see freelance radio, television and general electrical appliance repair technicians in virtually all residential areas. Without an electrical supply, it is not possible to repair radios and televisions because testing is impossible. Whilst many technicians in remote areas use dry batteries or automotive batteries, those who can work at rural service centres do so because these centres are the target of the rural (grid) electrification programme. Having access to grid electricity removes many barriers faced by these technicians, including lack of light for evening work, inappropriate voltage for televisions other than 12 volt black and white sets, and limited power for tools such as soldering irons.

- The provision of evening supplementary lessons by teachers, as found in the Sanyati survey, is also common in urban areas. The difference is that while in urban areas electrical lighting is almost universally available, in rural areas it is the exception. Good light is a prerequisite for holding evening classes. Only those teachers with SHS or with access to similar sources of good lighting capable of illuminating a large room can earn income from supplementary lessons. Adult literacy classes are also greatly facilitated because most adults are not free for lessons during the day.

- Sewing and knitting as income-generating activities are easy to start because the initial capital requirements are minimal in comparison to other manufacturing initiatives. It is possible to start either activity by hand without machinery, and then acquire machinery to increase productivity. The availability of modern energy sources will allow further productivity gains through use of powered sewing machines instead of manual ones for example. Good lighting will increase the possible working hours to an extent only limited by the needs or capability of the entrepreneur.

- For baking and handicrafts, very similar considerations apply.
- Carpentry tends to be large-scale, and such enterprises tend to be based at rural service centres where access to suitable power is assured. The use of power tools is common, though the use of hand tools is unavoidable in smaller enterprises located at more remote sites. Good light can also extend the working hours and lead to greater productivity. Similar issues arise in metal fabrication enterprises. The fabrication of sheet metal products such as buckets, dishes, wick lamps, poultry feed dispensers and letterboxes can be accomplished without power tools, but even for these, good lighting will allow more production. More elaborate products, like door and window frames, grate stoves, gates and burglar bars require soldering and welding. For these, power becomes necessary. Other services such as spray-painting require compressed air. Virtually all small air compressors are electrically driven.

Modern energy sources clearly expand the scope for rural enterprises. Rural enterprises will place a premium on these sources and it is common to find a proliferation of income-generating activities where the grid has reached a rural service centre. Indeed, one of the criteria used in Zimbabwe for selecting and prioritizing rural service centres for grid extension is the perceived potential demand for power – not so much from households, but from enterprises. The Expanded Rural Electrification Programme approved by the Zimbabwe government in 2002 incorporates a facility directly aimed at the creation of sustainable incomes in rural areas, thereby ensuring demand for electricity. The End Use Infrastructure Finance facility is designed to assist customers to acquire capital equipment that uses electricity for productive end uses (ZESA, 2002). Eligible equipment includes:

- irrigation equipment for irrigation schemes;
- food-processing equipment;
- metal and woodworking equipment;
- grinding mills;
- oil pressing machines;
- baking ovens;
- sewing machines;
- other machines that may be identified.

The Rural Electrification fund provides the required equipment up front and the customer is offered repayment terms over 3–5 years at 17 per cent, at a time when the prime rate is over 60 per cent.

Hypothesis 3: Prioritizing components for the promotion of RETs

Table 3.9 lists some of the major rural energy initiatives that have been undertaken in Zimbabwe. It shows a number of recurring critical components that tend to contribute to the success or failure of the initiatives. The table shows most of the rural energy initiatives that have been implemented in Zimbabwe. The biogas and woodstove projects have been predominantly of the welfare type, largely implemented by government in the 1980s. The technocrats in government decided what the energy problems were, and went on to formulate technical solutions that sough to improve efficiency, conserve wood and allow use of resources not used for energy in the same way before. This approach was inherently top-down and, not surprisingly, missed the actual needs of the intended recipients, which had not been established beforehand.

The other category of projects, which include the PV pumping and UNDP/GEF solar projects, are partially ‘welfare’ in that considerable donor support was provided and the approach was partly top-down. In addition, numerous major institutions were involved, with the attendant complications this entails. The high capital costs involved meant that, where end user purchase was intended, financing arrangements were part of the project, thereby bringing in a financing institution. The complicated arrangements did not help in facilitating provision of maintenance.

Table 3.9 Summary of rural energy initiatives in Zimbabwe

Initiative	Installed	Functional status & verdict	Welfare or economic	Components leading to failure/ success
Biogas	Over 200 units nationwide, approximately five for income generation.	Approximately 10–15 units in use at least occasionally in 1997. Overall failure.	Predominantly welfare. Economic if gas and slurry are used. Private sector initiatives for income.	Lack of training to build digesters properly. Poor operation, lack of maintenance. No financing.
Mini/micro hydro	Eight sites mostly in the Eastern Highlands of Zimbabwe.	Seven out of eight units are operational in 2000. Successful.	Not welfare, not even in the community scheme at Nyafaru in Nyanga district.	Suitable institutional structures in place. Operation costs from tariff.
Solar PV (UNDP/GEF)	Approx. 12,000 45 Wp equivalent systems.	Over 60% of systems only partly operational in 2002. Lack of maintenance support and spares.	Predominantly non-welfare, except installations at clinics and schools.	Top-down implementation. Lack of maintenance back-up. Short-lived financing mechanism.

Solar PV (ESCO)	Almost 600 units in all (BUN, ZESA, ORAP).	Over 90% expected to be operational in 2002. Effective local maintenance available. Successful.	Economic, but facing increasing inability to pay by clients as economy worsens.	Effective institutional arrangements. Guaranteed local maintenance. Suitable payment scheme.
SOLAR PV (DIY/private)	Approx 72,000 systems of highly variable quality.	80% of systems semi-operational in 2002. Dissemination success, maintenance failure.	No welfare systems.	Flexible payment through gradual build-up. Lack of training leads to poor design and maintenance.
PV water pumping	15 sites nationwide.	Most sites functional in 1997. Locally trained maintenance is in place. Successful.	No welfare systems.	Effective institutional arrangements. Maintenance arrangements. Multi-stakeholder approach. Cost recovery.
Wood/coal stoves	Approximately 14,000+ coal and wood stoves. Coal stoves<1%.	Most in working order but over 95% abandoned by 1997. Failure.	Welfare. Demo type installations often unsuited for cooking on the large scale needed for income generation, e.g., brewing.	Top-down design & implementation. Not suitable for intended use.
Gasification	About six units of which two were government research trials.	Four commercial units operational 1997. Government test units abandoned 1993. Successful.	Economic. Dominated by commercial units in industry.	Effective institutional arrangements. Maintenance guaranteed. Suitable financing.
Wind pumps	650 units, all privately installed.	Most expected to be functional in 1997. Successful.	Income-generating objective. Economic. No welfare installations.	Effective institutional arrangements. Maintenance guaranteed. Suitable financing.
Gensets	Thousands. Approx. 3,000 diesel grinding mills in all.	Most expected to be functional in 2000. Successful.	Economic. No welfare installations.	Effective institutional arrangements. Maintenance guaranteed by supplier and available locally. Suitable financing.

Source: DoE Biogas and Stove project records; BUN Solar project records; ESMAP, 2000

Initiatives in the last category, including industrial gasifiers, gensets and windmills, were driven predominantly by the private sector and almost all concerned with income-generating activities. Where financing was necessary it tended to be through normal commercial channels and maintenance was through the equipment supplier or his agent. This approach is inherently bottom-up since any equipment supplied is in response to end user demand. The success of the initiatives in terms of actual adoption and sustained use tends to improve as one goes down the three categories presented above.

Key components responsible for the success of most projects

A SUITABLE INSTITUTIONAL ARRANGEMENT must be in place to support the initiative at all stages. Typically this is seen to be the case with commercial projects like the biogas plants at Malwatte and Monte Cassino, the gasifiers manufactured by a Harare company and installed at client companies in Harare and Mutare, the windpumps and gensets. In all cases, commercial companies who have local agents capable of interfacing with clients sell the equipment. This approach is inherently bottom-up in the sense that the supplier can only sell if the end user wants the goods, and these are backed up with warranties and technical support. The opposite case is illustrated by the general failure of government RET initiatives because of the top-down thinking that led to a technology-dominated approach.

FINANCING ARRANGEMENTS that are suited to the client need to be in place. This and appropriate cost recovery measures like tariffs in the case of mini-/micro-hydro schemes are important for project sustainability. One of the reasons cited for the failure of the biogas programme in its early phases is the high cost, comparable to a small solar home system, in the absence of any suitable financing scheme. The woodstove programme, because of subsidies on stove kit components like grate and chimney, was able to achieve high dissemination numbers even though it ultimately failed for other reasons. The ESCO solar home systems have also fared much better than the UNDP/GEF solar home systems (both accommodated homes and also small retail businesses) because the former had a far more flexible payment system, suited to rural farmer income profiles, and reached more clients not in formal employment.

MAINTENANCE is a critical component in the post-installation stages of projects. Even though the UNDP/GEF solar home system project notched up relatively impressive dissemination figures, lack of maintenance backup led to failure in the post-installation phase. In 2002, 63 per cent of a sample of photovoltaic systems installed by that project were found to be only partly functional (BUN/JICA/DoE, 2002). In comparison ESCO solar home systems have also fared much better than the UNDP/GEF solar home systems (both accommodated homes and also small retail businesses) because the former guarantees maintenance by a trained resident technician. Only the DIY/privately installed photovoltaic systems fared worse that the UNDP/GEF Solar Project systems, with about 80 per cent of sampled systems malfunctioning. Another useful example is the case of gensets. Even though in most cases the suppliers are urban-based, the equipment is sold under warranty (typically one year). More importantly, the client still has access to competent local technicians after the warranty period because skills to service cars are widespread. It is common to find motor mechanics and electricians in virtually all rural centres.

The gasifiers provide another illuminating example of the pivotal role of maintenance. The manufacturer, Cochrane-NEI in Harare, initially sold gasifiers to client companies, including food and household chemicals manufacturers. It was discovered that the client companies were not able to run their gasifiers optimally. Cochrane then adopted an ESCO approach whereby they would own and run the gasifiers installed at client premises and sell the gas to the clients. The clients were left to focus on their core businesses. The client was also covered by a guarantee on gas supply which stipulated that if there was a gasifier failure and the client was forced to run on an alternate fuel like diesel, for example, Cochrane would cover any costs resulting from the temporary fuel substitution.

The above components would seem to merit the highest priority in the promotion of RETs for income generation. They address the issues of accessibility, suitability, affordability and reliability, which are important for a business client.

Biogas example

A comparison of successful and unsuccessful biogas rural initiatives for income generation in Zimbabwe is provided in Table 3.10.

Comparison of biogas initiatives

The table attempts to highlight certain components and their relative importance in two income-generating biogas projects. Clearly at different points in the life of the projects the importance of different components will change, as indicated in the table.

Market research is seen as being of low importance in the above comparison because in both cases the end users sought to have biogas plants installed. It was not a case of a vendor attempting to identify markets for the technology. In the case of Mr Mapanga, the digester was self-built and the primary use is gas generation for refrigeration using a modified gas-absorption refrigerator. This modification is rather simple, though probably not optimized. The original gas burner, manufactured for high pressure LPG, is modified by enlarging the jet and air inlet holes to allow it to work with low-pressure biogas.

Table 3.10 Comparison of two income-generating biogas installations

Components	Stage when critical	Malwatte guest house, Marondera	Mapanga shop, Murewa	Level of importance
Market research	Planning of the project	Modest effort	Modest effort	Low
Financing mechanism	Installation of the project	Instalment payment	Cash basis	Moderate
Training & capacity building	All stages of project, esp. for operators	Provided by installing company with manual	Self-taught	High
Operation & maintenance	Post-installation phase	Working very well	Facing some problems	High
Gender considerations	Planning stage of project	Not an issue	Not an issue	Low
Quality control	Mostly installation stage	High	Minimal	Moderate

The primary purpose of the Malwatte installation is two-fold: waste treatment and energy production. The waste treated includes kitchen waste and sewage for the small restaurant and guest house complex.

The *financing mechanism* component is judged as of moderate importance since in both cases the end user paid in stages as the installation proceeded and did not need specific provisions for third party financing. The progress of payment was negotiated directly between the end user and installer in the case of the Malwatte installation, and dictated by the requirements as construction progressed in the case of the Mapanga installation.

Training and capacity building is clearly of high importance since it will affect the quality of *maintenance and operation* of the installation in both cases. The higher the quality of maintenance and operation, the more satisfactorily the installation will perform and last.

Gender considerations are judged low in the above example, which is very different to what may be expected in the case of household energy. The operation of the above installations and the utilization of their outputs do not have gender-specific characteristics.

Quality control in this comparison is judged as being moderately important in view of the fact that the installation was undertaken by motivated and well-qualified personnel, and would be the case if significant installation of biogas plants for commercial clients were to take off. One reason would be the demand for high quality by the paying client, and the need to maintain a good reputation on the part of the installing company.

Solar PV Example

The UNDP/GEF Solar Project is compared with the JICA-funded ESCO projects in Table 3.11. Both projects are PV and both were open to household and rural commercial clients. This means the projects had a mixed focus (income-generating and non-income-generating clients). Both projects involved a number of large institutions, perhaps more in the case of the UNDP/GEF solar project.

In the sense that both projects provided income-generating opportunities for the installers (mostly small companies from the nearest town or rural centre), they can also be seen as having an income-generating focus. The technicians who service ESCO installations are always local and earn income from this. The rural shops who procured PV systems were getting income before the systems were acquired; the reason for adding good quality lighting was mainly to increase working hours and therefore add to income. What difference this made has still to be quantified through selected case studies.

The comparison of the UNDP/GEF Solar and ESCO projects illustrates the importance of selected components. Although neither project was aimed exclusively at income generation, they were both open to rural enterprises, and numerous general dealer shops or small bars acquired solar PV lighting systems in order to extend operating hours beyond nightfall, and to power radios for the entertainment of clients.

Operation and maintenance arrangements differed markedly between the two projects. The ESCO approach had this component as a priority from the outset. The ESCO risks non-payment of fees by the client if the system is not working. In the UNDP/GEF project, on the other hand, the installing company was making its money from installations and had little incentive to provide any maintenance back-up. In BUN's experience, the ESCO PV systems have fared far better technically and contact with clients through the local technicians and institutions is good (BUN, 1995). It should also be noted that, within the UNDP/GEF project, the NGO mode allowed some autonomy of approach: participating NGOs appointed facilitators with responsibility for marketing, providing information and undertaking basic maintenance. These facilitators in some cases ended up providing services to other clients who had obtained their systems from elsewhere but did not have access to maintenance back-up.

Operation and maintenance is judged to be critical in both cases, which involve modules expected to last over 15 years, but containing electronic components that can fail frequently (charge regulators and 12 volt DC fluorescent lights). Batteries are also prone to premature failure if not handled correctly. The UNDP/GEF solar project did not have a built-in maintenance mechanism and the collapse of many of the installing companies may have left most clients without access to competent maintenance services. On other hand, the ESCO approach has, as an integral component, trained local maintenance personnel and limited user access to key components to minimize tampering.

Financing mechanisms constitute another major difference between the projects. Whereas the UNDP/GEF project generally required regular monthly payments, the ESCO project allowed payments to coincide with the patterns of income from the sale of agricultural produce of the rural farmers. The result is that over 90 per cent of the UNDP/GEF project clients were relatively affluent rural-based civil servants like teachers and extension officers. Rural farmers, with no regular monthly income, predominantly accessed the ESCO projects. The small installing companies were also in need of working capital and this need was usually accommodated by the Agricultural Finance Corporation (AFC) through short-term loans. The issues of purchase credit and working capital were also identified as crucial to the successful growth of the SHS industry (Northrop *et al.*, 1996).

Table 3.11 Comparison of components in two solar photovoltaic projects in Zimbabwe

Component	UNDP/GEF Solar Project	JICA/ESCO (Energy Service Company)	Impact on project
Operation and maintenance	Limited user training. No specific long-term maintenance provisions in project. Systems scattered, no deliberate clustering.	Ongoing user training through monthly technician visits. User access to battery and charge regulator restricted. Technician provided with tools and bicycle. Systems clustered for easy access.	Critical to reputation and sustainable operation of project. ESCO approach made much difference.
Financing mechanisms	Largely loan system administered by Agribank. Repayments monthly at subsidized interest rate. Installing company paid in full upon inspection of installation. (Agribank takes the risk of default.)	User pays service fee, not purchase instalment. Payment frequency flexible to take into account rural income patterns, often tied to harvests. ESCO faces risk of default.	Can make or break project, especially at start. Flexibility in payment frequency allows wider access.
Market research	Considerable effort through outreach programme to locate markets and advertise.	Considerable efforts made to locate areas with existing income-generating activities to ensure ability to pay.	Fairly minor difference made. Important to improve targeting.

Institutional arrangements	Multi-institutional and complex, including government, UNDP, industry associations. Change difficult – one-year delay caused by administrative adjustments in midstream.	Single. ESCO contracted to implement project in specific clusters, though project owner is government. Administratively simpler.	Can strongly influence flexibility and efficiency in project planning and execution.
Quality control	Initially weak. Large number of installers, quality initially variable. Industry association used to regulate practices. Standards developed as part of project in collaboration with Standards Association of Zimbabwe.	Quality level more consistent through contracting ESCOs with track record. Maintenance technicians under contract to ESCO.	Critical to user satisfaction & technology reputation. This was later recognized in UNDP/GEF project.
Gender considerations	No specific gender-related measures. Equal opportunity approach. Some female-headed companies participated.	No specific gender-related measures. Equal opportunity approach. First of two maintenance technicians was female.	No strong impact on dissemination noted in either project.

Source: Partly compiled from DoE and BUN project records

Institutional arrangements were seen to have been a major issue in the UNDP/GEF solar project, with changes leading to prolonged delays in project execution. The involvement of several large players (government, UNDP, AFC, industry associations) made a certain amount of bureaucracy inevitable, leading to slow decision making. In contrast, the NGO mode of the same project, which enjoyed considerable autonomy in approvals and loan disbursement, was able to move quickly despite starting in 1996, only two years before the end of the project.

In 1998 the Chinese government donated some 110 solar home systems to the government of Zimbabwe. These were installed in Chiweshe communal area, Mazowe district, free to villagers at Kawanzaruwa village. It was belatedly realized that provision had not been made for maintenance, and ZESA was requested to arrange to provide the necessary support. This led to the opening of negotiations with the villagers, to agree on maintenance fees. This has proved to be difficult since the villagers did not accept the SHS installations with the anticipation of having to pay any fees, and ZESA cannot provide a free maintenance service. To date the systems do not have organized maintenance cover. This shows the value of effective coordination between relevant institutions at all stages of a project.

It is clear that operation and maintenance, financial arrangements, and institutional arrangements are relatively more important in the level of impact on project implementation and sustainability. In this case gender issues were of relatively minor importance.

4

Draft Policy Options

In this chapter recommendations were developed out of the findings presented in Chapter 3. In most cases each main finding led to a recommendation or related recommendations. It was also possible for several findings to lead to a common recommendation.

A process of filtering was applied to the recommendations to test their feasibility given the prevailing situation in Zimbabwe. The four filtering criteria used were: (1) institutional and management capability; (2) legal framework; (3) economic and financial; and (4) human resources and technical capacity.

Table 4.1 Hypothesis 1: summary findings and recommendations

Findings	Recommendations
The private sector is almost entirely involved in income-generating rural energy initiatives and has been successful in this in examples cited in the study.	A policy that is sensitive to the needs of the smaller entrepreneur would assist access to modern energy by that sector. An example would be duty and tax concessions that differ with size of genset, with the greatest rebates on sizes identified to be most used by small rural entrepreneurs.
There is a synergy between public sector initiatives and private sector success. The public sector can successfully raise awareness and demonstrate, preparing the ground for private sector enterprises. There is a large number of installed SHS with inadequate access to maintenance, leading owners to attempt maintenance without adequate knowledge. Mistakes are common in system matching. The lack of charge controllers leads to expensive battery failures. Since most modules are small, the risk of overcharge is less than that of over-discharge in existing systems. By the time users notice that the battery voltage is low, it will be at a level representing severe deep cycling.	Emphasis should move away from promotion of even more new PV systems to projects aimed at building capacity for design and maintenance of SHS by the private sector, especially local technicians. This will work in favour of PV technology in the long run. A similar argument can be made for biogas and stoves. There is need to promote projects that address the need for discharge control for both existing SHS and battery-only systems as they both would benefit from control of battery discharge. Government should carefully plan projects that are tailored to hand over dissemination to the private sector.

Hypothesis 1: Decentralized private sector vs centralized public sector energy initiatives

It has been established that the private sector did not undertake welfare energy projects and that its efforts have generally been successful. In contrast, public sector efforts have had a strong welfare bias and fared less well in comparison. Interestingly, there was found to be synergy between the two, where private sector dissemination benefited from prior public sector introduction and demonstration of certain technologies. The findings and draft recommendations are summarized in Table 4.1.

Policy sensitive to the needs of smaller entrepreneurs

Institutional and management capability

By its nature this recommendation cuts across the responsibility of a number of government departments. The major departments affected are the Revenue Authority (tax and duty), Department of Energy, National Affairs and Job Creation, and Social Welfare (where the Registrar of NGOs is based). The first problem is to decide which department will own the process, a decision that depends on what is seen as the key issue, energy provision or rural job creation.

Legal framework

Harmonization of existing legislation is needed in order to ensure that the territorial tendencies that often hinder collaboration across departments and between different stakeholders is minimized. This problem has been recognized for some time and has led, for example, to reorganization of government ministries and revision of legislation, particularly that relating to the environment, in recent years. In view of existing awareness, it should be relatively easy to tackle the issue of harmonization of the relevant legislation. The Department of Energy is already working on a draft Energy for Rural Development Strategy that looks beyond just energy services provision and will force collaboration with sister departments involved in rural development.

Economic and financial

No significant economic or financial implications are foreseen in the implementation of this recommendation.

Human resources and technical capacity

As far as the formulation of the policy is concerned, there exists good capacity in the various government departments. The emphasis on rural development is already quite strong. This capacity can be augmented through consultation with independent stakeholders outside government. There are precedents for this: for example, the developing National Biomass Energy Strategy and Energy for Rural Development Strategy have entailed consultative workshops to which virtually all relevant local stakeholders have been invited on numerous occasions.

Conclusion: The recommendation should be easy to implement on the basis of the generally positive outcome of the filtering process.

Building capacity to design and maintain solar home systems

Institutional and management capability

This recommendation entails considerable emphasis on training. In terms of the necessary institutions and capacity to manage the process, several institutions besides the Department of Energy have been directly involved with SHS and can actively contribute. These include NGOs that were involved in the UNDP/GEF solar project, and the JICA/ESCO solar study and pilot project.

Legal framework

The existing legal framework will accommodate the recommendation without need for any changes.

Economic and financial

There could be sizeable financial implications for capacity building. The source of such funds depends on the approach taken. Donor funding is likely to be more difficult to obtain than it is for projects that disseminate solar home systems. One way to tap into funds for dissemination is to require that all budgets for disseminating solar systems allocate, say, 20 per cent for capacity building for design and maintenance. Had this been policy in Zimbabwe at the start of the UNDP/GEF Solar Project in Zimbabwe, nearly US$1.5 million would have been raised out of the budget of more than US$ 7 million.

Human resources and technical capacity

Sufficient capacity and experience exists locally for the implementation of the recommendation. In fact, when the Stockholm Environment Institute wanted to start an energy service company pilot project in Zambia, a Zimbabwean NGO, the Biomass Users Network, was selected to train the Zambian companies. This was in view of the experience accumulated in Zimbabwe.

Conclusion: The most difficult requirement of this recommendation is funding. The recommendation is not likely to be feasible in Zimbabwe under the conditions prevailing in 2002–3. The serious economic and political problems besetting the country have led to the departure of most donors, and a change in focus to food relief.

Plan projects that are tailored to hand over dissemination to the private sector

INSTITUTIONAL AND MANAGEMENT CAPABILITY

This recommendation refers to a model that has worked before – in effect, if not by design. The institutional and management capacity is available. What is being proposed is a more deliberate approach to fine-tune the roles of the private and public sectors in a mutually beneficial relationship.

LEGAL FRAMEWORK

The existing legal framework is sufficient to cope with the needs of the recommendation. No new provisions are required.

ECONOMIC AND FINANCIAL

The changing role of the government is a potential constraint. For example, the Department of Energy is moving away from implementation and towards policy. If this means that no more demonstration projects will be funded by government, then the catalytic role is lost. It is however possible for the Department of Energy to demonstrate desirable options through commissioned projects that are carried out by third parties on contract to the Department of Energy. This means the Department of Energy would still fund such projects.

HUMAN RESOURCES AND TECHNICAL CAPACITY

Past experience with biogas and solar home systems suggests that the human resources and technical capacity required for the implementation of this recommendation are available in the country.

Conclusion: This recommendation fails – filtered out by economic and financial considerations reflecting the present crisis in Zimbabwe. Under normal conditions the Department of Energy could perform the proposed role, albeit mainly using donor funds.

Hypothesis 2: Income-generating activities vs domestic energy use

It has been shown that income-generating activities operate at higher power levels than household uses: how much more depends on the specific type of income-generating activity. It is also clear that modern energy services open up certain opportunities that would not exist without them, or only on a smaller scale. The existence of income-generating activities has been shown to enhance the market for modern energy services. These findings and the recommendations that follow can be summarized as shown in Table 4.2.

Table 4.2 Hypothesis 2: summary findings and recommendations

Findings	Recommendations
Modern energy services open up opportunities for income generation more than traditional energy sources. Some of the opportunities are impossible without modern energy services. It is likely that rural livelihoods will be uplifted through the provision of modern energy services since these provide an enabling environment for the establishment and growth of income-generating activities.	Modern energy services should be provided with a bias towards income generation. It is important that a range that is wide enough to accommodate the poorer and smaller entrepreneurs is made available.
Income-generating activities operate at higher energy intensities than household uses. The amount of energy consumed by income-generating activities is generally greater because income-generating activities target customer bases larger than the typical family size and also often rely on processes not encountered in households.	
The existence of income-generating activities raises the potential market for modern energy services. This is due to the need for improvement of existing income-generating activities, which can almost always expand production once they have access to modern energy services.	The promotion of income-generating activities and modern energy services need to be integrated. This will ensure that entrepreneurs will be offered a menu of all necessary elements for success.

Modern energy services have been promoted for many years in Zimbabwe, but the approach has generally been top-down and welfare-focused. It has become increasingly clear that the overall impact has been poor, with wholesale failure of most initiatives. It is recommended that a broad range of modern energy services be made available. This will ensure that the poorer entrepreneurs who operate at the household level are not left out. By availing this group of modern energy services, a larger number of entrepreneurs with the potential for expansion is captured. This expansion will see growing demand for modern energy services: for example, a home-based income-generating activity such as hand sewing grows and then moves into a small shop and acquires machinery.

There is a need to take an integrated approach to the promotion of income-generating activities and modern energy services. The usual approach is for different arms of government to take responsibility for these different aspects of rural development. In Zimbabwe much of the small-scale rural entrepreneurial development thrust has been under the

Department of Cooperatives. One of the main approaches was to encourage the establishment of rural cooperatives. This was, of course, a top-down aspect of the approach. For energy, the Department of Energy has dominated efforts for several decades. The two departments have not worked out a combined approach focusing on income-generating activities so that business skills training, financing, and modern energy services could be packaged and delivered to suit the target group. This approach would be more likely to succeed and would lead to greater demand for modern energy services in rural areas alongside the success and growth of income-generating activities.

Box 4.1 Summary of the new Expanded Rural Electrification Programme (EREP)

On 23 January 2002 the Zimbabwe government ratified the Rural Electrification Fund Act (REFA). The new act is related to the new Electricity Act, 2001, which provides for the transformation of ZESA into a 100 per cent government-owned company.

The REFA provides for the establishment of a Rural Electrification Agency (REA) with its own broad-based 13-member board. The REA will work closely with ZESA to implement the EREP. The EREP will provide a 60 per cent capital subsidy to community-initiated projects. The community pays 40 per cent of the cost of electrification up to the consumer meter. Entrepreneurs running enterprises that benefit the community such as grinding mills also qualify for the capital subsidy. The Rural Electrification Guarantee Scheme will assist communities that have a shortfall for the 40 per cent contribution. As long as the community can raise 10 per cent deposit and show evidence of regular income, the connection is undertaken. The balance can be repaid over a maximum of five years at an interest rate of 17 per cent (prime rate over 60 per cent). This facility allows communities to have the work done at once, thereby avoiding price escalations.

Another mechanism is the Rural Institutions Electrification Revolving Fund which offers loans to interested institutions over 24 months, also at 17 per cent annual interest rate. This revolving fund is financed by GTZ. The loan will only cover a maximum of 40 per cent of total required funds.

The End Use Infrastructure Finance option allows the Rural Electrification Fund to acquire in bulk selected equipment to be used in income-generating activities such as grinding mills, irrigation equipment, oil presses, sawmills, sewing machines and food-processing appliances. The equipment will be available to eligible customers who will be required to pay over three to five years at 17 per cent annual interest rate.

To finance the EREP, the current 1 per cent rural electrification (RE) levy on electricity tariffs will be raised to 3 per cent and a RE Bond (US$ 40 million) will also be raised. There will also be tax exemptions on EREP equipment. The total requirements for the EREP have been put at US$0.54 billion between 2001 and 2004 (exchange rate Z$55 per US$).

Source: ZESA, 2002

A very good example of the type of approach advocated above is the approach taken by ZESA in the recently announced Expanded Rural Electrification Programme (EREP) outlined in Box 4.1. The scheme is clearly aimed at enhancing the use of grid electricity by facilitating the setting up of rural business enterprises. The enterprises catered for range from individual to community level.

Modern energy services should be provided with a bias towards income generation

Institutional and management capability

The institutional and management capacity for the implementation of this recommendation already exists in Zimbabwe. It has already been indicated that a range of modern energy services have been promoted, particularly in rural areas. The only change required is to focus more on income-generating activities rather than on a welfare approach. The other main institutional development of interest is the refocusing of Department of Energy functions towards a more policy-related role, leaving the implementation of projects to other players.

Legal framework

The legal framework has improved in favour of this recommendation in view of the liberalization of the power sector. Parliament has ratified two important Acts, the Electricity Act, 2001 and the REFA, both very early in 2002. The resulting legal environment facilitates the entry of more players.

Economic and financial

The Zimbabwean economy is going through difficult times and many implementing agencies and customers will find it difficult to cope with the costs of anything other than the most basic needs such as food and shelter. The alleviation of rural poverty will nevertheless entail empowerment of rural income-generating activities. It is to be expected that in a few years' time this effort will once again gain impetus.

Human resources and technical capacity

Despite the changing role of the Department of Energy, there are many development organizations such as NGOs and church-backed groups that are capable of disseminating modern energy services through good community links. The utility ZESA has also been involved in SHS pilots and has gained experience in working at rural household level in the process.

Conclusion: This recommendation could be implemented through non-governmental channels. Donors are prepared to fund non-bilateral projects in times of disagreement with the government. This recommendation addresses poverty alleviation by enhancing income-generating potential at a time when the formal sector of the economy is shrinking. This leads to greater numbers of people moving to the informal sector.

Promoting and integrating income generation and modern energy

Institutional and management capability

This recommendation is quite challenging to implement practically. It requires that either government departments work together in a much more coordinated manner, or become willing to take a wider view than before. The new EREP shows the way by planning to supply electricity together with the machinery needed by entrepreneurs and concessionary financing. The Department of Energy is also in the early stages of drafting its Energy for Rural Development Strategy, which acknowledges the fact that an integrated approach to rural development is needed, not simply promotion of energy technologies as an end in itself.

Legal framework

There are no specific legal issues other than related issues already discussed under the first and second recommendations on Hypothesis 2.

Economic and financial

The same short-term constraints that have been cited under the first and second recommendations apply to this filter.

Human resources and technical capacity

The capacities and human resources in the different potential players differ considerably. There are unlikely to be many persons who will be familiar with the approach that is being recommended. Careful coordination of the inputs of the different players into a coordinated rural development programme, including business skills training, financing and administration of loans, provision of necessary modern energy services, community organization and maintenance is critical. This is seen as a challenge that will pose some difficulty in the short term.

Conclusion: This recommendation faces short-term constraints but should be feasible in several years' time when, it is assumed, the prevailing crisis in Zimbabwe will be closer to resolution.

Hypothesis 3: Prioritizing components for the promotion of RETs

It has been found from the analysis of past projects that certain components are more important than others. This level of importance has been shown in some cases to vary depending on the stage of project implementation. Three components have been singled out as being particularly important and these are summarized in Table 4.3, followed by discussion and filtering.

This policy recommendation on supportive institutional arrangements relates to the institutional role that the government has played in the past and the fact that most major initiatives continue to involve government. It is recommended that government defines its role more clearly as a facilitator, and produces a policy that clarifies the roles of parastatals.

Some of the roles of key players are subject to legal instruments such as the Electricity Act. The installation of the necessary institutional framework is likely to entail some changes to existing legislation. Such changes will obviously affect many players in view of existing overlaps.

Where international partners are involved, it is necessary that the partnering with local institutions is carefully harmonized to avoid the need for major reorganization in mid-project, as was seen in the UNDP/GEF solar project.

Table 4.3 Hypothesis 3: summary findings and recommendations

Findings	Recommendations
Institutional arrangements that are supportive of energy initiatives were found to be a key success factor. This was exemplified by the case of gensets with their marketing and maintenance infrastructures. This contrasts with the recent solar home system donation installations in Mazowe district, in difficulty because no institutional arrangements were put in place to support them. The availability of appropriate financing mechanisms was seen as a key contributing factor to the dissemination of solar home systems by both the public and private sectors. On the other hand, biogas digesters costing as much as a small solar home system had no financing and achieved far more modest dissemination numbers.	Policy must change to reflect the evolving situation where government increasingly takes on a facilitator role. Legislation needs to be harmonized because of overlapping provisions in the roles of different departments and parastatals. In order to include the poor, appropriate financing mechanisms are necessary. Careful targeting is essential and financial institutions, including local small organizations can play an important role in the administration of some of these mechanisms.
Maintenance was found to have been the major problem in the post-installation phase for the UNDP/GEF solar project in Zimbabwe. In contrast, gensets generally have readily available maintenance, as do commercial gasifiers.	The issue of long-term maintenance provision must be made a requirement for government support of new projects – in the same way that environmental impact assessment has become obligatory in many countries.

Appropriate financing arrangements are needed for end users to be able to take advantage of initiatives that may call for resources beyond their immediate means. Appropriately targeted financing mechanisms can be made available through specific measures like tax incentives or special lending windows administered through banks or similar institutions. The government has from time to time shown that it understands the specific needs of certain disadvantaged groups with regard to access to appropriate finance. This is shown by the existence of specialized financing institutions like Agribank, Small Enterprise Development Corporation, and, more recently, a special fund to stimulate indigenous participation in the mainstream economy.

It has been said that the government and donor agencies can make one of their most effective interventions in the area of financing, for example by seed-funding revolving credit schemes that allow poorer communities to access modern energy services (ESMAP, 2000).

Just as governments in many countries have imposed conditions such as the need for an environmental impact assessment before approving projects, so policies can be adjusted to ensure that projects to be supported or approved take into account the need for maintenance from the outset. The maintenance arrangements will be sustainable if it is profitable for trained technicians to service installations. This calls for numerous issues to be borne in mind, including the physical lay-out of the project, minimizing distances to be covered for maintenance. This may mean clustering, for example, an approach used by ESCO in Zimbabwe. It is also important to avoid a monopoly by the service technicians, which would lead to high charges and low service quality.

Supportive institutional arrangements

Institutional and management capability

Management capacity to effect the recommended changes may be limited because a certain amount of institutional reform is implied, but institutional reform is occurring in many sectors anyway as part of current economic reforms. The main point of concern is that the thrust of the ongoing reforms may not lead to a more supportive environment. This is because the drivers for these changes are macro-economic and often of external origin.

Legal framework

Legal changes are likely to be simple and can be handled by government. At most the legal steps that may be required are amendments to existing legislation to facilitate interaction and coordination of the different departments and other stakeholders.

Economic and financial

It should be possible with some stakeholder consultation to map the way forward. The need for direct funding for these activities should be minimal.

Human resources and technical capacity

The existence of a wide variety of relevant stakeholders, including departments of government involved with development, NGOs, religious groups and CBOs, suggests that the issue of human resources and capacity is well under control. Multi-stakeholder effort involving government and the private sector is likely to be both feasible and mutually beneficial.

Conclusion: This recommendation is seen as being easy to implement because minimal resources are required beyond those already in place.

Appropriate financing mechanisms

Institutional and management capability

The Zimbabwean banking sector is relatively sophisticated and competitive and, besides the commercial banks, special banks exist for specific credit windows, for example Agribank (Agriculture) and the Small Enterprise Development Corporation (SMEs). This diversity ensures that local capacity should be ample to cope with the niche demands that may be imposed by this recommendation.

Legal framework

No new legal provisions are needed.

Economic and financial

As is the case in other recommendations with significant financial and economic implications, there exist short-term limitations due to the present crisis and general hardships being experienced in the economy – though it is expected that the situation will normalize in the next few years.

Human resources and technical capacity

The financial sector has adequate human resources and capacity as shown by the high level of indigenous participation in the sector. In recent years the number of successful indigenous banks has grown to rival the main multinational commercial banks. Newcomers that have successfully established themselves include Metropolitan Bank, Kingdom Bank, National Merchant Bank and First Bank.

Conclusion: This recommendation is seen as being feasible in the medium term once the prevailing cash crisis eases: beyond the shortage of cash, the other filtering criteria are positive.

Maintenance policy

Institutional and management capability

This recommendation should be implementable with existing resources. It will require consultation so that whatever policy is eventually adopted is practical and effective. The capacity to evaluate the maintenance provisions contained in elaborate project proposals presented for approval is likely to be inadequate at first. Through a process of learning from experience, the responsible government departments are likely to become better at the initial evaluation with time.

Legal framework

There are no complicating legal requirements that need to be attended to in order for the maintenance policy to be put in place.

Economic and financial

The enactment of the policy has no significant financial implications.

Human resources and technical capacity

The maintenance policy can be carried through with existing resources in relevant government ministries. Staff most likely to be involved are those already responsible for endorsing or approving projects submitted for government support or approval. There may be a need for training and collaboration with more technical sister ministries in the case of certain proposals requiring detailed technical insight. An inter-ministerial committee may be one option.

Conclusion: This recommendation can be implemented even under the present economic and political crisis as it does not require significant resources beyond enactment of a new policy.

5

Final Policy Recommendations

The final policy recommendations presented in this chapter are those recommendations that are thought to have a good chance of being implemented. The process of filtering that has been attempted in the previous chapter is the basis for the shortlisting of these recommendations.

Hypothesis 1: Decentralized private sector vs centralized public sector energy initiatives

The first recommendation is that modern energy services should be provided with a bias towards income generation. A wide range of energy supply options should be made available to accommodate the poorer and smaller entrepreneurs. In other words it is important to match the modern energy services to the scale, pattern and other characteristics of customer needs.

It is apparent from the filtering process that the two linked recommendations emanating from hypotheses 1 and 2, apart from some short-term complications due to the present political and economic problems in Zimbabwe, are feasible. One important fact is the lead now given by the REA in providing electricity with a very direct link to income generation by proactively making available the necessary equipment to facilitate income-generating activities.

The final policy recommendation made in this case is for the REA to take a wider approach that goes beyond grid electricity to include other relevant modern energy sources. This means, in areas unlikely to be reached by the grid, that if gensets are the most cost-effective option, these should be made available with the relevant back-up support, including financing and appropriate income-generating activity equipment. In South Africa, for example, ESKOM is energizing rural areas, not only through grid extension, but with LPG and solar PV systems where appropriate. In principle this approach, which takes a broader view of electrification, has much to recommend it. It also satisfies the other recommendation: to match energy options to demand, so that the chances of the poorer entrepreneurs being included are enhanced.

Hypothesis 2: Income-generating activities vs domestic energy use

The recommendation to pursue an income generation bias in modern energy, ensuring that the needs of micro-enterprises are not overlooked, and for better overall matching of what is offered in modern energy initiatives, should be relatively easy to implement under the prevailing conditions in Zimbabwe. The recommendation only demands an altered approach that is more bottom-up to ensure that needs are accurately known before interventions are initiated.

The second recommendation – to integrate the promotion and dissemination of modern energy services with that for income-generating activities – is more demanding in view of the dwindling role of government in dissemination projects and, more importantly, the financial requirements of promoting income-generating activities, which entails training and financing. The current high interests rates of over 60 per cent mean that even the relatively low concessionary rate of 17 per cent offered by the REA is still high compared to the bank savings rate in South Africa of up to 10 per cent.

Hypothesis 3: Prioritizing components for the promotion of RETs

The establishment of a maintenance policy for any new projects that require government support or approval can be accomplished with relative ease and will significantly improve the long-term performance of rural energy projects. The government is in a position to influence this process decisively because even projects that are not bilaterally funded usually need some documented government support. A demonstrable maintenance component can be required in all cases.

Institutional arrangements that will support programmes for the provision of energy for income generation can be beneficial to both the private sector and government – although, should enacting the necessary steps require even modest resources from government, the short-term prospects are dim in view of the prevailing economic and political crisis in Zimbabwe. If the process can be accomplished without requiring government resources, however, the recommendation should be viable.

The recommendation concerning financing arrangements may not be looked at favourably in the short term by government in view of factors already discussed above. This applies if any provisions affect government's ability to earn revenue through taxes and duties, which is likely.

Part III Select Bibliography

Bhagavan, M. R. 1999. *Reforming the Power Sector in Africa*. London: Zed Books.

BUN 1995. *Economic Feasibility Study: Plant Oil For Fuel Project*. Harare: Biomass Users Network.

BUN/JICA/DoE 2002. Unpublished First Draft Report on the Survey of the Status of Solar Home Systems in Zimbabwe. Harare: Biomass Users Network/Japan International Cooperation Agency/Department of Energy.

Corvinus, F. and Mapako, M. 2000. *Mid-Term Programme Evaluation*. Harare: ProBEC.

CSO 1997. Intercensal Demographic Survey report. Harare: Central Statistical Office.

CSO and Macro International Inc. 2000. *Zimbabwe Demographic and Health Survey 1999*. Calverton, Maryland: Central Statistical Office and Macro International Inc.

DoE 1992. *Energy Bulletin*, August. Harare: Department of Energy

DoE/GTZ 1997. *The Alternative Energy Strategy for the Department of Energy*. Harare: Department of Energy/GTZ.

Dube, D. 2000. 'Managing Change Effectively in the Private Sector: the Zimbabwe Experience', paper presented at the British Council Seminar on 'Leading Change', Harare.

Elliot, K M. 1983. 'Water Pumping Costs for Small-Scale Irrigation in Zimbabwe', paper presented at the Symposium on Energy in Agriculture, Harare, 11–12 May.

ESMAP 2000. *Photovoltaic Applications in Rural Areas of the Developing World*. Technical Paper 009. Washington: Energy Sector Management Assistance Programme.

Financial Gazette 2002. 'Power Sector Reform Gets Green Light'. Privatization Supplement to the *Financial Gazette*, 7–13 February 2002. Harare.

Foley, G. 1993. *Rural Electrification in Mozambique, Tanzania, Zambia and Zimbabwe*. Synthesis Report from the SEI/BUN Workshop on Rural Electrification. Energy, Environment and Development Series No. 16. Stockholm: Stockholm Environment Institute.

Government of Zimbabwe 1999. National Energy Policy (draft). Harare: Government of Zimbabwe.

Helmsing, A. H. 1992. *Small-Scale Rural Industries in Zimbabwe: an Overview*. ZERO Working Paper 17. Harare: Zimbabwe Environmental Research Organization.

Hulscher, W. and Fraenkel P. 1994. *The Power Guide*. London: Intermediate Technology Publications.

Karekezi, S. and Ranja, T. 1997. *Renewable Energy Technologies in Africa*. London: Zed Books.

Hall, D. O. 1997. *Biomass Energy Policy in Africa*. London: Zed Books.

Kjellstrom, B. *et al*. 1992. *Rural Electrification in Tanzania*. Energy, Environment and Development Series No. 15. Sweden: Stockholm Environment Institute.

Leach, Gerald and Johnson, Francis X. 1999. 'Modern Bioenergy. An Overview of its Prospects and Potential'. *Renewable Energy For Development*, 12, 4 (December).

Mapako, M. C. 1993. Unpublished internal report on a biogas study tour to Botswana. Harare: Biomass Users Network files.

—— 2001a. *Renewables and Energy for Rural Development Theme Group: Zimbabwe Country Report*. Nairobi: AFREPREN/FWD.

—— 2001b. Survey carried out in July 2001 in Sanyati, Kadoma District, in Zimbabwe.

—— 2002. ‘Solar Home Systems in Zimbabwe: Status, Problems and Possible Solutions’. Submitted as a policy paper in partial fulfilment of MSc programme requirements, University of Cape Town.

Ministry of Energy and Water Resources and Development/ZESO/GTZ 1989. *Electrification Masterplan Zimbabwe*. Harare: Ministry of Energy and Water Resources and Development.

Northrop M. F., Riggs P. W. and Raymond, F. A. 1996. ‘Selling Solar: Financing Household Solar Energy in the Developing World’. Report based on a workshop at the Pocantico Conference Centre of the Rockefeller Brothers Fund, New York, 11–13 October 1995.

Petringa N. 1993. *Decentralized Power Production in Zimbabwe*. Harare: Biomass Users Network.

Ranganathan V. 1992. *Rural Electrification in Africa.* London: Zed Books.

University of Zimbabwe/Department of Energy 1994. *Working Towards a Biomass Energy Strategy for Zimbabwe*. Harare: University of Zimbabwe.

ZERO 1991a. *A Business Analysis of Rural Small-Scale Bread, Beer and Brick Making Industries*. Working Paper 21. Harare: Zimbabwe Environmental Research Organization.

—— 1991b. *Technology Assessments of Bread Making, Brick Making and Beer Brewing Industries in Zimbabwe*. Working Paper 28. Harare: Zimbabwe Environmental Research Organization.

—— 1991c. *Rural Electrification and Growth Point Industries*. Working Paper 33. Harare: Zimbabwe Environmental Research Organization.

—— 1991d. *Energy Technology and Rural Industrial Development: Issues and Prospects*. Special Paper Series No. 1. Harare: Zimbabwe Environmental Research Organization.

—— 1998. *Energy and Sustainable Rural Industries: Issues from Pilot Studies in Tanzania, Zambia, Botswana, Mozambique and Zimbabwe*. Harare: Zimbabwe Environmental Research Organization.

ZESA 2002. *Extended Rural Electrification Programme*. Supplement to the *Financial Gazette*, 7–13 February 2002. Harare.

Part III Appendices

IIIA.1 Basic solar home system sizing method

Only the sizing of the battery and module are outlined. The charge controller is selected on the basis of the required current carrying capacity. The wires are sized on the basis of the current the wire has to carry, the length of the wire and the system voltage. The above information is only available after the system size has been calculated as shown here. Wiring is not sized here as it was not checked in the survey and no observations can therefore be made.

Load

It is first necessary to list the appliances that are to be powered by the solar home system. This is done by listing the items, their power ratings and the number of hours each is to be run per day, for example the following rough estimates may be used for illustration:

Appliance	Power rating (watts)	Hours of use per day	Watt-hours per day
Bedroom light	9	1	9
Lounge light	11	3	33
Kitchen light	11	2	22
30 cm black & white TV	30	3	90
Portable radio	10	8	80
Total load			234

The watt-hours are converted to ampere-hours by dividing by the system voltage, which is usually 12 volts DC. This division gives 19.5 ampere-hours.

Battery

This means the battery must be capable of delivering this amount of energy daily. This does not mean that a 19.5 Ah battery will suit this system.

There are several factors to be considered. These are:

- Number of days the system can continue to operate while receiving little or no charge;
- Battery depth of discharge: this will depend on the type of battery, which may be deep cycle or shallow cycle. Depth of discharge refers to the extent to which the battery is discharged in daily use.
- Winter temperature compensation, which depends on what the expected minimum winter temperature of the battery is. Battery capacity is temperature-dependent.

The formula for calculating the total battery capacity is:

$$\text{Battery capacity} = \frac{\text{load size (Ah)} \times \text{days of autonomy} \times \text{temp. compensation factor}}{\text{depth of discharge}}$$

Assuming three days of autonomy, a minimum temperature of 15°C with a compensation factor of 1.11 (this figure is available from the battery manufacturer), an 80 per cent depth of discharge of the battery, the load given above (19.5 Ah) will require storage capacity of 81.2 Ah.

Clearly this storage capacity is valid only for the system specified here, complete with the assumptions made. Should four days autonomy be required, the battery capacity would have to be slightly above 100 Ah.

Module sizing

Additional factors to be taken into account in module sizing are:

- Battery charge/discharge efficiency. This is because the energy sent to the battery during charging is not recovered 100 per cent on discharge.
- Sun-hours per day. This is the number of hours when effective insolation is available at the module surface, and does not correspond to day length. It could reasonably be assumed to be 10:00 hrs to 14:30 hrs, that is 4.5 hours. This was the standard figure used for GEF solar systems in Zimbabwe.

The total current required from the module or array of modules is:

$$\text{Total module current} = \frac{\text{Load (Ah)}}{\text{Sun hours} \times \text{charge/discharge efficiency}}$$

Taking a charge/discharge efficiency of 80 per cent (0.8) and 4.5 sun hours with the load calculated earlier (19.5 Ah), the module current is then 5.42 amperes.

As an example for module selection, Siemens Solar specifies module current and wattage ratings as shown in the following selection:

	Siemens SM50	Siemens SM55	Siemens SP75	Siemens SM100	Siemens SM110
Peak watt	50	55	75	100	110
Rated current	3.05	3.15	4.4	5.9	6.3
Rated voltage	16.6	17.4	17	17	17.5

Source: Website www.siemensolar.com

For this example the module that would ideally suit the load specified is the SM100, with a rated current of 5.9A. This is the smallest size available that meets the calculated 5.42A.

If the location had a larger number of sun hours, the module current formula given above would give a lower module current, which could allow a smaller module to be used for the same load. One way to greatly increase the sun hours is to use a tracking mechanism to keep the module facing the sun. Tracking mechanisms add to the complexity and cost of a system and are not used except in large and expensive arrays.

IIIA.2 Solar system survey questionnaire 2001

Form number	Name of interviewee
Address	Status in household
	(Wife, husband, daughter-in-law, etc.)

System background:

Who owns the solar system?	When bought?
Price charged?	Payment terms
Payment progress	Parent project

System configuration:

	How many	Power rating Watts or Amps	Make	Model	When first used
PV module					
Charge controller					
Battery					
Other					

System mounting method: Roof ☐ Pole ☐

Load details:

	How many units	Power (W or A)	Make	Model	Describe	Hours per day	How much income	Frequency of income
Radio								
TV								
Lights								

Fault history:

	Date of fault	Date reported	Date fixed	Cost of repair	Who repaired	Present status
Battery						
Charge controller						
Wiring						
PV module						
Switch						
Fuse						

User skills

Do you have a solar system user manual?	No	Yes	*Comment*
Were you trained? If yes, by who?	No	Yes	*By*
What maintenance do you carry out? *(Cleaning panel, adding battery water, etc.)*			
Your highest educational qualifications?			

User comments

If you did not have solar, would you buy a solar system today knowing what you know about it? (*explain answer*)	
Is maintenance of your system adequate? (*explain answer*)	

IIIA. 3 Selected time series data: Zimbabwe

Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
National population (millions)	10.40	10.80	11.20	11.50	11.50	11.50	11.70	11.90	12.10	12.82
National population growth rate (%)	3.0	1.9	2.9	1.9	1.8	2.7	1.7	1.7	1.9	1.10
Rural population (millions)	7.3	7.6	7.8	8.1	7.7	7.7	7.7	7.8	7.9	8.4
GDP (US$ millions)	7,156	7,280	7,690	7,610	8,260	8,475	6,500	8,240	7,838	7,172
GNP per Capita (US$)	688	674	687	662	718	737	556	504	688	480
Total modern energy consumption ('000 toe)	4,713	4,381	4,722	4,673	3,160	3,110	3,110	3,740	3,314	
Modern energy consumption per capita(kgoe)	450	471	432	424	282	270	265.8	263.0	273.9	
Total energy production ('000 toe)	8,740	8,560	8,390	8,310	8,250	8,050	8,240	8,320	8,710	
National debt (US$ millions)	4,060	4,285	4,524	5,007	4,976	4,919	4,707	4,566	4,244	3,780
Merchandise exports, f.o.b (US$ millions)	1,530	1,610	1,947	2,216	2,496	2,424	1,925	1,924	1,791	1,715
Installed capacity (MW)	1,961	1,961	1,961	1,961	1,961	1,961	1,961	1,961	1,961	1,961
Electricity generation (GWh)	10,282	8,760	9,544	10,123	10,495	11,311	11,891	12,363	12,090	11,972
National electrification levels (%)	28	29	31	32	34	35	36	39	40	40
Urban electrification levels (%)	69	67	69	72	70	74	78	80	84	84
Rural electrification levels (%)	11	14	15	14	17	16	15	18	18	19
System Losses (%)	8.6	11.0	12.1	11.0	11.0	10.8	10.7	13.2	13.0	14.6
Rural population with access to safe water (%)	64	64	64	64	64	64	64	64	64	64
Total Electricity Consumption (Gwh)	8,850	9,115	9,094	9,488	8,591	8,119	8,085	6,938	9,196	9,102
Electricity consumption per capita (kWh)	851	844	812	825	747	706	691	583	760	710

Sources: Kayo, 2002; Mapako, 2002; Dube, 2002; AFREPREN, 2003; World Bank, 2000; World Bank, 2003

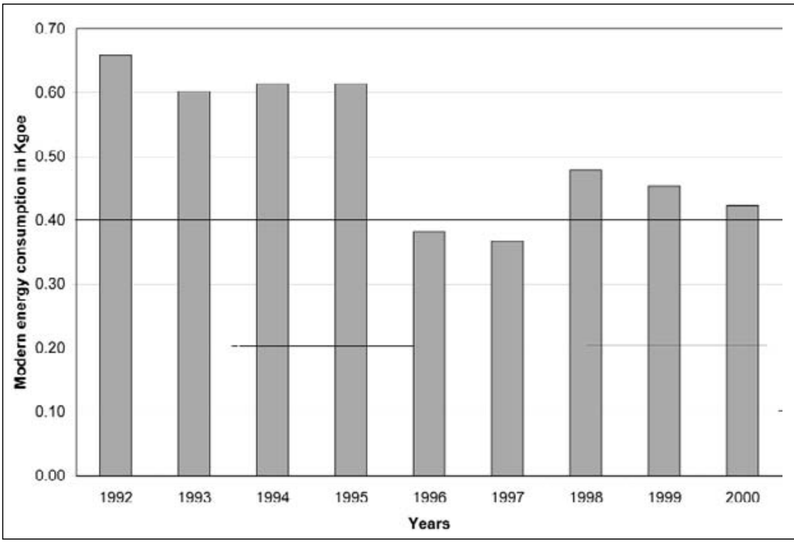


Figure IIIA.3.1 Total modern energy consumption (Kgoe) vs GDP (US$) (Modern energy consumption per US$ of GDP)

Source: AFREPREN 2003

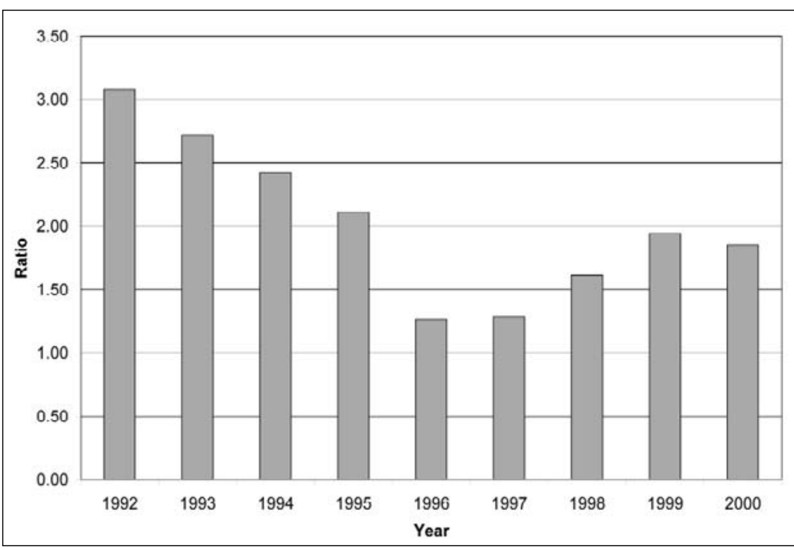


Figure IIIA.3.2 Total modern energy consumption (Kgoe) vs merchandise export (US$) (Modern energy consumption per US$ of merchandise export)

Source: AFREPREN 2003

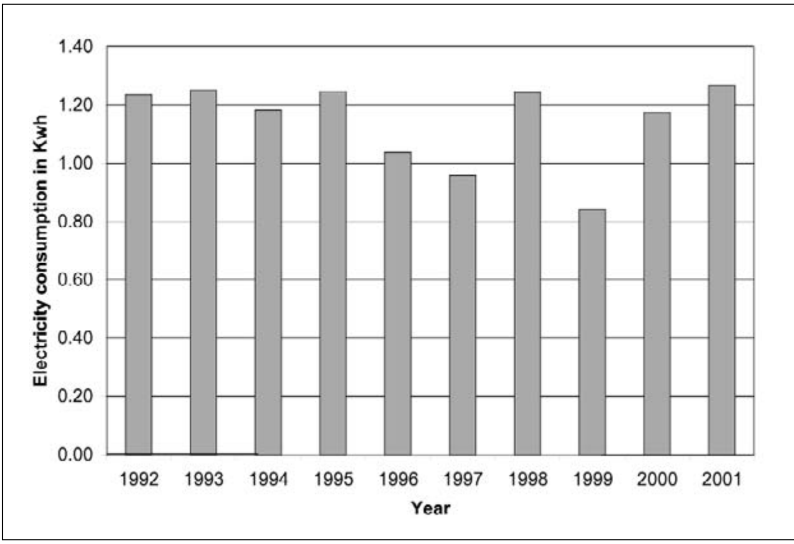


Figure IIIA.3.3 Total electricity consumption (Kwh) vs GDP (US$) (Electricity consumption per US$ of GDP)

Source: AFREPREN 2003

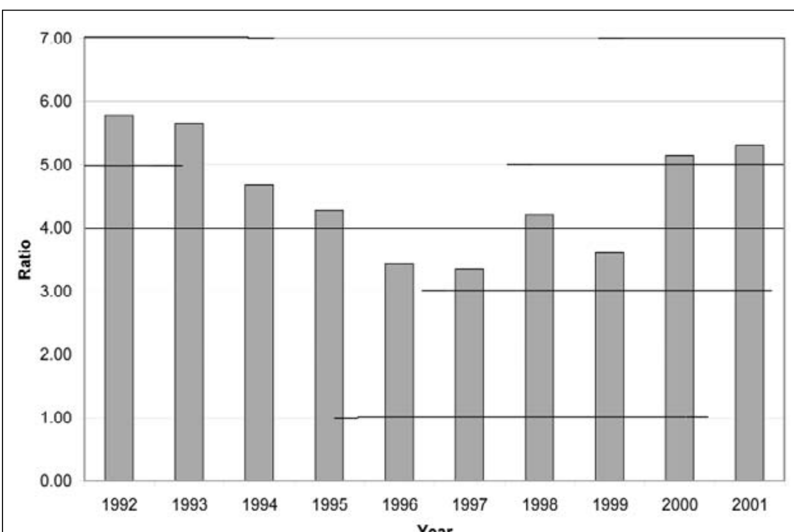


Figure IIIA.3.4 Total electricity consumption (Kgoe) vs merchandise exports (US$) (Electricity consumption per US$ of merchandise exports)

Source: AFREPREN 2003

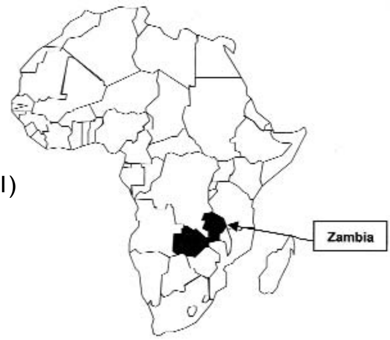
Part IV

ZAMBIA

Abel Mbewe

COUNTRY PROFILE

Zambia



SELECTED INDICATORS

Population (millions): 10.38 (2001)
Rural population (% of total): 60.2 (2001)
Land area (km^2): 753,000
Capital city: Lusaka
GDP growth rate (%): 4.9 (2001)
GNP *per capita* US $): 320 (2001)
Official exchange rate:
Zambian Kwacha 5,054 = US$1 (June 2003)
Economic activities: Agriculture, industry, manufacturing, mining, financial services
Energy sources: Biomass, hydro, imported petroleum, solar, wind
Installed capacity (MW): 1,786 (2001)
Electricity consumption *per capita* (kWh): 474.4 (2001)
Electricity generation (GWh): 9,110 (2001)
System losses (%): 27 (2001)
Electrification levels (%): (2001) National: 20
Urban: 48
Rural: 2.0
Biomass consumption as a percentage of total energy: 78.8 (2000)
Poverty levels (1998):
(%) population living below US$1 a day: 63.7
(%) population living below US$2 a day: 87.4

Sources: AFREPREN, 2003

Acknowledgements

This study has been made possible through the generous support of the Swedish International Development Cooperation Agency (SIDA).

I would like to acknowledge with thanks the support received from various AFREPREN staff and in particular Stephen Karekezi, Director, and Waeni Kithyoma, Backstopping Officer, who provided background material to the study. I owe a special debt of gratitude to these two individuals for reviewing and providing invaluable comments and suggestions on several draft reports. Thanks are also due to external reviewers whose comments were useful in revising the different versions of the draft reports. I would also like to thank Maxwell Mapako for reviewing the draft manuscript and providing useful comments.

Many thanks are due to the research assistants, Eugenius Mumba and Annie Nsenduluka, who collected primary data, and Mirriam Simasiku, who was responsible for secondary data collection. Lastly, I would like to thank AFREPREN members who provided useful comments on various draft reports during theme group meetings and AFREPREN general assemblies.

6

Introduction

Background to the development of the energy sector

Zambia is a landlocked country and lies in Central Africa between 8 and 18 degrees latitude south and 22 and 34 degrees longitude east. The country has an area of 753,000 square kilometres bordered by eight countries: Democratic Republic of Congo and Tanzania in the north, Malawi and Mozambique in the east, Zimbabwe and Botswana in the south, Namibia in the south-west and Angola in the west. In 2000, Zambia had an estimated population of 10.3 million people (61 per cent rural, 39 per cent urban) with a growth rate of 3.1 per cent per annum (CSO, 2000). The country is divided into nine provinces. Each province is divided into districts, 57 in all. Most urban centres are concentrated along the south–north rail line from Lusaka, the capital city, to the Copperbelt area (A. Mbewe, 1992).

Zambia became independent from Britain on 24 October 1964 and inherited a buoyant economy: it was said to be the third-richest country in sub-Saharan Africa. The country's economy revolved mainly around the mining industry, which accounted for 61 per cent of formal employment and about 48 per cent of the GDP.

The government at the time decided to encourage agriculture as a means of developing rural areas. Government approaches to rural development included the provision of easy credit, resettlement, integrated rural development programmes and the introduction of rural reconstruction centres. The government set up credit institutions that would provide loans to farmers: the Land Bank, the Credit Organization of Zambia, the Rural Development Corporation, the Cooperative Bank and Lima Bank. Government put emphasis on availability of credit and in some areas developed infrastructure such as roads and bridges to support the agricultural revolution. However, other critical inputs such as the provision of telecommunications and modern energy services were not available. Despite the substantial resources put into these measures, no noticeable change has occurred in the lives of people in rural areas.

Energy is a critical input in any economic activity. Thus development of a society inevitably raises issues related to energy consumption in which problems of availability and convenience of energy resources are of vital importance. The history of development identifies modern energy as one of the prerequisites that facilitate social development and economic growth. Lack of modern energy services is therefore one of the important factors explaining lack of development in rural areas. Modern energy can increase the production and processing of food, as well as the availability of clean water. It can improve the health and education status of communities through the provision of lighting to health centres and schools. Energy can improve rural businesses by supplying the motive power and heat required for various processes. Without access to modern energy services, the efforts of the rural population are severely hampered as they attempt to move beyond subsistence existence and escape poverty. Previous studies on rural electrification in Zambia show the positive impact on the economic activities of certain rural areas after they were electrified (A. Mbewe, 1992).

The majority of rural people do not have access to modern forms of energy such as electricity, gas and petroleum products. Commercial energy is produced outside rural areas and the availability of these resources is usually dictated by factors beyond the rural population. An adequate supply of commercial fuels to the rural areas has been constrained by the huge cost of extending electricity transmission lines and the high cost of transporting petroleum products. Government considers investing in rural energy a low priority because of dispersed population and low *per capita* commercial energy consumption in the rural areas. The majority of rural people have been denied opportunities to grow economically through their lack of access to infrastructure and modern energy services. An increase of modern energy is necessary for improvement in the living conditions and for sustained development of rural and agricultural areas.

The lack of modern energy services in the rural areas means that the fuel mix in Zambia's rural areas is characterized by the predominance of biofuels. Given the dependence of the rural energy system on biofuels, biomass resources are of primary importance to the rural communities. The majority of people depend primarily on biomass for cooking and heating requirements, and on human and animal power for work-related energy. Animal energy is used in agricultural and transport activities. Many small and medium-sized enterprises (SMEs) depend on woodfuel as their major source of energy. SMEs play a crucial role in rural development. D. Mbewe (1992) observes that rural industry and agriculture are two critical sectors that need increased energy inputs to boost production in order to raise the economic welfare of rural people.

Rural energy planning

Planning in Zambia's energy sector mainly focuses on centralized energy supply technologies. This fact is evidenced by huge investments in the petroleum and electricity subsectors. Petroleum feedstock is imported as a mixture of crude oil and refined products from the Middle East. The feedstock is transported via a crude oil pipeline extending 1,700 kilometres from Dar es Salaam in Tanzania to INDENI Petroleum Refinery in Ndola, Zambia, where it is refined into petroleum products. Zambia's electricity network comprises interconnected and isolated systems. The interconnected system consists of all the major hydropower plants and the national grid, whereas the isolated system is composed of the small hydro and thermal plants that supply most rural areas. Major infrastructure in the electricity subsector comprises, among other things, generation and transmission networks. Heavy investments were made in the generation and transmission networks, principally to meet demand for the mining and other industries on the Copperbelt and towns along the line of rail. Modest investments were made in the isolated system. Despite Zambia maintaining surplus power to the extent of about 400 MW, against a peak demand of about 1200 MW, electricity is unavailable to 80 per cent of the population. Data compiled by the Department of Energy (DoE, 1998) show that for the year 1998 capacity availability of the isolated system serving the rural areas was 44.4 MW and 56 GWh of electricity was generated. The amount of electricity generated for the rural centres was 0.7 per cent of the total electricity generated for the entire country.

Experience shows that most government and utility rural energy initiatives are centralized in nature, while those of the private sector are largely decentralized. In Zambia, rural electrification is the most common and desired means of supplying modern energy services to the rural areas. Diesel generating sets, solar thermal and photovoltaic systems are some of the decentralized energy options that are employed by the private sector.

Clearly, Zambia's is not a problem of shortage of indigenous energy supplies but one of 'transporting' energy to areas of demand. There is need, therefore, to promote delivery of modern energy to meet demand in the rural areas. Bhagavan and Karekezi (1992) suggest that formulation and implementation of energy programmes be based on a mix of centralized and decentralized approaches. Further, they explain that these approaches require local structures, relations and institutions to be given due consideration. Other factors to be considered should include cost of the technologies, technical capacity to install and maintain energy systems, proper demand analysis and financing mechanisms. In this study, it was discovered that there are synergies between centralized public and decentralized private initiatives. The ESCO solar PV project in the Eastern Province is a good example of a project where government initiatives have given birth to successful private sector initiatives.

Energy use in the rural areas

The bulk of Zambia's energy consumption takes place in rural areas, most of it in the form of biomass energy comprising wood, charcoal, crop residues and animal waste. In rural and urban areas, woodfuel is consumed in the form of firewood and charcoal respectively.

The basic features of energy consumption in rural areas are a high degree of inefficiency, low productivity and attendant health problems. Inefficient rural energy consumption leads to significant waste of natural resources. For household and income-generating activities, biomass fuels need to be collected in large quantities because the technologies used are inefficient. However, there are energy technologies that can improve the efficiency of biomass use in rural households and energy-intensive production activities: efficient charcoal production kilns, improved cook-stoves and biomass gasification. Biomass gasification is an enabling technology that provides routes to electricity, liquid fuels and chemicals. Solid biomass is transformed into syngas (hydrogen and carbon monoxide mixtures), which can be converted to liquid fuels for use in advanced energy technologies.

Table 6.1 Energy use in the rural areas

Sector	Activity
Agriculture	Land preparation, planting, water pumping, harvesting
Processing	Drying, hulling, grinding, cooking, grating
Industry	Workshops for manufacture and repairs
Preservation	Drying, cooling
Transportation	Marketing, social and health, entertainment, education
Social needs	Medical treatment, lighting, entertainment, education
Household needs	Cooking, lighting, space heating and ironing

Source: Adapted from Bassey, 1992

Zambia's woodlands and forests formerly covered about 612,000 square kilometres, taking about 81 per cent of Zambia's total land area. There has been significant reduction in wood resources over the years and current estimates of forest cover are between 400,000 and 530,000 square kilometres (DoE, 2000).

Recent studies on climate change in Zambia show that improved charcoal kilns have a conversion efficiency rate of 30 per cent compared to 20 per cent of the current one. The improved mbaula has an efficiency of 25–30 per cent compared to 10–15 per cent for the traditional stove. Improved firewood stoves have an efficiency of 25 per cent compared to 12 per cent for the traditional firewood stove (Mulenga, 2000). These technologies, if implemented, can reduce firewood consumption substantially.

Energy use in small rural enterprises

The supply of modern energy services to rural areas offers opportunities to enhance production in small and medium-sized enterprises. The benefits of modern energy services include lower energy costs due to increased energy conversion efficiency and reduced manpower needs for production processes.

Biomass is a major source of energy for income-generating enterprises that require heat for various applications. It is used on a smaller scale in industrial boilers found in many rural agro-related industries. Charcoal is used in applications where smoke is to be avoided, such as space heating for brooding of chicks and piglets. Applications for solar photovoltaics include provision of power for entertainment (bars and night clubs), lighting for schools and water pumping, and lighting and medical refrigeration for rural health centres. Solar thermal applications are popular for water heating in guesthouses and tourist lodges. On the other hand, conventional energy sources play a minor role in rural energy supply. The contribution of fossil fuels and conventional electricity is invaluable because of their productive functions. Diesel is used for agro-processing activities such as grain milling and rural transport. Electricity is used in various applications such as fabrication of basic agricultural tools, repair shops and in small and medium-sized commercial enterprises.

Energy use in households

Rural household energy needs are mainly for cooking, lighting and space heating. High-quality cooking fuels such as kerosene, liquefied petroleum gas (LPG) and electricity are expensive and not easily available in rural areas.

One notable characteristic of rural energy is that, traditionally, women are responsible for the energy needs of the household. In many cases women spend large amounts of human energy and walk long distances to gather firewood. According to ZERO (1998), Zambian women spend up to six hours per day on collection of firewood in densely populated areas that no longer have adequate woodfuel resources. Ndekuka (1999) observes that problems associated with scarcity of energy to women include the following:

- shortage of time, due to the long hours it takes to collect firewood: this leaves women in the vicious circle of poverty and economic disempowerment;
- physical ailments caused by carrying heavy loads of firewood;
- the use of low-quality fuels such as cow dung, due to scarcity of fuelwood, causes indoor air pollution from smoke;
- purchase of fuelwood, which formerly was free, adds a financial burden on most women;
- use of traditional energy technologies, which are inefficient.

The supply of modern energy services to rural areas has a significant impact on the standard of living of rural households. Some of the benefits that accrue to households include elimination of indoor air pollution, a better environment for children when they study in the evenings, and more free time, especially for women, to spend on social and income-generating activities.

Rationale of the medium-term study

In Zambia, a wide range of energy options is available for supplying rural households and income-generating activities, as shown in Table 6.2. Among the modern energy services, electricity is a more desirable option for those who can afford it. However, many households are poor and, even if they were given free grid electricity connections, could not afford to use large quantities of electricity. The costs of electric cooking appliances, pressing irons and geysers are beyond the reach of the majority of people both in the urban and rural areas (CEEEZ/UNEP, 1999). The use of kerosene is mainly confined to running refrigerators for vaccine refrigeration and cool drinks. Households use kerosene for lighting. There is limited use of LPG (mainly by a few SMEs) as delivery infrastructure is not available in rural areas. Solar energy is mainly used in the form of PV systems providing lighting to schools, health centres, some households and small businesses.

The rationale behind this study is to demonstrate that modern energy technologies can contribute to improving quality of life in households and activities in SMEs in the rural areas. Biomass has been used in its traditional and unprocessed form. This notwithstanding, there are energy technologies that can use biomass in an efficient and environmentally friendly manner. Other energy technologies suitable for rural areas include mini-hydro and diesel power plants, and solar and wind energy. Access to these technologies can boost activities for income generation.

The following are the available technology options:

CONVENTIONAL ENERGY TECHNOLOGIES

- Extension of the national grid;
- Diesel power plants for electricity generation;
- Gensets for a wide range of applications;
- Coal for process heat;
- Petroleum products for use in transport and agricultural machinery.

RENEWABLE ENERGY TECHNOLOGIES

- Solar thermal and photovoltaics;
- Mini-hydro power plants;
- Wind;
- Biogas;
- Biomass.

The available modern energy generation technologies make it possible to integrate some of these into hybrid systems for continuous energy supply. Hybrid systems could be an ideal solution to the problem of the uncertainty of power availability arising from wind and solar applications. Among such possible hybrid systems we can include the combinations suggested below (see p. 116):

Table 6.2 Energy options available for rural areas

Energy source	Technology option	Household application	SME application
Grid extension	Centralized	Household electrification	Food processing, grain milling, sawmilling and welding
Diesel (power plant)	Centralized	Water pumping for potable water, electricity generation	Water pumping for irrigation, grain milling, food processing, battery charging, electricity generation, power for agricultural machinery
Diesel (genset)	Decentralized	Water pumping for potable water, electricity generation	Water pumping for irrigation, grain milling, food processing, battery charging, electricity generation, power for agricultural machinery
Kerosene	Decentralized	Cooking and lighting	Refrigeration for vaccine and drinks
LPG	Decentralized	Cooking	Welding services
Coal	Decentralized	Household cookstoves (coal briquette)	Brick and pottery production, pottery
Biomass	Decentralized	Cooking and lighting	Food processing, pottery and brick production, baking, beer brewing, boiler services, electricity generation
Biogas	Decentralized	Cooking and lighting	Space heating for chicks and piglets, electricity generation
Wind	Decentralized	Water pumping for portable water	Rural water supply and irrigation, mechanical power, battery charging
Solar PV	Decentralized	Lighting, water pumping, TV and radio	Water pumping for irrigation, battery charging, lighting of shops, bars, restaurant and guesthouses. Power for music in bars, telecommunications
Solar thermal	Decentralized	Hot water, drying of crops	Water heating for guest houses
Small hydro	Decentralized	Household electrification	Grain milling, sawmilling and welding
Animal power	Decentralized	Ploughing, transport	Transport

Source: CEEEZ, 1997

- biogas and diesel;
- solar and biogas;
- solar and wind;
- solar, diesel and wind.

These technologies can be categorized into various applications for household and income-generating applications, as shown in Table 6.2. Best (1992) advises that the selection of the technology should be based on the viability of the option for the needs of the community. He suggests assessment of the following factors:

- acceptability of the technology;
- financial resources;
- economic and social benefits;
- environmental sustainability;
- training and skill levels;
- planning and management capabilities.

Lack of awareness of these technologies can be a hindrance to the successful dissemination of modern services. Most rural people are not aware of the existence of modern energy technologies (CEEEZ, 1997). The need for providing energy information to the rural areas through the national media, such as radio and newspapers, cannot be over-emphasized.

Summary of major findings from the short-term study

The major findings of the short-term study are summarized below.

HYPOTHESIS 1A: *Rural energy initiatives by governments and utilities have failed/are failing because they were/are not backed by full political commitment.*
Political commitment for delivery of modern energy systems to the rural areas is lacking. Although the system of governance does provide for checks and balances to ensure that government policy statements do not end up as mere rhetoric, the *status quo* still holds. Ministerial statements made in Parliament have no impact on the release of funds for rural electrification. The Committee on Government Assurances takes to task ministers and permanent secretaries for non-implementation of government projects that are approved in the budget. Despite taking this action, there were no disbursements of funds for rural energy projects. Further, lack of political commitment was demonstrated in the following:

- The results of the key word search in the leading daily newspaper, the *Times of Zambia*, showed that key government and utility officials had not mentioned the words 'rural energy' in the last five years. This indicates that rural energy was not an important issue.

- There was no proper administration of the Rural Electrification Fund (REF). The REF is a three per cent levy imposed on all electricity bills. The Rural Electrification levy has no legal backing. The levy is regarded as an excise duty and is collected by the Zambia Revenue Authority (ZRA) which passes it on to the treasury. The levy is subjected to delays and in many cases is never remitted to the Rural Electrification Fund. The erratic disbursements of the REF delayed completion of projects and in most cases project costs escalated as a result of project overrun and inflation.
- Records examined showed that government and the utility paid more attention to urban electrification. Expenditure reports showed that more money was spent on urban electrification than rural electrification. In some cases the burden of financing rural electrification schemes was placed on the utility. The utility was disadvantaged as some of the rural electrification projects were not financially viable owing to high costs of investment, operation and maintenance, and low load factors.
- Government was responsible for policy formulation and implementation. The gender dimension was ignored in the National Energy Policy. This resulted in women, who are the majority in the rural areas, being marginalized in various aspects of rural energy supply.

HYPOTHESIS 1B: *Rural energy initiatives by governments and utilities have failed/are failing because they were/are not implemented with vigour.*
Lack of vigour by the government in the implementation of rural energy programmes was found to be another factor that contributed to failure in rural energy initiatives. Available evidence showed that no rural electrification project had been completed on time. Almost all the rural electrification projects that were implemented had been formulated more than three years before. The delay was attributed to erratic REF disbursements. In addition, it was established that want of vigour was not the only reason that had contributed to failure of rural energy initiatives. Senior government officials and energy analysts were of the view that other factors contributed to failure, including low load factors, lack of feasibility studies, and social/cultural issues.

HYPOTHESIS 1C: *Rural energy initiatives by governments and utilities have failed/are failing because they were/are welfare-focused and not targeted at income-generating activities, and/or were/are uneconomic.*
From the results of the study, provision of modern energy services targeted at income-generating activities had a better rate of success than welfare-focused projects. The following were major findings of the study with respect to the hypothesis:

- Rural energy initiatives focused on welfare schemes such as schools and clinics failed, whereas projects that targeted income-generating activities succeeded. Financial analysis of case studies of rural energy projects that were targeted at income-generating activities showed high internal rates of return, hence success of the projects.

- Lack of maintenance of equipment was cited as a major cause of failure of rural energy projects. Without maintenance, nothing was sustainable.
- Rural electrification through grid extension was expensive. It was, therefore, important that proper feasibility studies were done before the national grid was extended to the rural areas to ensure success of rural electrification projects.

HYPOTHESIS 2: *The institutional framework of government and the utility was not appropriate to the design and implementation of rural energy initiatives.*
The results of the study showed that there were inadequacies in the way the energy sector was organized and managed. Energy planning was highly centralized with no institutional structures at local level for supervising implementation of rural energy projects. Major findings of the study in respect of the hypothesis were as follows:

- There was little institutional interaction of stakeholder organizations. Women were marginalized in all aspects of energy. There was no linkage between grassroots organizations for women and energy institutional structures.
- Policy on rural energy was inadequate. The National Energy Policy did not explicitly address renewable energy technologies.
- The energy delivery system was ineffective. The Department of Energy had no financial and human resources to monitor rural energy projects. The national utility, the Zambia Electricity Supply Corporation (ZESCO), gave low priority to rural power stations. This was evidenced by the low output of some of the rural power stations due to lack of maintenance and spare parts.
- The private sector institutional structure had a better rate of success. This was attributed to the profit motive being the driving force.

Link between short-term and medium-term study

As a follow-up to the formulation of the National Energy Policy, a programme of action was developed to implement national policy. The short-term study analyzed the broad policy measures of the policy and also assessed the impact of the government/utility institutional framework on the provision of modern energy services to the rural areas. Two hypotheses were tested to assess the impact of energy policy and institutional framework on the dissemination of modern energy services to the rural areas. The short-term study provided a foundation on which the medium-term study built.

The two studies complement each other in that the hypotheses tested are linked. The short-term study examined the public sector rural energy initiatives that are welfare-focused. The medium-term study assessed the impact of modern energy on income-generating activities. The study tested the contention that rural energy initiatives failed because they were welfare-focused and did not target income generation.

7

Study Findings and Conclusions

Hypothesis 1: Decentralized private sector vs centralized public sector energy initiatives

Decentralization private sector energy production and distribution have a better rate of success than centralized public sector initiatives in the delivery of modern energy to the rural households and for income-generating activities

A number of options for the generation and distribution of energy in the rural areas have been developed and tested in Zambia. Available data shows that there has been an increase in the number of rural-based small and medium enterprises. Table 7.1 shows that there was an increase in the total number of income-generating activities from 5,600 in 1994 to 6,500 in 1999, representing a growth of 15.9 per cent. Agricultural, commercial, manufacturing and mining SMEs predominate in rural Zambia. Details of activities in each sector are given below.

Agricultural sector

Agricultural enterprises include growing grain and other crops such as beans, soya beans, vegetables and irrigated crops. Other activities include poultry, animal husbandry and horticultural farming.

Commercial sector

Retail outlets, catering services and restaurants dominate the commercial activities in the rural areas. Sale of alcoholic beverages coupled with entertainment are important business activities.

Manufacturing sector

Manufacturing and technical services in the rural areas include metal fabrication, food processing, tailoring, shoe manufacturing, grain milling, timber sawmilling, bakeries and so on.

Mining sector

Important activities in the rural areas include mining of precious stones and quarrying.

Table 7.1 Number of income-generating activities in the rural areas

Sector	1994	1995	1996	1997	1998	1999
Agricultural	1,170	1,205	1,241	1,278	1,317	1,356
Commercial	3,060	3,152	3,246	3,344	3,444	3,547
Manufacturing	1,215	1,251	1,289	1,328	1,367	1,409
Mining	150	155	159	164	169	174
Total	5,595	5,763	5,935	6,114	6,297	6,486

Source: CSO, 2000

In testing Hypothesis 1, two case studies, each involving centralized and decentralized systems, were used. Case studies involving rural grid connections and distribution of petroleum products in the rural areas were compared and contrasted for centralized and decentralized energy systems respectively, to determine which one delivered more energy services to the people.

Centralized energy supply

Centralized energy supply refers to energy generated at a central location and distributed to areas of demand: for example, the supply of electricity from the national grid to various parts of a country. In Zambia, the supply of modern energy to the rural energy areas has mainly been confined to centralized energy supply technologies such as extension of the electricity national grid and mini-hydropower.

Decentralized energy supply

Decentralized energy supply refers to energy technologies that can be localized to generate and supply energy at the point of demand. Localized generation technologies include diesel power plants, renewable sources, coal and gensets. Useful decentralized energy supply options include solar, wind, mini-hydro, coal and diesel/petrol genset technologies. Diesel power plants as a public decentralized energy option are common in some rural areas.

Case Study 1: supply of electricity to rural areas (centralized supply)

The government, through the Ministry of Energy and Water Development, has funded a number of rural electrification projects through extension of the national electricity grid. The Department of Energy, on behalf of government, supervises implementation of rural electrification projects, while ZESCO acts as the government's contractor. Government finances rural electrification projects through the national budget. These funds are augmented, as we have seen, by a Rural Electrification Fund levy that is collected on all electricity bills. The government established a Rural Electrification Committee whose main function is to scrutinize and approve all rural electrification applications and allocate funds for projects from the Rural Electrification Fund. There is evidence that the national utility has also made huge financial contributions to rural electrification projects. The choice of technology is usually between extending the national electricity grid and installing diesel generators. Of late, solar photovoltaics have been included in the technology options for some rural areas. Once the Rural Electrification Committee approves a project, it is handed over to ZESCO and funds are then released for implementation. Government's responsibility ends at the stage where the project is completed and commissioned. Any costs associated with the running of the project after commissioning are the sole responsibility of the electricity utility.

Table 7.2 shows that there was an increase of eight commercial electricity customers, representing a growth of 0.19 per cent, between 1995 and 1999, while the number of customers in rural households increased by 77, representing a growth of 0.21 per cent.

Table 7.2 Number of electricity connections in rural areas

Sector	1995/6	1996/7	1997/8	1998/9
Households	37,253	37,279	37,305	37,330
Commercial and manufacturing	4,258	4,260	4,263	4,266
Others	11,714	11,716	11,724	11,732
Total	53,225	53,255	53,292	53,328

Source: ZESCO

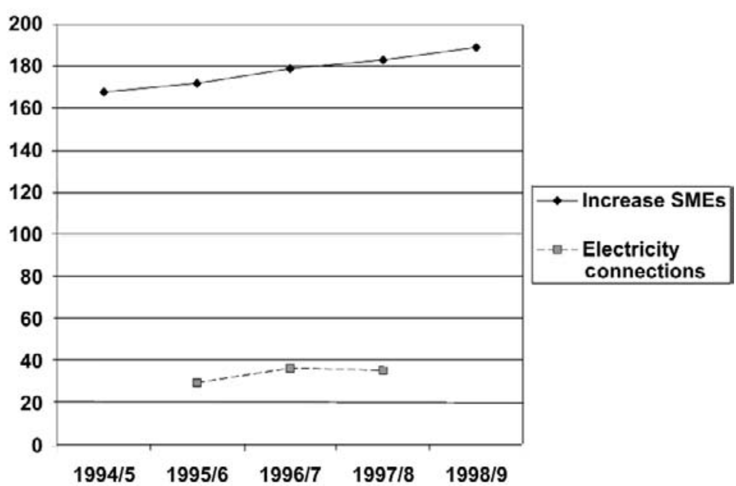


Figure 7.1 Comparison between increase in number of SMEs and number of electricity connections

Tables 7.1 and 7.2 show that there is no correlation between the increase in the numbers of income-generating activities and increases in electricity connections. The majority of the new enterprises being established therefore depend on non-grid electricity. The increase in number of SMEs in Table 7.1 and the number of electricity connections in Table 7.2 were used to construct Figure 7.1. The graphs in Figure 7.1 show that there is no match between the increase in the number of SMEs and the number of electricity connections. The majority of new SMEs depend on non-grid energy.

Twapia case study

The Twapia Electrification Project case study from the short-term study is a good example of approaches that can be adopted in national rural electrification programmes. Given the fact that there has been an increase in the number of rural-based SMEs (Table 7.1) opportunities exist for successful implementation of national rural electrification programmes using the approaches applied in the Twapia Electrification Project. Similar approaches could be used for electrification programmes targeting both enterprises and households. As in the Twapia Electrification Project, what is required is to assess the projects taking into account all important factors for rural development in order to ascertain the efficiency of resource allocation. Although the National Energy Policy does support rural electrification by grid extension, a proper policy framework that will support programmes for rural energy is required. Policy issues regarding electricity price setting need to be revisited. In addition, other important issues such as private sector participation and domestic credit systems need to be introduced and supported at policy level.

ANALYSIS AND DISCUSSION – CENTRALIZED ENERGY SUPPLY SYSTEM

It can be seen from Figure 7.1 that growth in the centralized supply of electricity has not matched the increase in the number of rural commercial and manufacturing enterprises. Increased electricity connections to the rural areas are constrained by shortages of capital. Previous studies on rural energy in Zambia have shown that rural electrification is often not viable. Diesel power plants are not viable due to high operational and maintenance costs, poor load factors and low revenues from electricity sales (Mbewe, 1992). Even allowing for an encouraging increase in the number of rural SMEs, electricity supply to new enterprises would be difficult because of high costs involved. Table 7.3 shows the connection fees and unit costs of electrical energy for various customer categories. Incomes of rural enterprises and households are generally low, as shown by the results of the field surveys conducted in the rural areas around Lusaka. The survey results shown in Table 7.4 indicate that the majority of these enterprises do not generate enough income for them to afford modern energy devices.

Table 7.3 Electricity connection fees and unit charges

Type	Description	Connection charge (US$)	Fixed charge (US$)	Tariff Unit charge (US$)
Residential	Single phase overhead standard service	55	1.30	0.04
Commercial	3 phase overhead standard service	373	6.40	0.04
Industrial	16–7500 kVA	50% of cost	15.00	1.50 energy charge/ kVA/month 0.02 energy charge/kWh

Note: Exchange rate: US$1= K4520 (September 2002)
Source: ZESCO

Table 7.4 Annual incomes of some small and medium-sized enterprises

Activity	Small (US$)	Medium (US$)
Hospitality (restaurants)	4,800	20,000
Bakery	2,100	4,330
Bar/tavern	5,400	28,800
Fish trading	500	13,500
Poultry	2,000	10,000
Hammer mill	1,900	4,500
Weaving baskets	750	3,800

Note: The classification of small or medium-sized is based on the annual turnover and type of the enterprise.
Source: Information obtained from surveys, 2000

Incomes and expenditure on energy

Zambia's economic performance has been declining since 1974 with the fall in copper prices. The decline in economic performance has resulted in a shrinking formal sector and less disposable income for the majority of the Zambian people. Table 7.7 shows results of a survey on incomes and energy expenditure. Based on these incomes, household incomes can be grouped into three categories. Most rural households form the majority of the low-income group. Table 7.5 shows how much people earn and how much they spend on their energy needs. Electricity, whether supplied by isolated systems or the national grid, costs the same. There are no energy subsidies for the rural areas. Woodfuel costs nothing as it is just picked from the bush, whereas kerosene is mainly used for lighting using a wick lamp. The cost of kerosene is on average US$1 per three litres per month. This may help to explain why low-income households spend a small amount of their income on energy.

Table 7.5 Rural household incomes and energy expenditure

Income group (monthly)	Energy form	Cost (US$)	Energy expenditure as percentage of income
Low income	Woodfuel	0	0
(US$13–62)	Kerosene	1.00	2.7
Medium income	Woodfuel, candles, kerosene	2.52	1.6
(US$62–248)	Kerosene, charcoal, candles	9.29	6.0
	Charcoal, kerosene	7.80	5.0
High income	Electricity	12.40	5.0
(above US$248)	Electricity	52.50	21.2
	Charcoal, candles, kerosene	9.99	4.0

Source: Information obtained from surveys, 2000

Another factor that may contribute to the lack of success of centralized energy supply systems is lack of development of the rural areas. There is imbalance in the provision of services between urban and rural areas. Development is biased towards the urban areas. Investments made in the centralized energy system to improve rural energy supply may not produce any returns if there is no increase in the development of the rural areas and household incomes are falling. The World Bank (1996) has observed that the higher a country's *per capita* income, the greater the use of modern fuels. The Bank has further observed that countries with *per capita* incomes of US$300 or less have 90 per cent or more of their population depending on traditional fuels. On the other hand, countries with *per capita* incomes above US$1,000 switch completely to modern fuels. Table 7.6 shows the steep fall in Zambia's *per capita* income.

Table 7.6 *Per capita* incomes

Year	*Per capita* (US$)
1990	692.9
1991	450.0
1992	251.1
1993	140.1
1994	139.0
1995	139.4
1996	119.7
1997	147.7
1998	128.4

Source: National Economic Reports 1995–9

Gender

The burden of fuel gathering for household energy needs falls on women and children and this has direct impact on the time available for household chores and opportunities for income generation and improving quality of life. In some cases, children, especially girls, are forced to participate in fuel gathering at the expense of their education.

There have been no efforts by government or ZESCO to consider gender as an important element in rural electrification programmes. This is because of the lack of a gender dimension in the National Energy Policy.

Case Study 2: Distribution of petroleum products to rural areas (decentralized supply)

Oil marketing companies distribute petroleum products in all towns and major rural centres. Oil marketing companies own the distribution and marketing infrastructure. The oil marketing companies purchase petroleum products in bulk from INDENI Refinery or sometimes import and transport them to their bulk storage depots for onward distribution. At retail level, the infrastructure (fuel depots and service stations) is wholly owned by private petroleum marketing companies. The oil marketing companies appoint dealers who run the service stations and sell petroleum products. The dealers charge a mark-up on the prices of the petroleum products as agreed with the oil marketing companies. The mark-up is a profit that dealers get on the price at which they buy the petroleum products from the oil marketing companies. Pump prices of petroleum products differ from place to place as a surcharge is made to cover transportation costs of petroleum products from the refinery. In remote rural areas, SMEs (groceries, shops) buy kerosene and diesel in bulk and re-sell these products to people at village commercial centres. The distribution structure of petroleum products is shown in Figure 7.2.

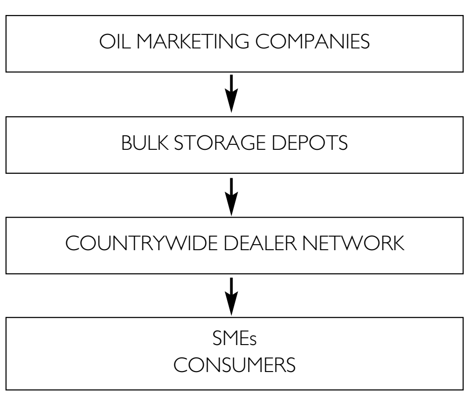


Figure 7.2 Distribution structure of oil marketing companies

Analysis and discussion – decentralized energy supply system

The decentralized supply of energy as shown in Figure 7.2 facilitates the supply of petroleum products to the people in remote areas of the country. Although kerosene retail prices are higher in rural areas than in urban centres, reflecting the increased number of intermediaries and transportation costs, its availability makes it a dependable energy option. The oil marketing companies are able to supply their products to remote areas because they are motivated by the good profits they make. According to one dealer, the following are some of the requirements for a person applying for the dealership of a service/filling station:

1 working capital of not less than US$70,000;

2 resident of the area where the service/filling station is located;

3 proven business and managerial experience.

The above information was cross-checked with another dealer who has a dealership with a different oil company: he confirmed that similar requirements were necessary. The dealer added that the working capital requirement is a stringent measure that the oil marketing companies insist on before an application can be accepted. Once an applicant has satisfied the above requirements, he/she may be invited for an interview. To a successful applicant, the oil marketing company will provide on-site training on how to run the service station. Periodically the oil company sends its inspectors to check the various service operations and ensure that set standards are maintained, otherwise the dealership is withdrawn. The stringent requirements imposed by oil marketing companies on dealers have contributed to the success of many dealerships. The rationale behind these conditions is that if an applicant can meet them, then chances for success in the business are high. The distribution of kerosene in the rural areas through service/filling stations is one example of a successful decentralized distribution of modern energy.

The potential of decentralized energy options in rural areas is significant. Previous studies on rural energy in Zambia have indicated that the level of awareness of rural people on applications of modern energy systems is low (CEEEZ, 1997). Although the National Energy Policy provides for measures by the Department of Energy to conduct energy fairs and awareness campaigns, these have not been conducted for lack of sufficient financial and human resources.

Since petroleum products are widely available in the rural areas, potential uses would include diesel/petrol gensets capable of generating electricity to power numerous applications, including a wide range of agro-related machinery and transport.

National Energy Policy as it relates to rural energy supply

The National Energy Policy is aimed at promoting the dissemination of centralized energy systems, such as the national grid, to rural areas. The policy also provides measures that will increase dissemination of renewable energy technologies. However, there are no policies aimed at promoting the dissemination of conventional energy sources such as coal and petroleum products in the rural areas. Moreover, the National Energy Policy states that there should be a complete divestment of government from the refinery and the distribution of petroleum products (NEP, 1994).

Views of senior government officials

Senior government officials are of the view that the decentralized energy supply is a better option for delivering modern energy to the rural areas. The centralized energy delivery option requires huge investments. In addition, they feel that dispersed rural population settlements would make centralized energy distribution costs higher. This would add to the huge costs that government and the utility would incur. In the past, government tried to introduce village re-grouping schemes. This was done with a view to bringing people closer so that social services could be provided easily to the rural areas, but these schemes failed. In part this failure was attributed to traditional and cultural beliefs. However, the officials felt that where feasibility studies showed greater potential in terms of demand and good rates of return on the investment, centralized energy systems should be adopted.

Gender

There is no evidence that gender considerations have helped to shape decentralized energy delivery systems. This again is attributed to the absence of gender issues from the National Energy Policy. The ESCO PV project targets households, income-generating activities and social institutions. The project has no gender dimension as it focuses on those that have the ability to pay for the service. Only 13 women benefited from the 100 solar systems that were distributed in the ESCO project. Three women recipients were engaged in income-generating activities (Chandi, 2002).

Conclusions

From the foregoing, it can be concluded that dissemination of centralized energy supply to the rural areas is difficult because of the high cost of delivery infrastructure. Since the pace of development in the rural areas is slow, it would be both expensive and time consuming for modern energy to be delivered through centralized approaches. Moreover, the rate of return on the investment will be low due to low load factors. Decentralized energy technologies can offer better delivery modes of modern energy services to the rural areas as long as they are based on business approaches. These approaches can create new opportunities for energy entrepreneurs and lead to increased productivity of rural activities. This would in turn lead to improvement in the living standards of the population in the rural areas and contribute to economic development.

Hypothesis 2: Impact of income in promoting rural energy initiatives

Income-generating activities have greater impact than domestic use in promoting the delivery of modern energy to the rural areas.

The short-term study identified factors that affect rural development, such as poverty, imbalance in the provision of services between rural and urban areas, lack of access to modern energy by the majority of people and high population growth rates. Further, the study established that energy and poverty were related. The dependence of the majority of the people on biomass energy traps them in a poverty cycle. Collection of biomass takes a lot of time that could be used for productive activities. Women and girls are vulnerable to this as they spend a considerable amount of time every day fetching firewood. A number of studies have indicated that rural households on average spend at least two hours daily and between 5 and 10 per cent of their income on fuel (Muchiri and Gitonga, 2000). In addition, biomass fuels need to be collected in large quantities, as they are used inefficiently to provide energy for the various needs. This results in depletion of wood resources, leading to environmental problems.

In 1994, the government formulated a National Poverty Reduction Strategic Framework (NPRSF), which is government policy on poverty reduction. This policy was to guide government in reducing poverty levels from 70 per cent (then) to less than 50 per cent by the end of 2004. The Framework's key poverty reduction strategies included, *inter alia*, achieving a broad-based economic growth through agriculture and rural development. According to the NPRSF, this strategy envisaged agriculture playing a key role in the development of agro-industries that would enhance rural development (MCDSS, 1988). The NPRSF identified energy as a factor in economic growth and poverty reduction. In 2000, the government in collaboration with the International Monetary Fund and the World Bank enhanced the NPRSF to Poverty Reduction Strategic Paper. According to government Poverty Reduction Strategic Paper (PRSP, 2000) poverty reduction needed institutional and structural reforms in various sectors of the economy. New strategies for disseminating modern rural energy by rural electrification (national grid) and solar energy were proposed in the PRSP and included in the Zambia Structural Policy Matrix, 2000–2.

The lack of development in rural areas is partly attributed to the absence of modern energy services. Energy is a crucial element that enables various activities to be performed that are necessary for sustenance of human existence. Energy should therefore be seen as an important factor that is necessary for other factors to be applied efficiently and effectively in the development process. Thus any development plan that the country formulates should embrace a broad-based programme of policies that promote economic growth and overall development. The

World Bank (1996) has recognized that well-conceived investments in rural energy may not yield desired results if economic conditions are not favourable.

Case Study 1: Survey of rural households and income-generating areas

Energy use in households can be compared with energy use in income-generating activities to determine the comparative use of modern energy in both qualitative and quantitative terms. In this case study, modern energy needs for household and income-generating activities were compared both qualitatively and quantitatively, on the basis of the survey results.

Results of sample surveys conducted in the Kasisi area were used to test the hypothesis. Kasisi is a rural area situated about 60 kilometres from the city of Lusaka. The area surveyed has approximately 170 households, a number of small commercial enterprises, some small farms and a very large commercial farm (Agri-Floral Limited) on which vegetables are grown for export to Europe. In addition, there is Kasisi Mission, run by the Roman Catholic Church. The mission has an orphanage, a girls' secondary school and an Agricultural Training Centre. These establishments are surrounded by a number of villages. The mission centre has grid electricity and the surrounding areas depend on traditional fuels for their energy requirements.

A survey of 12 households and 10 income-generating activities was carried out in the Kasisi area, with the results given in Tables 7.7 and 7.8.

Table 7.7 Summary results of household survey

Occupation	No. of people in h/hold	Monthly income US$	Energy technology	Energy sources	Monthly energy cost US$	Energy cost as % of income	Preference of modern energy
Farm worker	4	28.00	Traditional woodstove Wick lamp	Firewood Kerosene	2.00	7.1	None
General worker	3	32.00	Traditional woodstove Wick lamp	Firewood Kerosene	3.70	11.6	None
General worker	2	37.00	Traditional woodstove Traditional charcoal stove Wick lamp	Firewood Charcoal Kerosene	6.25	16.9	None
Office orderly	6	50.00	Traditional woodstove Traditional charcoal stove	Firewood Charcoal Candles Batteries	8.10	12.2	None

Table 7.7 cont.

Occupation	No. of people in h/hold	Monthly income US$	Energy technology	Energy sources	Monthly energy cost US$	Energy cost as % of income	Preference of modern energy
Cook	7	58.00	Traditional woodstove Traditional charcoal stove	Firewood Charcoal Candles Batteries	8.70	15.0	None
Driver	5	60.00	Traditional woodstove Traditional charcoal stove	Firewood Charcoal Candles Batteries	8.90	14.8	None
Farm supervisor	8	64.00	Traditional charcoal stove Wick lamp	Charcoal Candles Kerosene Batteries	10.80	16.9	None
Teacher	3	67.00	Traditional charcoal stove Kerosene stove Kerosene lamp	Charcoal Kerosene Batteries	11.40	17.0	Solar PV Ceramic stove
Transport officer	5	78.00	Traditional charcoal stove Kerosene stove Kerosene lamp	Charcoal Candles Kerosene Batteries	13.50	17.3	Solar PV Ceramic stove
Typist	3	92.00	Traditional charcoal stove Kerosene stove Kerosene lamp	Charcoal Candles Kerosene Batteries	13.40	14.5	Solar PV Ceramic stove
Nurse	4	105.00	Traditional charcoal stove Kerosene stove	Charcoal Candles Kerosene Batteries	14.70	14.0	Solar PV Ceramic stove LPG
Admin. Assistant	5	116.00	Traditional charcoal stove Kerosene stove Kerosene lamp	Charcoal Candles Kerosene Batteries	15.20	13.1	Solar PV Ceramic stove LPG

Notes:

Exchange rate: US$1= K3,650 Key: LPG – liquefied petroleum gas; PV – photovoltaics

1 The number of people per household includes husband, wife, children and dependants.

2 Low-income households use kerosene solely for lighting using a wick lamp.

3 Medium-income households use kerosene for lighting and cooking meals quickly, such as breakfast in the morning when there is little time.

4 Entertainment refers to the use of batteries (torch and motor vehicle types) to provide power for radios and black and white television sets. The energy cost per month includes purchase of dry batteries and battery-charging expenses.

5 Ceramic stove in this survey refers to the coal briquette ceramic stove.

6 A 50 kg bag of charcoal was estimated to cost US$2.50.

7 Firewood was estimated to cost US$0.25 per woodlot (10 kg approx.).

8 Energy costs per month in winter were likely to go up to meet space heating needs.

Table 7.8 Summary results of income generating survey

Activity	Energy technology	Energy sources	Monthly income US$	Monthly energy cost US$	Energy cost as % of income	Preference of modern energy
Bar	Kerosene lamps Car battery	Candles Kerosene Batteries	361	22	6.1	Solar PV Genset
Grinding Mill	Kerosene lamp Motor driven by engine	Kerosene Diesel	557	134	24.1	Solar PV for lighting
Vegetable growing	–	Human energy	128	–	0	Solar PV
Grocery	Kerosene lamp	Kerosene Candles	222	3	1.35	Solar PV
Poultry	Kerosene lamp Traditional charcoal stove	Kerosene Charcoal	721	59	9.57	Solar PV Coal briquette stove Biogas
Restaurant	Traditional institutional stove Kerosene lamp	Kerosene Candles Firewood	216	37	17.1	Solar PV Coal briquette stove LPG
Bakery	Traditional oven	Firewood briquettes	476	77	16.2	Coal
Traditional Beverages	Traditional institutional stove	Firewood	149	28	18.8	Coal briquette stove
Butchery	Kerosene lamp	Candles Kerosene	473	3	0.63	Solar PV
Pottery	Traditional kiln	Firewood	269	49	18.2	Biogas Coal briquettes

Notes:
Exchange rate: US$1 = K3,560
Key: PV – photovoltaics; LPG – liquefied petroleum gas; genset – diesel/petrol generating set
1 Lighting needs for most income-generating activities are only for a few hours after it gets dark..
2 Bars and grocery shops cool drinks by putting them in containers that are covered with wet sacks.
3 Energy needs for poultry are for brooding of chicks and lighting poultry houses.
4 Entertainment refers to the use of car batteries to provide power for music systems. The energy cost per month includes battery-charging expenses.
5 A 50 kg bag of charcoal was estimated to cost US$2.50.
6 Firewood was estimated to cost US$0.25 per woodlot.

The survey team also visited the Kasisi Agricultural Training Centre where there is a metal foundry that uses wood as a fuel. The Centre has a biogas plant and a solar section that are used for training students on how to generate methane gas and make solar box cookers respectively.

OBSERVATIONS

The majority of the people in this area were familiar with modern energy technologies such as biogas, windmill and solar energy, since installations of these technologies exist at the mission. However, the majority of the people were not aware of improved stoves, coal briquette and LPG technologies.

ANALYSIS AND DISCUSSION

Comparative analysis of energy and expenditure

The results of the survey in Table 7.7 show that the majority of households depend on traditional fuels for their energy needs. In this survey, households used firewood for their energy-intensive activities, such as cooking, water and space heating. All households surveyed used at least one form of traditional energy for such activities. The household survey data results in Table 7.7 show a close linkage between energy consumption and the distribution of income. In this survey, people in the lower-income group earned between US$28 and US$60 per month, and those in the medium-income group between US$64 and US$116 per month.

In low-income households, women and children collect firewood as part of their domestic chores and there is no cost attached to the firewood. The cost of energy is basically what is spent on kerosene for lighting. In medium-income households, firewood is bought in woodlots, as it is relatively inexpensive compared to other forms of energy. High energy costs in some medium-income households relate to expenditure on dry batteries and kerosene for radios and lighting respectively.

Low-income households are unlikely to spend any more money on energy. However, the picture may be different when people's incomes increase. The people in the higher-income group are willing to spend a little more on modern energy if it is accessible. For example, people were more willing to switch to LPG for cooking if the technology was available and affordable. The results concerning willingness to pay in this case study are similar to those obtained in the case study of the ESCO solar PV project. These results confirm the notion that low-income households are on the lower end of the energy ladder and depend on traditional fuels. On the other hand, high-income households consume more energy and they are at the upper end of the energy ladder.

The results of the survey in Table 7.8 show that energy-intensive SMEs use firewood in their activities. On average, highly energy-intensive SMEs spend 18.9 per cent of their monthly income on firewood. SMEs purchase the firewood from woodfuel suppliers. In addition to expenditure on firewood, other SMEs spend a substantial amount of money on kerosene and batteries for lighting and operating entertainment equipment respectively. The percentage of energy cost compared to income is higher for SMEs than households.

Interviews conducted with business owners revealed that most SMEs were willing to spend more on modern energy. This was seen as an opportunity to enhance productivity in their business. For example, a bar owner was willing to invest in a genset as it would provide power for a music system and refrigerators to cool beverages. The genset would enable the bar owner to provide better service and this would in turn attract more patrons, resulting in more business. Other business owners who foresaw the potential for business enhancement expressed similar views on switching to modern energy technology. However, households and business owners saw the high cost of technologies as the major obstacle preventing them from switching to modern energy.

The survey results show that most SMEs use kerosene and batteries for some of their energy needs, that SMEs spend more money on energy than households in percentage terms, and that SMEs are willing to switch to modern energy technologies if they are made available and affordable. In view of the foregoing, it can be deduced that the impact of modern energy is greater in income-generating activities than in households.

Case study 2: electrification of Mpika Zambia National Service Camp and Chibuye Rural Health Centre

This case study was used to test the hypothesis by comparing the cost–benefit ratio. Both projects are situated in the Northern Province and were electrified by extending the national grid. The two projects were completed in 1999.

Mpika Zambia National Service Camp

The electrification of the Mpika ZNS Camp was implemented at a total cost of US$84,000. The power was intended for use in a metal fabrication workshop, and for the irrigation of crops such as wheat, vegetables and sorghum. In addition, electricity was connected to some of the households in the area. Table 7.9 shows the cash flow for Mpika.

Assumptions

The following assumptions were made:

- Average collection rate from retail sales was assumed to be about 70 per cent;
- Operational expenditure mainly includes administration, transport and financial costs.

Table 7.9 Year 2000 cash flow for Mpika Zambia National Service camp

	Jan./March	April/June	July/Sept.	Oct./Dec.	Total
Total revenue (US$)	1,400	2,074	2,074	2,074	7,622
Total operating expense (US$)	1,114	2,148	2,010	2,211	7,483

Note: Exchange rate US$1 = K3,388 (Average rate for the year 2000)
Source: DoE

The cost–benefit ratio was determined by comparing the revenues collected with the operating expenses. It is evident from Table 7.9 that the revenues exceed the operating expenses, giving a cost–benefit ratio of 1.025.

CHIBUYE RURAL HEALTH CENTRE

The Chibuye Rural Health Centre was electrified at a cost of US$170,000. This was a welfare project intended to improve the quality and provision of medical care services. A few households near the centre were also electrified.

Assumptions

- Average collection rate from retail sales was assumed to be around 50 per cent;
- Operational expenditure mainly includes administration, transport and financial costs.

Table 7.10 Year 2000 cash flow for Chibuye Rural Health Centre

	Jan./March	April/June	July/Sept.	Oct./Dec.	Total
Total revenue(US$)	467	691	691	709	2,558
Total operating expenses (US$)	557	1,074	1,005	1,105	3,741

Note: Exchange rate US$1= K3,388 (Average rate for the year 2000)
Source: DoE

It is evident from Table 7.10 that the revenues do not cover the operating expenses, giving a cost–benefit ratio in this case of 0.683.

In comparing the two projects, it is evident from the results that the cost–benefit ratio for the Mpika ZNS Camp (1.025) is better than that of the Chibuye Rural Health Centre (0.683). Although in this example an income-generation activity has been compared with a welfare-based activity (health), it can be deduced from these case studies that income-generating activities have greater impact than households in promoting the use of modern energy services in the rural areas. Energy use in households is basically for cooking, heating, lighting and entertainment, which are all related to the welfare of the households.

Case study 3: Energy Service Company (ESCO) project in Eastern Province

While 20 per cent of Zambia's population has access to electricity, only 2 per cent of the rural population has access to electricity compared to 35 per cent in urban areas. The growth rate of households that are connected to electricity is 2.5 per cent while the growth rate of households is 3.5 per cent (SEI/DoE, 2001). The high cost of supplying grid electricity outside urban areas has motivated the search for alternative ways of supplying modern energy to the rural areas. Solar PV was identified as one of the alternatives for delivery of modern energy services to the rural areas that can provide basic power for lighting and operating appliances such as radios and television sets. The objective of the ESCO project in the Eastern Province was to develop a pilot project as a test framework for providing rural communities with electricity services using the concept of energy service companies (ESCOs).

The Eastern Province of Zambia was selected because it has a relatively wealthy population compared to most rural areas of Zambia. The area has a strong agricultural base but is not well served with electricity from the national grid. The first ESCO, Nyimba Energy Service Company, is fully operational with 100 clients supplied with PV systems as at December 2000 (Table 7.11).

Table 7.11 Installation of PV systems in Nyimba

Segment	No. installed	% share
Business units	30	30
Households	48	48
Institutions*	13	13
Farm units	9	9
Total	100	100

* Includes government, church and educational institutions
Source: DOE

According to the Department of Energy, four PV demonstration units were installed in four households in Chipata. Another four demonstration units were installed in three households and one business unit in Lundazi. All the above PV systems were purchased and installed at a total cost of US$101,000.

Objectives of the socio-economic survey and analysis of the target communities

According to SEI/DoE (2001), a mission of experts was sent to the Eastern Province to conduct a socio-economic survey before project implementation. The objectives of the socio-economic survey were as follows:

- get an understanding of energy needs of the rural population in the areas to be targeted by the project;
- examine energy use, costs and problems in the Eastern Province;
- identify barriers in the PV market in Zambia;
- determine what could be done to overcome the barriers.

Results of the survey

- There was inadequate infrastructure for dissemination of PV systems in the Eastern Province of Zambia.
- People with average incomes could not afford to buy PV systems outright.
- Monthly expenditure on energy in the survey areas was between US$1.09 and US$10.90.
- Most respondents were willing to pay up to US$5.46 per month for improved energy services.
- About 13 per cent of the respondents were willing to pay up to US$16.38 per month.

Willingness to pay. The results of the survey showed that 75 per cent of the respondents were willing to pay US$5, while only 13 per cent were willing to pay US$16 and very few were willing and able to pay more than this amount. According to SEI/DOE (2001), there was good understanding that there would be income-generating opportunities that could be explored with the introduction of solar PV. Most people felt solar PV could provide power for entertainment and boost local businesses.

Comparison of electrification programmes

Government rural electrification programmes target areas where there is potential economic activity. However, there are exceptions where government feels it has a social responsibility to extend electricity for welfare institutions such as schools, health, police and community centres. Electrification of rural areas is done by grid extension and decentralized diesel power plants. Any category of consumer is free to apply for connection. In contrast, the ESCO project is divided into various consumer categories such as business units, households, farm units and social institutions.

Regional commonality

The ESCO project studied in the Zimbabwe medium-term study was compared with the Zambian ESCO project with a view to identifying points of commonality and experiences that could be of benefit to the Zambian study. The following experiences drawn from the Zimbabwean ESCO project could be of particular benefit to future Zambian projects.

- Appointing as an ESCO a local NGO experienced in rural energy issues (such as the Biomass User Network) is a step in the right direction. BUN is an experienced organization already familiar with rural energy issues and this boosts chances of project success. In the Zambian ESCO project, unfortunately, the owners of ESCOs are new to the energy sector and in particular to rural energy issues.
- The targeted households are all involved in income generation activities at night: this enables them to generate some income to improve

their living standards and also pay for the solar systems. In addition, the families benefit from improved lighting for school children studying at night.
- The introduction of annual as opposed to monthly user fees enables more people to afford solar systems. Most people in rural areas are engaged in subsistence farming. They earn income by selling surplus crops. This means that their incomes are seasonal: they only have money at certain times of the year. If annual fees applied in the Zambian case, many more people in other rural areas could pay for solar PV.

Qualitative comparison of impact: income-generating activities vs domestic use for promotion of modern energy

Surveys conducted in the short-term study revealed that energy initiatives targeted at income-generating activities had higher impact and performed better than those targeted at domestic and welfare schemes. The solar systems installed for two income-generating projects in different parts of Lusaka Rural, one in Chikanchila Village, Kasisi and the other in Shalulwe Village, Shibuyunji, are good examples of rural energy initiatives that have been successful. The solar systems have had a big impact in terms of enhancing business opportunities. Solar PV has improved income generation of these enterprises by extending operating hours. Business owners pay particular attention to proper operation and maintenance of the systems.

Fifty-five households in the Eastern Province benefited from solar electrification under the ESCO project. The impact of this project on the households is seen in terms of benefits that have contributed to improvement in the quality of life. According to the Department of Energy, the benefits include increase in business opportunities, as women are able to work at night. Further, there has been an improvement in children's performance at school as they are able to study at night (Chandi, 2002).

From the foregoing, it can be concluded that the impact of modern energy initiatives targeted at income-generating activities is greater than those targeting households.

Interviews with senior government officials and other energy experts

Senior government officials interviewed felt that the majority of modern energy projects funded by government should target income-generating activities. Their notion was that energy projects targeted at income-generating projects would be self-sustaining as opposed to projects targeted at welfare projects. This view was based on the assumption that some of the income generated from the activities could be used for maintenance of the energy systems. This would ensure sustainability of

Table 7.12 Comparison of Zambian and Zimbabwean ESCOs for solar PV

Zambia	Zimbabwe
• Project commenced in 2000 • Funded by Swedish International Development Agency (SIDA) and implemented by the Department of Energy in collaboration with the Stockholm Environment Institute (SEI) • Project supports formation of local companies (ESCO) that would be autonomous • Three ESCOs established since commencement of the project • Project targets households, business units, farms and social institutions (104 systems installed as at December 2000) • Zambian government owns the solar systems, ownership to be transferred after loan repayment • Solar systems given to ESCOs on loan to be repaid in 20 years at 1% interest • Technical and business management training provided to owners and employees of ESCOs • Future training to focus on accounting and service of charge/discharge regulators • ESCOs market their services to potential customers • Customers pay monthly user fees • Battery Replacement Fund created to ensure that there are enough funds for battery replacement; ESCOs pay one third of battery purchase price per year • Back-up service provided locally by ESCO technicians • Survey to determine impact of project on income-generating activities of businesses and households after electrification not yet done	• Project commenced in 1996 • Funded by Japanese International Cooperation Agency (JICA) and implemented by the Department of Energy • Local NGO (BUN) contracted to act as an ESCO • Targeted at households (100 systems installed by 1998) • Technical training on installation and maintenance provided to BUN technicians • Majority of customers are farmers and pay annual user fees when they have sold their crops • Back-up service provided locally by BUN technicians • Survey to determine impact of project on income-generating activities of various households after electrification done

Source: SEI/DOE, 2001; Mapako, 2001

the energy project. On the other hand, welfare projects would require government's support in terms of maintenance of the energy systems – support which government currently does not have adequate human and financial resources to provide. Views expressed by senior government officials were consistent with some of the criteria of the REF. The criteria required that project promoters demonstrate that the energy project to be funded would be self-sustaining and generate economic benefits for the area. Further, the views of senior energy officials were consistent with the following findings from the short-term study:

- Provision of modern energy services targeted at income-generating activities had a better rate of success than welfare-focused projects.
- Rural energy initiatives focused on welfare schemes such as schools and clinics had failed, whereas projects that were targeted at income-generating activities had succeeded.

Senior officials at the National Institute for Scientific and Industrial Research (NISIR) were of the view that government should disseminate proven modern energy technologies that have been developed and adapted to the Zambian situation. NISIR had carried out successful projects on these lines. The officials felt that government efforts should be directed towards promoting wider usage of energy-efficient technologies such as biogas and improved ceramic stoves that use biomass and coal briquettes as fuels. These technologies can meet most of the energy needs in households and income-generating activities. NISIR has made local designs of the floating dome biogas digester, gas stoves and lanterns. These technologies have been tested and proven and are available on the market. NISIR has set up demonstration biogas plants in various parts of the country. Between 1980 and 1999 NISIR installed 18 biogas plants in various parts of the rural areas (Mbewe, 2000).

Officials from the Central Statistics Office felt that modern energy services should be made available to the rural areas for income generation activities. They observed that areas that had modern energy services had a good number of people enjoying better living standards because some people operated businesses and earned income. This contributed to the development of the rural areas.

Conclusion

Promotional efforts directed at income-generating activities have a greater impact than those directed at households when it comes to advancing the use of modern energy services.

Hypothesis 3: Prioritizing components for the promotion of RETs

Of all existing and potential components for the promotion of RETs geared to income-generating activities in rural areas, some are far more critical than others and therefore need priority attention and action.

A number of rural energy initiatives have been implemented in Zambia by the government, ZESCO and the private sector. Zambia has implemented rural electrification programmes based on grid extension, development of mini-hydro and diesel power plants. Despite considerable investments in rural grid extension, we have seen that only 2 per cent of the rural population has access to electricity compared to 35 per cent in urban areas.

Research on RETs conducted in the late 1980s focused on biomass cookstove projects largely for welfare activities. Government, the University of Zambia and NISIR implemented the projects. The research activities concentrated on the improvement of combustion efficiency of the cookstoves with a view to reducing the amount of biomass used for cooking. Other benefits of improved cookstove efficiency were reduction in time spent by end users in collecting firewood and decrease in smoke. During the same period, the Technology Development and Advisory Unit (TDAU) at the University of Zambia conducted some limited research on solar water heaters. Table 7.13 shows the dissemination of energy technologies for households and institutions. Other rural energy initiatives involving dissemination of technologies such as solar PV, windmills and gensets were largely driven by the private sector and targeted at income-generating activities.

Table 7.13 Stove dissemination (household and institutions)

	Technology	1990	1991	1992	1993	1994	1995	1996	1997	1998
Urban h/holds	Electric	41381	42743	441449	45602	47102	48651	50252	51797	53525
	Charcoal	351741	363314	375267	387613	400365	413537	427143	440277	454965
	Firewood	82763	85486	88298	91203	91204	97303	100504	103595	107051
	Kerosene	31036	32057	33112	34201	35326	36489	37689	38848	40144
	Coal briquettes	10345	10686	11037	11400	11775	12163	12563	12949	13381
Rural h/holds	Electric	15518	16029	16556	17101	17663	18244	18845	19424	20072
	Charcoal	225011	232414	240060	247958	256116	264542	273246	281648	291044
	Firewood	527612	544970	562900	581419	600548	620306	640714	660416	682448
	Kerosene	7759	8014	8278	8550	8832	9122	9422	9712	10036
Institutional	–	–	–	–	45	45	57	57	63	65

Source: DoE

For the purposes of testing this hypothesis, the ESCO project in the Eastern Province will once again be used as a case study. Although this project is not yet completed and evaluated, it is well documented. Reference will also be made to other case studies of rural energy initiatives.

Case study: ESCO solar PV project in Eastern Province

We have seen that this pilot project is an attempt to employ an alternative approach for providing energy services using solar photovoltaic equipment to people in rural and poor peri-urban areas. The approach is based on ESCOs, which in this case provides energy services through solar PV systems. Each ESCO is given a long-term credit facility (20 years) for hardware by a donor agency through the Zambian government. There are three ESCOs, serving a total of 400 customers. At the beginning of the year 2002 a total of 100 solar PV systems had been in operation for 1–2 years while 300 systems had been in operation for 2–6 months. Installation and maintenance of solar systems is provided by the ESCO which owns the equipment. The solar systems are installed in households or businesses that have demonstrated both their willingness and ability to pay the monthly user fee to the ESCO for the electricity service that the solar system provides. The fee is intended to cover a small profit, the full cost of maintaining the system, battery replacements and a substantial part of the capital cost of the system. The main incentive for the ESCO is to ensure continued operation of the equipment by regular servicing and maintenance as the customer only pays for the time that the services are actually provided.

According to latest reports, there has been great enthusiasm among rural people in the Eastern Province to acquire the solar systems to provide power for lighting and radios. Experience has shown that there is a good payment record. The reports show that there has been no vandalism or theft of equipment, although a number of systems have been repossessed and installed in other households after default on payment.

Key components for success of renewable energy technology projects

Resource assessment and statistical data base

Lack of data and information on the energy resource base and technologies are major obstacles for policy makers in making appropriate decisions. Only large energy undertakings such as ZESCO, the oil refinery and marketing companies, and the coal company submit data on their operations to the Ministry of Energy and Water Development. The small energy entrepreneurs do not. It has been observed that there is growth in activities carried out by the small energy entrepreneurs. For example, there has been an increase in the sale of diesel gensets by the private sector. However, this information is not available to government, making it difficult for planners and policy makers to make necessary decisions and interventions for dealers and customers.

Market survey/needs assessment

This is one of the fundamental and critical components for the success of disseminating any energy technology. Some of the key issues in the market survey/needs assessment should be:

- energy needs of the people in the target areas;
- energy use;

- cost of energy and problems associated with particular technologies;
- how much people are prepared to pay for the technology;
- barriers and what can be done to overcome them.

There is no evidence that institutions involved in the research and dissemination of improved biomass stoves conducted a market survey for the technologies. The force behind the dissemination of improved stoves was the price incentive, since the cost of production of the stoves was subsidized by the Danish International Development Agency (DANIDA). Prices of improved stoves were kept low compared to traditional stoves in order to ensure rapid diffusion of the technologies in both the urban and rural areas. The dissemination of the cookstoves has not fared well after donor fatigue.

The first step in the Eastern Province ESCO project was to conduct a market survey. The market survey was done to determine who the customers were, income and expenditure, competing energy services, ability to pay, and energy use and expenditure to be replaced by PVs. The results of the market survey identified potential problems and provided useful information that helped in design and implementation of the project. In addition, the market survey helped in estimating the penetration of the technology. Project reports reveal that there are about 900 people on the waiting list of the three ESCOs for solar systems in the Eastern Province. The success of this project is due to the fact that it is a market-driven project.

Financing mechanism

Suitable finance is the most important component for success of disseminating rural energy initiatives. It does not matter how well the project is conceived and designed, if there is no suitable financing mechanism for would-be entrepreneurs and end users, it is unlikely that the project will succeed. Sustainable rural energy initiatives require affordable domestic credit financing. The absence of local financing initiatives is a threat to the promotion of RETs. The ‘critical mass’ question that remains unanswered is the magnitude and duration of support required to ensure that the RETs are disseminated on a sustainable basis without requiring regular donor support. RETs have relatively large up-front costs, and few potential end users can afford outright purchase. The ESCO project in Eastern Province has demonstrated that given a suitable financing scheme, some households and small businesses can afford solar PV systems. The ESCO approach can also be used to promote dissemination of solar water heaters, biogas and wind energy technologies.

It was established in the short-term study that a number of factors had limited government and ZESCO rural energy initiatives. Some of the factors were lack of financial resources and a local-level institutional framework for disseminating rural energy initiatives. These factors call for new approaches to the dissemination of rural energy technologies. One way of solving this problem is to attract the private sector to invest in rural energy businesses. However, the initial cost of acquiring the equipment constitutes a significant barrier to many people in the rural areas who wish to purchase RETs. Table 7.14 shows the estimated cost of various RETs. These costs are beyond the reach of the majority of the people in the rural areas. Another problem is that investors in dissemination projects will need large sums of money to acquire equipment and accessories. However, no investor will be willing to put money into a business providing products that do not sell because people cannot afford them. Moreover, credit from local banks is expensive: interest rates currently stand at 40–65 per cent. Innovative financing schemes such as the ESCO approach are needed to address both the financial needs of the investors and affordability to end-users. Other financing mechanisms should include leasing arrangements through cooperatives, establishing concessions, and revolving fund facilities for using the 'energy fund' obtained from licensing fees charged by the Energy Regulation Board.

Table 7.14 Estimated cost of renewable energy technologies in 2001

Type of technology	Units disseminated	Estimated cost/unit (US$)
50 Wp photovoltaic system	5,000*	1,200
100 litre solar water heating system	–	625
Wind pump	100	4,206
Biogas	18	1,653

Source: AFREPREN, 2002
* Number includes other sizes of photovoltaic panels

Training and capacity building initiatives

Training and capacity building are vital for promoting rural energy initiatives. A critical mass of policy analysts, economic managers, engineers and technicians is required if rural development is to be achieved. Training should be an integral component of rural energy initiatives in order to ensure that essential skills for operation and maintenance of the energy systems are available. In the Eastern Province ESCO project, several training seminars were conducted aimed at training ESCOs in planning, sizing, installation and maintenance of solar systems. Course participants were directors, technicians from ESCOs and technicians from the University of Zambia. The training course material was developed jointly by a technical consultant of the project, technical personnel from the University of Zambia Physics Department and experts from the Stockholm Environment Institute. In addition, technicians underwent further training in Zimbabwe conducted by the Biomass Users' Network. In addition, all ESCOs received training in business development and accounting. Through this project, technical capacity building in operations and maintenance of solar systems has been built not only for ESCO technicians but also for local technicians at the University of Zambia. In the long-term this will help to create a pool of local technicians with sufficient knowledge to install and maintain solar photovoltaic systems.

Operation and maintenance

The short-term study identified lack of maintenance as a major reason for failure of energy projects that had been implemented by government for welfare reasons. Some of the problems with the equipment could have been rectified if people had possessed basic skills in maintenance. The solar project in the Eastern Province has performed well because the ESCOs have skilled technicians available locally who conduct regular check-ups and make basic repairs to the equipment. A technician manual for the PV systems was developed with the assistance of the technical expert who pioneered the energy service company concept in the Pacific. The manual contained, among other things, a wide range of useful information on operational guidelines, maintenance and repair of systems, and advice for customers. The manual provides a useful source of reference for solar system troubleshooting.

Gender considerations

Technologies are available to improve efficiency for all energy users. Experience has shown that many energy projects do not explicitly differentiate how men and women are intended to benefit from a project. Statistics in the short-term study showed that the Zambian population had more women than men. The majority of Zambian women living in the rural areas are engaged in subsistence activities. These activities are energy-intensive and their viability is affected by energy availability and prices. The dissemination of an improved cookstove by Care International in Lusaka peri-urban areas has had remarkable success because women as stakeholders were involved from the beginning and consulted on the design aspects of the stove. There is no evidence from the planning and implementation of the ESCO project that gender was considered as an important issue in the project.

Quality control

The issue of standards is very important if cases of supplying substandard equipment to customers and bad installations are to be avoided. The Energy Regulation Board (ERB) in conjunction with the Zambia Bureau of Standards has developed quality and reliability standards of solar (PV) systems as follows (ERB, 1999):

- Photovoltaic (PV) module specifications;
- DC luminaries specifications;
- batteries for use in photovoltaic systems: test methods;
- photovoltaic energy system design and installation: code of practice.

Representatives from the Energy Regulation Board, SEI and the University of Zambia inspect ESCO installations. In this way quality in terms of product specification and installation is controlled.

Table 7.15 Ranking of components and regional comparison

Component	ESCO project	Other energy projects	Zimbabwe study
Market research/ needs assessment	**High priority** A socio-economic assessment and analysis of the target communities was done to assess energy needs and market for PV and determine ability to pay	**Low priority** Selection of target communities for government-funded projects largely based on equal distribution of resources and political considerations	**Low priority** End users acquire the technology
Financing mechanism	**High priority** Funds for purchase of equipment donated to government by SIDA. Equipment owned by Solar Fund of Zambia which manages funds from proceeds of sale of equipment to ESCOs	**Low priority** Most projects were donor-driven and could not continue after donor funds were exhausted	**Moderate importance** End users did not need financing
Training and capacity building	**High priority** Training was provided in all aspects of the technology and business management	**Low priority** No training was available for the projects that had been implemented	**High priority** Provided to ensure good quality installation and maintenance
Operations and maintenance	**High priority** Technical manual produced to ensure high operational standards and provide reference for good maintenance of the systems	**Low priority** No maintenance was provided for the projects	**High priority (ESCO project only)** Other projects did not provide back-up services
Gender considerations	Not an issue	Not an issue	Low priority
Quality control	**Moderate importance** Considered after post-installation phase	**Not an issue**	**Moderate** Considered at installation stage

Sources: Mapako, 2001; SEI/DoE, 2001

Ranking of components

Table 7.15 presents the ranking of the components in terms of their level of importance based on the analysis of the ESCO solar project case study. The results of the analysis are compared with the previous renewable energy projects implemented in Zambia and the results of the Zimbabwean study (Mapako, 2002) in order to draw regional commonality. It can be seen from Table 7.15 that the two components crucial for success in disseminating RETs both in Zambia and Zimbabwe are:

- training and capacity building; and
- operations and maintenance.

In the case of Zambia, in addition to the above, financing of RETs is crucial for promoting them in the rural areas. These components need priority attention and action.

8

Draft Policy Options

This chapter presents draft policy options that aim at solving some of the problems that have been identified in testing the hypotheses. A rural energy strategy is recommended. The strategy should consider all key issues and priorities that are necessary for steering the development of rural energy supply. Based on the preliminary analysis, several policy initiatives were recommended, examined and subjected to a filtering process reflecting the current situation in Zambia, using the following factors:

- institutional and management;
- legal framework;
- economic and financial;
- human resources and technical capability.

After the filtering process, final draft policy options are presented for each of the hypotheses.

Hypothesis I: Decentralized private sector vs centralized public sector energy initiatives

Decentralized private sector energy production and distribution have a better rate of success than centralized public sector initiatives in delivery of modern energy to the rural households and for income-generating activities.

This study established that centralized public and decentralized private energy dissemination approaches have synergies. Centralized private sector delivery approaches benefited from public sector initiatives and demonstration projects. The ESCO model was a government initiative and the private sector was contracted to implement. Both centralized and decentralized approaches are required in the formulation and implementation of energy programmes. Based on the findings of this study, decentralized energy supply is a better option than the centralized as the former has a faster diffusion rate. More effort should be placed on decentralized energy options. In order to enhance dissemination rates of decentralized energy options, the following policy options are recommended:

- enhance data and statistics collection pertaining to rural energy technologies;
- provide subsidies for electricity customers in rural areas;
- introduce awareness and promotional campaigns for decentralized energy options;
- encourage private sector participation in the delivery of rural energy services;
- review energy policy to include women's specific needs and all forms of energy technologies for rural areas.

Enhance data and statistics collection pertaining to rural energy technologies

Data on rural energy activities are limited. The ideal methodology in testing this hypothesis was to compare dissemination of like energy technologies using the same delivery approaches. Comparing centralized public and decentralized private approaches is constrained by data limitation. In this study, it was difficult to find primary data related to the dissemination of RETs. For example, a number of gensets and pump sets have been disseminated and the majority are believed to be used in rural areas, but data are not available at the Department of Energy. Suppliers of gensets are reluctant to give data on their sales as they fear that competitors could access this information. Measures should be introduced that will persuade energy equipment dealers to provide data on their sales. The data would be useful for government to know the type and numbers of energy technologies that are being disseminated to the rural areas. The information could also be useful for the planning and implementation of future rural energy programmes.

Institutional and management. The current institutional and management structures at the DoE are sufficient to implement this option. Energy companies submit statistics regularly on their operations. The DoE produces Energy Statistics Bulletins that are used in energy planning and are also available for sale to the general public.

Legal framework. The Ministry of Energy and Water Development (MEWD) has a mandate to guide activities of the entire energy sector in the country. MEWD can call for any data from energy dealers and suppliers without any legal requirements.

Economic and financial. There may be financial implications for implementing this option. Primary data collection, especially in rural areas, may require field surveys to be carried out that may be expensive. Experience has shown that funds disbursed to the energy sector are usually not sufficient to cover all budgeted activities.

Human resources and technical capability. Although skills for data processing and analysis exist at the DoE, data collection may require extra human resources. The DoE has failed to recruit and retain skilled staff.

Conclusion: It is not feasible to implement this option.

Provide subsidies for electricity customers in rural areas

Electricity tariffs for rural and urban customers are the same. In the case of customers connected to the isolated diesel systems, the electricity tariff is usually below the cost of production, reflecting the high cost of diesel fuel for generation. However, grid electricity is cheap since it is hydropower-based, except for the cost of extending transmission and distribution infrastructure. It is, therefore, recommended that rural customers connected to the national grid be given subsidies to make electricity more affordable and encourage demand.

Institutional and management. ZESCO has the institutional and management capacity to implement this option.

Legal framework. There are no legal implications in implementing this option.

Economic and financial. This option has financial implications for ZESCO, the national electricity utility. ZESCO incurs significant losses in running isolated diesel systems and receives no subsidies from government. Government does not subsidize fuels. ZESCO would be unwilling to subsidize electricity customers in the rural areas as this would worsen its financial position.

Human resources and technical capability. Human resource skills exist at ZESCO to devise subsidized tariffs for rural customers.

Conclusion: It is not feasible to implement this option.

Introduce awareness and promotional campaigns for decentralized energy options

The majority of rural people in Zambia are not aware of proven RETs. In order to make informed choices on the available options, the rural poor need energy demonstration projects. The National Energy Policy has described measures such as energy fairs, practical demonstrations and pilot projects as means of addressing this problem. These measures should promote the proven energy technologies. The electronic media can play an important role in disseminating information to members of the public. MEWD can learn from NAIS (National Agricultural Information Services) how information is collected and disseminated to farmers in the agricultural sector. NAIS, a publicity wing of the Ministry of Agriculture and Cooperatives, collects information on various topics on agriculture throughout the country and this is broadcast on radio and television. This is an effective way of disseminating useful information on agriculture to farmers and the general public. The same approach could be useful to the energy sector.

Institutional and management. The existing institutional and management structures at the DoE are sufficient to implement this option. The DoE has participated in a number of agricultural shows by exhibiting various energy technologies. The awareness and promotional campaigns could also be undertaken in collaboration with other institutions like the Ministry of Agriculture and Cooperatives, NISIR and TDAU.

Legal framework. There are no legal implications of implementing this option.

Economic and financial. For a long time the DoE has operated on insufficient budget allocations. Moreover, the short-term study identified a number of energy projects interrupted by non-disbursement of funds. It is unlikely that the DoE would be allocated more funds by government to implement this option.

Human resources and technical capability. Skilled human resources are in short supply at the DoE. Efforts to attract and recruit competent personnel have been frustrated by poor remuneration packages and conditions of service.

Conclusion: This option may not be feasible to implement.

Encourage private sector participation in the delivery of rural energy services

One of the recommendations of the short-term study was to 'increase funding for rural energy initiatives'. Rural electrification projects are delayed by inadequate disbursement of funds. New and innovative approaches are needed which can attract the private sector to participate in the rural energy businesses. This could be possible with approaches such as the ESCO model. In addition, the government should provide an enabling environment for rural energy entrepreneurs by giving them fiscal incentives.

Institutional and management. Relevant expertise and experience have been developed at the DoE through the ESCO project in the Eastern Province. This expertise can be utilized to mobilize the private sector to invest in rural energy businesses.

Legal framework. There are no legal barriers to implementing this option.

Economic and financial. The government needs to mobilize financial resources for developing the rural energy sector. The REF and the energy fund collected by the ERB could finance rural energy initiatives. Proper management and accountability of the REF and the energy fund are essential. Provision of fiscal incentives to rural energy entrepreneurs will have economic implications in the short term. However, in the long term government will create a larger tax base from anticipated rural industry growth.

Human resources and technical capability. Human resources exist for implementing this option. Capacity exists in various national institutions for training energy entrepreneurs in technical and business matters.

Conclusion: It is feasible to implement this option.

Review energy policy to include women's specific needs and all forms of energy technologies for rural areas

The short-term study revealed that there were no policies that focused on gender and conventional energy for rural areas. It is recommended that the National Energy Policy be reviewed. The policy review should include women's specific energy needs, and all forms of energy technologies for rural areas. This will contribute to empowerment of women and promotion of all available energy options.

Institutional and management. Institutional structures exist in the country to implement this option. MEWD in collaboration with the Gender in Development Division (GIDD) and the Gender Department at the University of Zambia could make proposals on gender. The ERB, NISIR, the TDAU and other stakeholders could make proposals on rural energy technologies.

Legal framework. No legal implications arise for this option.

Economic and financial. There are no significant economical and financial implications for implementing this option.

Human resources and technical capability. Human resources exist at MEWD and among stakeholders to review the National Energy Policy.

Conclusion: It is feasible to implement this option.

Hypothesis 2: Income-generating activities vs domestic energy use

Income-generating activities have greater impact than domestic use in promoting the delivery of modern energy to the rural areas.

The main finding in testing this hypothesis is that rural households depend more on traditional energy resources compared to income-generating activities. Analysis has shown that impact in promoting the use of modern energy is higher in income-generating activities than in households. To enhance the impact of modern energy in the rural areas, the following policy options are recommended:

- Create awareness on energy issues among key stakeholders;
- Offer guarantees to financial institutions willing to lend money for rural energy projects to SMEs;
- Promote wider use of energy technologies that have been developed locally;
- DoE should develop closer links with key stakeholders and set up energy demonstration projects in rural areas for income-generating activities.

Create awareness on energy issues among key stakeholders

Affordable and sustainable modern energy are essential requirements for promoting development in the rural areas. Experience has shown that many stakeholders in rural development are not aware of the importance of energy in socio-economic development. This is evidenced by the absence of modern energy projects in major development programmes. Further, the strategies that have been developed by government to reduce poverty lack suitable energy technologies that can contribute to rural development. While many subsectors of the NPRSF programme have received donor pledges, no pledges have been made for rural energy projects. Rural energy was not considered a priority in the strategy. This reflects a lack of awareness among key government institutions of the importance of energy in national development and its linkage to poverty reduction. This goes to show that energy has not been given due attention. There is a need to create energy awareness among all relevant stakeholders involved in rural development. Key stakeholders include government institutions, development agencies, cooperatives, religious institutions, CBOs, NGOs and rural communities. This will ensure that energy, which is a crosscutting issue in development, is considered in implementing rural programmes.

Institutional and management. MEWD can initiate meetings where interaction and exchange of ideas between stakeholders can take place.

Legal framework. There are no legal barriers to implementing this option.

Economic and financial. There are no significant economic and financial implications for implementing this option.

Human resources and technical capability. There are no human resource constraints on implementing this option.

Conclusion: It is feasible to implement this option.

Government should offer guarantees to banks, micro-lending institutions and leasing companies

Willingness among householders to pay for modern energy is low. Two case studies – Kasisi and the ESCO project – have shown that low-income households are not willing to spend more on energy. In order to increase dissemination of modern energy services in the rural areas, energy initiatives should be targeted at income-generating activities, as business owners have shown willingness to pay for modern energy services. However, a major issue was that business owners lacked capital to make an outright purchase of the energy technologies. Provision of loans would go a long way to assist SMEs to purchase energy devices.

Institutional and management. There are a number of micro-credit institutions in urban and rural areas. These institutions can provide credit for rural energy projects. However, the financial capacity of the micro-credit institutions is small and cannot meet the credit needs that SMEs would require to purchase energy devices. Except for the Zambia National Commercial Bank, the other large financial institutions have no representation in the rural areas. This makes it difficult to administer loans in the rural areas. Moreover, collateral requirements for obtaining loans from large financial institutions cannot be met by many SMEs.

Legal framework. There are no legal barriers to implementing this option.

Economic and financial. The government collects significant sums of money through the Rural Electrification Levy and licence fees through the ERB. These funds could be used to enhance the financial capacity of some of the micro-credit organizations. The government could also use the levies to offer guarantees to institutions that are willing to lend money for rural energy projects.

Human resources and technical capability. The energy fund can be used to strengthen the human resources capacity of the various institutions that may be required to implement this option.

Conclusion: It is feasible to implement this recommendation.

Promote wider use of energy technologies that have been developed locally

Energy needs of the majority of SMEs can be met by cleaner energy technologies such as improved institutional stoves and biogas. These technologies can be applied in various small rural businesses. The government should consider promoting these technologies on a wider scale.

Institutional and management. Available institutions such as NISIR and the TDAU have management capacity that can contribute to disseminating energy technologies. Stakeholders in the dissemination of energy technologies include the private and informal sectors, NGOs, CBOs, religious groups and rural communities.

Legal framework. The law provides for money collected through licence fees by the ERB to be used for the development of the energy sector.

Economic and financial. Implementing this option has financial implications. However, expenditure for such activities could be financed by money collected through licence fees charged by the ERB.

Human resources and technical capability. Human resources with technical expertise and experience exist at NISIR and the TDAU that can be used to implement this recommendation.

Conclusion: It is feasible to implement this recommendation.

THE DEPARTMENT OF ENERGY SHOULD DEVELOP CLOSER LINKS WITH KEY STAKEHOLDERS AND SET UP ENERGY DEMONSTRATION PROJECTS IN RURAL AREAS FOR INCOME-GENERATING ACTIVITIES

One way of addressing the poverty issue is to demonstrate in a few rural areas that have potential for developing their vast natural resources. It is envisaged that the demonstration projects and availability of suitable funding could catalyze a wider application of modern energy technologies. Institutions like the Kasisi Agricultural Training Centre should be strengthened and supported by government in training local people on solar cookers and biogas technologies. This support could also be extended so that the Centre introduces awareness campaigns and contributes to the dissemination of modern energy technologies to the people in the surrounding areas.

Institutional and management. MEWD, in collaboration with NISIR, the TDAU, CBOs, NGOs, cooperatives and local communities, can identify and implement energy demonstration projects.

Legal framework. There are no legal barriers to the implementation of this option.

Economic and financial. Activities under this option can be accommodated under the regular budgets of MEWD. Innovative funding should be developed to catalyze the wider application of energy technologies.

Human resources and technical capability. Human resources exist at MEWD and other stakeholders like government departments and ministries, NISIR, the TDAU, the University of Zambia, energy utilities and NGOs.

Conclusion: It is feasible to implement this option.

Hypothesis 3: Prioritizing components for the promotion of RETs

Of all existing and potential components for the promotion of RETS geared to income-generating activities in rural areas, some are far more critical than others and therefore need priority attention and action.

Not all rural energy projects implemented in Zambia have been successful. Reasons for failure vary but a key factor is lack of components necessary for promoting energy technologies. The main finding in testing this hypothesis is that in any energy project some components are more critical than others. Experience has shown that the components have not been given the required priority and attention. In order to increase the chances of success of rural energy projects, it is recommended that the following project components be included in rural energy strategies:

- financing mechanisms;
- market study/needs assessment;
- training and capacity building;
- operation and maintenance.

These components should be given priority attention in the design and implementation of rural energy programmes.

Financing mechanisms

Access to affordable finance is one of the major obstacles to RETs. The majority of householders and SME owners in rural areas cannot access bank credit because they do no have the collateral. Finance from micro-credit organizations is insufficient for purchasing energy equipment. Current government funding for rural energy initiatives is likewise insufficient. Political commitment is needed to mobilize local and external financial resources and create an energy development fund. An issue that is worth considering is to develop financing mechanisms based on local funding that will make the rural energy programme self-sustaining without donor support. This will prevent some good projects going into oblivion when there is donor fatigue. What is needed is to ensure that all funds collected through the REF and the ERB for the development of the energy sector are released and utilized for that purpose. Some of these funds can be channelled into a long-term rural energy revolving fund, which could be used to finance credit schemes. Donor funding should be used to play a catalytic role in helping to acquire energy technologies and devices, specialized training and provision of external expertise.

Institutional and management. Mechanisms exist for government institutions to collect and disburse funds for rural electrification projects.

Legal framework. There are no legal barriers to implementing this option.

Economic and financial. Implementing this option has no economic and financial implications. The only problem is the Treasury's tendency to divert funds to other expenditure.

Human resources and technical capability. Local financial experts are on hand to devise appropriate credit schemes for rural energy programmes.

Conclusion: It is feasible to implement this option.

Feasibility/market studies

Lessons from the past have shown that feasibility studies are essential for project success. The practice has been to approach rural energy problems from a supply rather than a demand perspective. Supply-oriented approaches have often times failed because they have not taken into account end-user needs and cultural practices. Needs assessments are important for evaluating energy requirements of the people in the selected area before implementation of projects. Further, it is possible to identify barriers to energy technologies being proposed and to determine what could be done to overcome them. Market surveys can help to determine the demand for the technology.

Institutional and management. The current institutional and management structures are inadequate to implement this option.

Legal framework. There are no legal barriers in implementing this option.

Economic and financial. Budget provisions will have to be made to hire more staff to conduct needs assessments, market surveys and project management. This may not be attainable owing to insufficient disbursements of funds for budgeted activities.

Human resources and technical capability. The DoE has experienced shortages of skilled labour. Efforts to hire staff have been unsuccessful owing to unattractive conditions of service.

Conclusion: It is not feasible to implement this option.

Training and capacity building

A critical mass of skilled human resources is required if the energy sector is to develop. Training and capacity building are, therefore, very important for the development of sustainable energy services. Training in installation and maintenance of energy systems should be provided for the private and informal sector. This will enable entrepreneurs to install and carry out maintenance of energy equipment. Basic training should also be provided for NGOs, CBOs and rural communities to enable them to carry out basic maintenance of energy equipment and devices.

Institutional and management. The current institutional and management structures are adequate to implement this option. NISIR and the University of Zambia – through its Physics Department and the TDAU – have the capacity to conduct technical training programmes for various levels of maintenance of energy devices/equipment. Other local institutions can also provide training in business management.

Legal framework. There are no legal barriers to implementing this option.

Economic and financial. Expenditure for capacity building can be included in the budget provision for rural energy.

Human resources and technical capability. Expertise exists in the institutions that have been identified.

Conclusion: It is feasible to implement this option.

Operations and maintenance

Maintenance should be an integral component of rural energy programmes: experience has shown that a number of rural energy projects have failed through lack of support in this area. Provision of after sales service is important for creating customer confidence in the technologies promoted. Where possible, service manuals should be made to help in troubleshooting and repair of equipment.

Institutional and management. The Physics Department has institutional capacity to develop training programmes in installation and maintenance of energy technologies such as solar PV. In addition, capacity can be developed for other energy technologies.

Legal framework. There are no legal barriers to implementing this option.

Economic and financial. Implementation of this option will not need significant financial resources.

Human resources and technical capability. Human expertise and technical capacity exist in the Physics Department at the University of Zambia.

Conclusion: It is feasible to implement this option.

9

Final Policy Recommendations

This chapter presents final policy options based on the filtering process in Chapter 8. These options are feasible and can be implemented. Zambia should prepare an integrated sustainable energy strategy for the rural areas. The use of renewable energy should be an important element of the strategy. The role of government in rural energy dissemination is important: it can devise the right policies to guide the activities of the energy sector. Success in implementing proposed policy options is linked to policy and institutional reform. Policy makers should formulate energy policies and enact laws that will provide an enabling environment to attract private investment in rural energy programmes.

Political commitment is needed to support the implementation of rural energy initiatives. Policy makers are key to the success of rural energy programmes. They should ensure that policies are consistent and avoid unnecessary changes and interventions. Some of the policy options proposed will need review of the National Energy Policy, as well as practices and procedures. Other options will need considerable financial resources to implement. Political commitment is required for expeditious disbursement of budgeted funds for rural energy projects. Policy makers can play a vital role in mobilizing local financial resources by ensuring that there is proper management of and accountability for rural energy funds in the government departments and agencies. Public awareness of modern energy technologies suitable for rural areas should be a vital component of the energy strategy. Of great importance is interaction between key stakeholders such as policy makers, donors, local financial institutions, NGOs, CBOs and local communities to jointly identify and tackle problems of rural energy supply.

The policy options presented are ranked using the following criteria:

- policy options that can be implemented using administrative measures;
- policy options that need National Energy Policy review before being implemented;
- policy options that can be implemented with modest funds and can be included in MEWD's regular budget;
- policy options that require substantial funds to implement and can be viewed as separate to budgeted activities.

The above criteria would help policy makers to plan implementation of the recommended policy options: they could assign to the short term policy options that require low-level funding; in the longer term, those needing large financial resources could be considered.

The policy options for the three hypotheses are presented below.

Hypothesis 1: Decentralized private sector vs centralized public sector energy initiatives

Dissemination of rural energy initiatives should focus more on decentralized energy options. Implementing the policy options outlined below would enhance dissemination of modern energy services to the rural areas.

Administrative and long-term

- *Encourage private sector participation in the delivery of rural energy services.* In the short-term, MEWD could organize meetings for would-be rural energy entrepreneurs and make presentations on opportunities that may be available. MEWD could discuss fiscal incentives that government might offer for rural energy businesses. In the long term, MEWD, in collaboration with the Ministry of Finance and Economic Development, could work out funding mechanisms appropriate for promoting rural energy initiatives.

National Energy Policy review

- *Review energy policy to include women's specific needs and all forms of energy technologies for rural areas.* This policy measure can be implemented immediately as no large sums of money or legislation are required. Implementation of this option requires stakeholders to review the National Energy Policy.

Hypothesis 2: Income-generating activities vs domestic energy use

Delivery of modern energy to the rural areas can be enhanced though targeting income-generating activities in the ways suggested below.

Administrative and modest funds

- *Creating awareness on energy issues among key government planners/ institutions.* This option can be implemented immediately. The DoE can conduct tours of energy projects for planning officers in ministries to create awareness. In addition, planning officers could be invited to energy fairs. This could be followed by setting up a committee that would coordinate planning of rural development programmes.

- *Developing closer DoE links with other institutions to set up energy demonstration projects in rural areas for income generating activities.*
- *Supporting and promoting wider use of energy technologies that have been developed locally.*

  These options could be implemented simultaneously and do not require large sums of money. MEWD could hold meetings with stakeholder line ministries to identify areas where modern energy would boost rural production and businesses. A programme of energy demonstration projects could then be designed and implemented in collaboration with stakeholder ministries.

Substantial funds

- *Providing guarantees to banks and financial institutions that are willing to lend money to rural energy projects.* Implementation of this option will require mobilization of local financial resources. The funds can be used to create financing mechanisms such as loans and leasing which can help rural people acquire energy technologies and devices.

Hypothesis 3: Prioritizing components for the promotion of RETs

Success of renewable energy technologies can be improved if priority and attention is given to the project components presented below.

Modest funds

- *Conducting feasibility and market studies.* Implementation of this option will require adequate funding for field visits. Funds will also be required for enhancing data processing capability and human resource skills to undertake these activities.
- *Providing training and developing capacity to manage the projects.*
- *Providing maintenance for sustainability of energy projects.*

  The above policy options can be implemented simultaneously with modest funding. A programme to implement these activities could be included in the regular budget of MEWD.

Substantial funds

- *Establishing suitable energy financing mechanisms.* This option could be implemented along the lines suggested under 'Financing mechanisms' on p. 156.

Part IV Select Bibliography

AFREPREN 2000. 'Renewables and Energy for Rural Development Theme Group Proposal'. Nairobi: AFREPREN/FWD Secretariat.

—— 2002. *African Energy Data and Terminology Handbook*. Occasional Paper No. 13. Nairobi: AFREPREN/FWD.

—— 2003. *African Energy Data and Terminology Handbook*, AFREPREN, Nairobi.

Bassey, W. 1992. 'Renewable Energy Research and Development in West and Central Africa', in M. R. Bhagavan and S. Karekezi (eds), *Energy for Rural Development*. London: Zed Books.

Best, G. 1992. 'The Role of Renewable Energy Technologies in Rural Development', in M. R. Bhagavan and S. Karekezi (eds), *Energy for Rural Development*. London: Zed Books.

Bhagavan, M. R. and Karekezi, S. 1992. 'An Introduction', in M. R. Bhagavan and S. Karekezi (eds), *Energy for Rural Development*. London: Zed Books.

CEEEZ 1997. *Assessment of Solar Energy Dissemination and Application in Zambia*. Lusaka: Social Recovery Project/Centre for Energy, Environment and Engineering, Zambia.

CEEEZ/UNEP 1999. *Zambia Country Study: Climate Change Mitigation in Southern Africa*. Lusaka: Ministry of Environment and Natural Resources, in collaboration with United Nations Environment Programme Collaborating Centre, Riso National Laboratory, Denmark.

Chandi, L. 2002. 'The Gender Perspective of Renewables and Energy for Rural Development'. Paper presented at AFREPREN/FWD Regional Evaluation Workshop, 4–7 June, 2002, Nairobi.

CSO 1996. Living Conditions Monitoring Survey Report. Lusaka: Central Statistical Office.

—— 1999. *Selected Socio-Economic Indicators*. Lusaka: Central Statistical Office.

—— 2000. *Zambia in Figures*. Lusaka: Central Statistical Office.

IEA, 2002. *Energy Statistics of Non-OECD Countries 1999–2000*. International Energy Agency. Paris.

EIU 2003. *Country Report: Zambia*. Economic Intelligence Unit, London.

ERB 1999. Annual Report, 1991. Lusaka: Energy Regulation Board.

Mapako, M. 2001. Renewables and Energy for Rural Development: Medium-Term Study, Updated Second Draft Report. Nairobi: AFREPREN/FWD.

—— 2002. Renewables and Energy for Rural Development, Medium-Term Study, Updated Second Draft Report, presented at Regional Evaluation Workshop 4–7 June 2002. Nairobi: AFREPREN/FWD.

Mbewe, A. 1992. 'Rural Electrification in Zambia', in V. Ranganathan (ed.), *Rural Electrification in Africa*. London: Zed Books.

—— 2000. 'Literature Review: Renewables and Energy for Rural Development in Zambia'. Nairobi: AFREPREN/FWD.

Mbewe, A, 2003: *Country Validation Data-Zambia*, AFREPREN, Nairobi.

Mbewe, D. J. 1992. 'Assessment of Rural Energy Supply and Demand', in M. R. Bhagavan and S. Karekezi (eds), *Energy for Rural Development*. London: Zed Books.

MCDSS 1988. *National Poverty Reduction Strategy Framework*. Lusaka: Ministry of Community Development and Social Services.

Muchiri, L., and Gitonga. S. 2000. *Gender and Energy Technology in the Household: the Case of East Africa*. Energia Secretariat, Leusden.

Mulenga, C. 2000. Mitigation Analysis: Household Sector, Final Draft Report, Zambia: Enabling Activities for the Preparation of Initial National Communication. Lusaka: Environmental Council of Zambia.

Ndekuka, L. 1999. 'Women and Sustainable Energy in Tanzania (with a Case of Limited TaTEDO Experience)' in *Proceedings of an International Workshop on 'Improving Women's Access to Energy: Policy, Projects or the Market?'*. Enschede: ENERGIA.

NEP 1994. *National Energy Policy*. Lusaka: Ministry of Energy and Water Development.

PRSP 2000. *Zambia Interim Poverty Reduction Strategy Paper*. Lusaka: Ministry of Finance and Economic Development.

SEI/DOE 2001. 'Rural Energy Service Companies: Experiences from Zambia, Final Report Phase I, 1998–2000'. Lusaka: Stockholm Environment Institute and the Department of Energy.

World Bank 1996. *Rural Energy and Development: Improving Energy Supplies for Two Billion People*, Washington, DC: World Bank.

World Bank, 2002. *African development Indicators, 2002*, World Bank, Washington DC

World Bank, 2003a. *African Development Indicators 2003*. World Bank, Washington DC.

World Bank, 2003b. *World Development Indicators 2003*. World Bank, Washington DC

ZERO 1998. *Energy and Sustainable Rural Industries: Issues from Pilot Studies in Tanzania, Zambia, Botswana, Mozambique and Zimbabwe*. Harare: Zimbabwe Environmental Research Organization.

Part IV Appendices

IVA.1 Questionnaires

QUESTIONNAIRE 1: Households

What is your occupation? ______________________________

How many are you in the household? ______________________________

How much do you earn per month? K______________________________

What are your energy needs? ______________________________

What are your energy sources? ______________________________

How much do you spend on energy per month?______________________________

Given your income, which of the following modern energy services would you prefer?

Solar, biogas, Kerosene, LPG, ceramic briquette stove? ______________________________

Are you willing to spend more than you are spending now on improved energy sources?

____

What problems do you foresee with the type of modern energy services that you have chosen? ______________________________

What are the problems do you experience with your current energy sources?

____

Thank you for your help

QUESTIONNAIRE 2: Income Generating Activities

What is your main business activity? ______________________________

What is your income per month? K ______________________________

What are your energy needs? ______________________________

What are your energy sources? ______________________________

How much do you spend on energy per month? K ______________________________

Given your income, which of the following modern energy services would you prefer?

Solar, genset, biogas, Kerosene, LPG, ceramic briquette stove? ______________________________

Are you willing to spend more than you are spending now on improved energy sources?

____

What problems do you foresee with the type of modern energy services that you have chosen? ______________________________

What are the problems do you experience with your current energy sources?

____

What kind of assistance in provision of modern energy would you need if any?

____

Thank you for your help

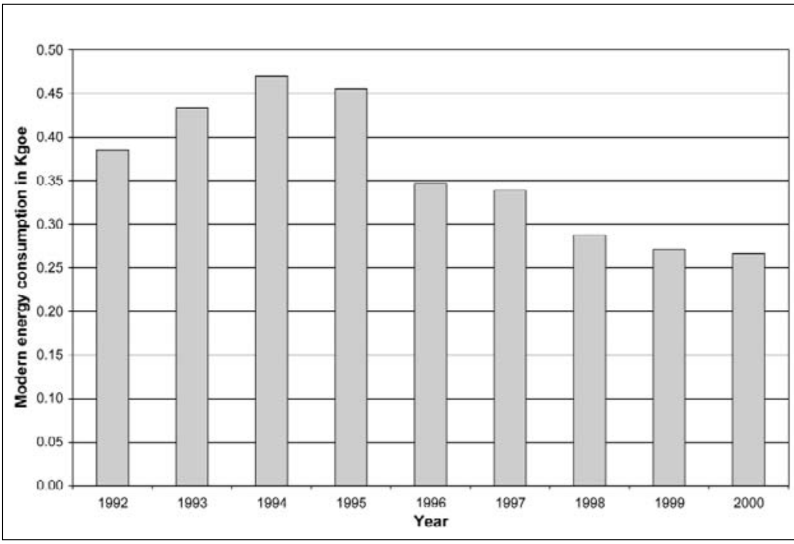
IVA.2 Map of eastern Zambia showing locations of energy service companies (Nyimba, Chipata and Lundazi)

Source: SEI/DOE, 2001

IVA.3 Selected trend data: Zambia

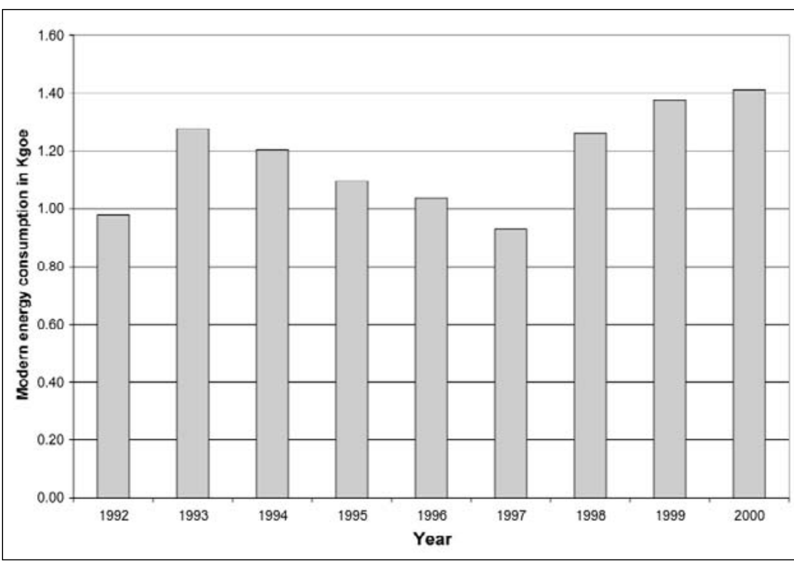
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
National population (millions)	8.30	8.50	8.70	9.00	9.20	9.40	9.70	9.88	10.20	10.38
National population growth rate	3.7	2.4	3.4	3.3	2.2	2.2	3.2	2.1	2.0	1.70
Rural population (millions)	4.9	5.0	5.2	5.5	5.7	5.8	6.0	6.0	6.3	6.44
GDP (millions US$)	2,843	2,926	2,734	2,861	2,966	3,064	3,580	3,826	3,959	4,166
GNP *per capita* (US$)	342	344	310	314	312	315	358	320	300	320
Total modern energy consumption ('000 toe)	1,096	1,270	1,286	1,302	1,030	1,040	1,030	1,040	1,054	
Modern energy consumption *per capita* (kgoe)	158	146	140	145	104	111	106.2	106.3	103.3	
Total energy production ('000 toe)	5,140	5,190	5,240	5,360	5,440	5,560	5,660	5,780	5,920	
National debt (US$ millions)	6,709	6,485	6,804	6,952	7,054	6,654	6,865	6,507	6,311	5,671
Merchandise exports, f.o.b. (US$ millions)	1,120	994	1,067	1,186	993	1,119	816	756	746	884
Installed capacity (MW)	1,786	1,786	1,786	1,786	1,786	1,786	1,786	1,786	1,786	1,786
Electricity generation (GWh)	6,517	8,082	8,115	7,824	7,089	7,870	7,658	7,798	8,213	9,110
National electrification levels (%)	15	15	15	18	18	18	20	20	20	20
Urban electrification levels (%)					45	46	48	48	48	48
Rural electrification levels (%)					2	2	2	2	2	2
System losses (%)	13	14	20	22	15	15	18	15	15	27
Rural population with access to safe water (%)	32	34	36	38	40	42	44	46	48	50
Total electricity consumption (Gwh)	5,532.78	5,727.30	5,421.84	5,235.30	5,681.92	5,619.32	5,536.76	4,948.89	5,466.14	4,924.27
Electricity consumption *per capita* (kWh)	666.6	673.8	623.2	581.7	617.6	597.8	570.8	500.9	535.9	474.4

Sources: Chandi, 2002; Kalumiana, 2003; Mbewe, 2003; AFREPREN, 2003; EIU, 2003; World Bank, 2002; World Bank, 2003; IEA, 2002.



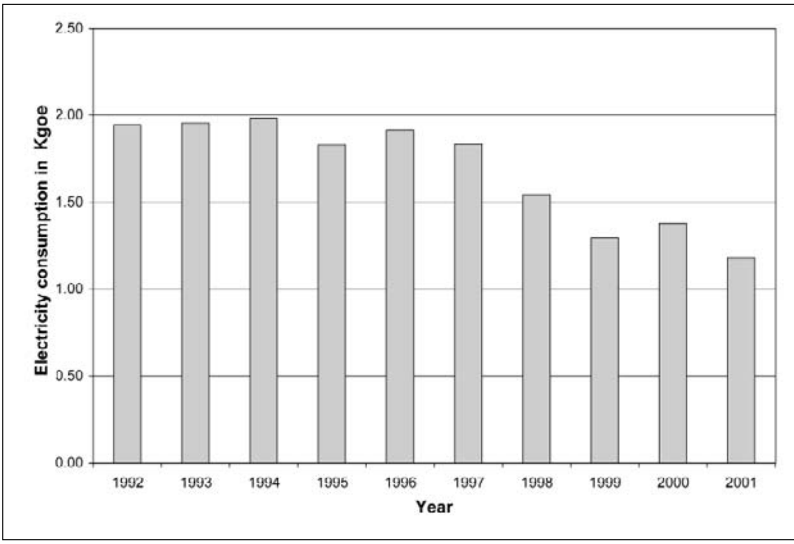
IVA.3.1 Total modern energy consumption (Kgoe) vs GDP (US$) (Modern energy consumption per US$1 of GDP)

Source: AFREPREN 2003



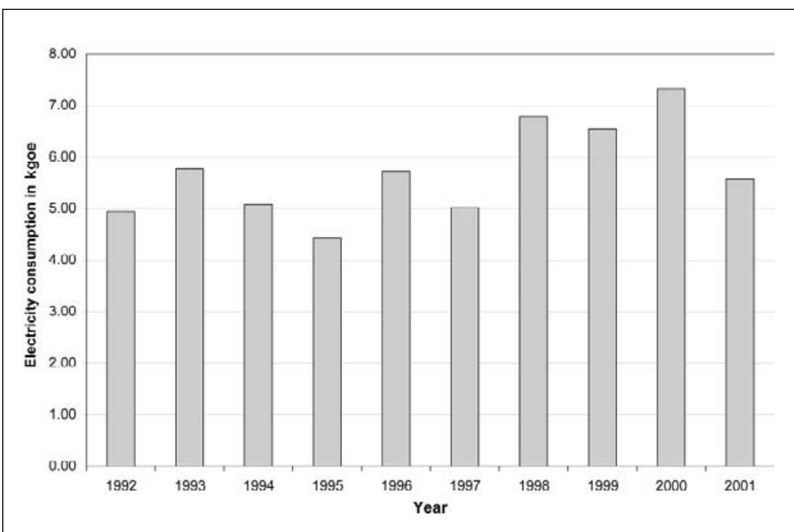
IVA.3.2 Total modern energy consumption (Kgoe) vs merchandise export (US$) (Modern energy consumption per US$ of merchandise export)

Source: AFREPREN 2003



IVA.3.3 Total electricity consumption (Kgoe) vs GDP (US$)
(Electricity consumption per US$ of GDP)

Source: AFREPREN 2003



IVA.3.4 Total electricity consumption (Kgoe) vs merchandise export (US$)
(Electricity consumption per US$ of merchandise export)

Source: AFREPREN 2003

Part V

BOTSWANA

Joseph Mbaiwa

COUNTRY PROFILE

Botswana

SELECTED INDICATORS

Population (millions): 1.7 (2001)
Rural population (% of total): 50.6 (2001)
Land area (km^2): 582,000
Capital city: Gaborone
GDP growth rate (%): 5.80 (2001)
GNP *per capita* (US$): 3,100 (2001)
Official exchange rate: Pula 6.33 = US$1 (June 2003)
Economic activities: Agriculture, manufacturing, mining, construction, and financial services
Energy sources: Biomass, imported petroleum, solar, wind
Installed capacity (MW): 132 (2002)
Electricity generation (GWh): 2,170 (2002)
System losses (%): 9.9 (2002)

Electrification levels (%) (2001):	National:	29
	Urban:	50
	Rural:	8

Biomass consumption as a percentage of total energy (%): 24.4 (2000)
Poverty levels: (1993)
(%) population living below US$1 a day: 23.5
(%) population living below US$2 a day: 50.1

Sources: Ditlhale, 2003; Mbaiwa, 2003; AFREPREN, 2003; EIU, 2003; World Bank, 2003a; World Bank, 2003b; IEA, 2002

10

Background

Botswana is located in Southern Africa and shares borders with South Africa, Namibia, Zambia and Zimbabwe (Figure 10.1). Botswana has a population of about 1.7 million (CSO, 2002). An estimated 50.8 per cent of Botswana's population lived in rural areas in 1999 compared to 80.8 per cent in 1981 (Bank of Botswana, 2000). As in other sub-Saharan African countries, in Botswana much of the modern energy is used in urban areas and less than 10 per cent in rural areas where the majority of the people live (Diphaha, 1992). Rural electrification efforts in Botswana are mostly limited to centralized, grid-based electrification. However, studies in African countries such as Malawi, Zimbabwe, Tanzania and Uganda indicate that energy distribution through a centralized public sector system is mostly inefficient especially in delivery to rural areas, because of factors such as bureaucratic interventions (Bhagavan, 1999). In Botswana, the centralized, grid-based electrification serves 195 out of 410 villages; 215 villages remain unserved (JICA, 2002). There are also 4,903 settlements or small villages, called localities in Botswana, which do not have access to grid electrification. These settlements have a total of 410,000 people and 82,000 households; they constitute 26.7 per cent of Botswana's population (JICA, 2002). According to JICA, there is no hope that these localities will be able to get any form of electrification in the next ten years. As only 3 per cent of the rural households in Botswana have access to electricity (JICA, 2002), there is a need to develop alternative strategies that will promote the delivery of modern energy to rural areas.

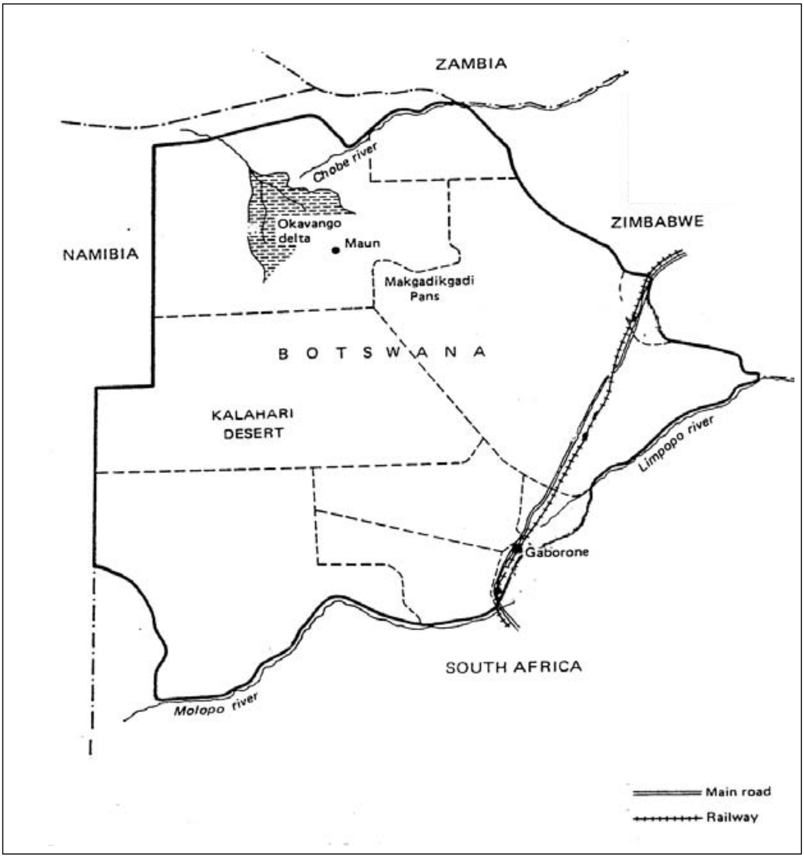


Figure 10.1 Map of Botswana

Source: Mbaiwa, 2003

11

Literature Review

This section provides a summary of the reviewed literature on the production and distribution of modern energy in rural areas in Botswana. The strengths and weaknesses of the literature are pointed out, and the existing gaps in the literature are identified.

Background to the energy sector

The major sources of energy in Botswana are fossil fuels (coal and oil); thermal power from coal; fuelwood; and renewable technologies such as solar and wind energy (Mosimanyana *et al.*, 1995; Zhou and Mhozya 1996; Botswana Government 1991, 1997). Generally, Botswana's energy profile is similar to that of most developing countries, particularly those in the Southern African Development Community (SADC) region (Botswana Government, 1997). Past and current studies show that Botswana's energy profile is dominated by the use of fuelwood (Kgathi 1992; Kgathi *et al.*, 1994; Kgathi and Mlotshwa, 1997; Botswana Government, 1998; Afrane-Okese and Zhou, 2001). Fuelwood has the largest share in total final energy consumption as most of the population still live in rural areas where woodfuel is mostly used (Kgathi *et al.,* 1994; Zhou, 2001). Other sources of energy include coal and petroleum products, while solar energy contributes an insignificant amount when compared with other energy sources in the country (Botswana Government, 1997). Renewable energy sources such as wind and biogas are poorly developed, like solar energy contributing insignificantly to the energy balance of Botswana (Mosimanyana *et al.,* 1995). These different energy sources in Botswana are briefly discussed below.

Coal

Most of the electricity generated in Botswana is thermal and is generated from coal. Coal reserves in the country are estimated to be in the region of 212.8 billion metric tonnes (MMEWA, 1996; Zhou and Mhozya, 1996). Botswana's coal reserves are found in various places, as shown in Table 11.1, although only Morupule's coal reserves are currently being mined and used for electricity generation in the country. Studies have shown that over 95 per cent of the coal supply is locally mined, while the

Table 11.1 Coal resources in Botswana (all figures given in million tonnes)

Coal field	Measured	Indicated	Inferred	Total resources
Morupule	2,864	2,706	12,520	18,090
Mmamabula	4,325	16,394	2,504	23,223
Letlhakeng	0	7,313	4,725	70,353
Ncojane	0	0	1,604	4,725
Dukwi	0	32	1,604	1,636
Mmamantswe	0	0	2,898	2,898
Serule	0	307	9,377	9,684
Dutlwe	0	2,070	69,670	71,740
Foley	0	0	6,860	6,860
Moijabana	0	0	3,054	3,054
Bobonong	0	0	179	179
Total	7,189	28,822	114,995	212,442

Source: MMEWA, 1998

remaining 4 per cent is imported from South Africa (Botswana Government 1991, 1997; MMEWA, 1998).

Petroleum products

Botswana has no oil reserves; as a result, the country's petroleum energy is imported in refined form mainly through South Africa (Botswana Government, 1996, 1997; Mosimanyana *et al.,* 1995). Settlements near the borders with Zimbabwe and Namibia import small additional quantities from these states. Imports are dominated by diesel and petrol, which are both used in the transport sector. In 1990, petrol and diesel constituted about 84 per cent of total petroleum energy imports. On average, liquefied petroleum gas (LPG) and paraffin (mainly for household use) constituted 8.3 per cent, aviation fuels 4.4 per cent, and other lubricants 3.4 per cent of the total (Mosimanyana *et al.*, 1995).

Fuelwood products

Wood biomass loading in Botswana is varied and ranges from 3.6 and 4.3 tonnes per hectare per year for shrub land savannah to 4.8 and 10.6 tonnes per hectare per year for dense forests (ERL, 1985). However, Ostyina and Walker (1990) note that average biomass loading of 15.8 tonnes per hectare per year is the average for south-east Botswana, where most people live.

Renewable energy sources

Apart from fuelwood, Botswana has a few renewable energy sources. These include the following:

SOLAR ENERGY

A study by Mosimanyana *et al.* (1995) revealed that Botswana is endowed with excellent sunshine, receiving 3,000–3,500 hours of sunshine per year and a mean annual insulation of about 2,200 kilowatt hours per square metre. The Manyana Pilot Project (1996), the Photovoltaic Feasibility Study in Manyana, Molepolole and Takatokwane (Zhou and Mhozya, 1996) and the Motshegaletau Power Station Socio-Economic Assessment Study (BIDPA, 2000) all recognized the potential of solar energy as an alternative energy source in most rural areas of Botswana.

WIND ENERGY

Mosimanyana *et al.* (1995) states that wind energy was exploited in Botswana before the country's independence in 1966. It was used mainly for pumping water for agricultural use. However, Mosimanyana *et al.* indicate that Botswana has a poor wind regime. Average annual wind speeds are in the range of 2 to 3.5 metres per second and in low wind speed months the wind blows in the range of 1.5 to 3.0 metres per second. Botswana also lies in a region characterized by high percentages of calm.

Findings from Mosimanyana *et al.* (1995) also note that windpump technology is not widely used in Botswana as only 250 windpumps are installed in the country, mainly for farming purposes around Ghantzi and Borolong areas. These are areas where there is a concurrent occurrence of shallow water tables and comparatively good annual wind speeds. The study revealed that a number of important factors curtail the widespread dissemination of windpumps in Botswana. For example, government policy prevents windpumps being considered for supply of water to the public sector – including mining, major villages, towns, and cities – as these consumers tend to require large quantities of water, which cannot readily be met from windpump operated boreholes (Botswana Government, 1991).

The Mosimanyana *et al.* study further revealed that the Department of Water Affairs became interested in the windmill technology, installing eight windmills in five villages in the 1980s. However, the technology failed because the windmills were poorly sited in the absence of good wind speed information. The windmills did not deliver sufficient water to justify their use in major villages where the water requirements were large. Despite the poor performance of the wind technology in Botswana and the government policy of not putting more emphasis on wind technology, especially to major villages, findings by Mosimanyana *et al.* (1995) indicate that Botswana has about 15,000 boreholes, while Perkins and Ringrose (1996) put the figure at 20,000. Most of these boreholes are owned by individuals and are used for livestock production facilities. Based on this data, Mosimanyana *et al.* recommended that the private sector consumers, mainly the livestock farmers with their limited demand for water, offer the greatest opportunity for the use of the windpumps for water lifting. While these findings offer possible areas for the use of wind energy technology in Botswana, Mosimanyana *et al.* recognize that the technology faces tough competition from the diesel engines used by 85 per cent of the boreholes in the country. The other problem is that private sector involvement in manufacturing and distribution of windpumps in Botswana is nearly non-existent: only one supplier is currently available in the country. This lack of extensive support infrastructure for windpump technology is an important factor inhibiting its uptake.

Traditional energy sources

The main traditional energy source in rural areas of Botswana is fuelwood, as already pointed out in studies by Kgathi (1992); Kgathi *et al.* (1994); Kgathi and Mlotshwa (1997); Zhou (2001); and BIDPA (2000). Biogas, cow dung and crop residues are some of the other traditional energy sources in the country (ERL, 1985; Kgathi, 1992; Kgathi *et al.*, 1994; Mosimanyana *et al.*, 1985; Kgathi and Mlotshwa, 1997). Regarding the use of biogas, Zhou (2001) notes that it is still limited and its use is restricted to a handful of households in rural villages. However, its potential as an energy source in Botswana is very low (BEMP, 1993). While such traditional energy sources exist in Botswana, their use is not as pronounced as that of fuelwood.

The above evidence of high reliance on fuelwood suggests that alternative energy sources are necessary for the relatively poor section of the society living in rural areas. It is necessary for government to review the previous strategies used in the past for extending modern energy to rural areas.

Modern energy (conventional and renewable) sources

Most of the rural energy studies in Botswana, notably by Kgathi (1992); Kgathi *et al.* (1994); Kgathi and Mlotshwa (1997); BIDPA (2000); and Zhou (2001) indicate that kerosene/paraffin, LPG, electricity, candles (considered a modern energy in Botswana) and batteries are some of the modern energy sources used in many rural households. Renewable energy sources in the form of solar, wind and biogas are rarely used. Some of the energy sources include petrol and diesel, which are sometimes used to power generators (BIDPA, 2000; Zhou, 2001).

As already noted, windmill technology is one of the modern energy sources that are available in Botswana. According to Mosimanyana *et al.* (1995), windmills have been used in Botswana ever since the colonial period as a source of energy. The same authors also note that studies on wind energy have been carried out since the 1920s. The data obtained in such studies were of agro-meteorological importance and winds were measured at a height of two metres. Mosimanyana *et al.* state that South African settlers brought the first windmills to Botswana in the early part of this century. The windmills were mostly used for agricultural activities. Mosimanyana *et al.* further note that these first windmills were installed in the freehold farming areas south of Lobatse, along the Molopo River border with South Africa, and in the farming area surrounding Ghantzi.

Current government efforts include the promotion of the use of solar power, especially in rural areas. The Manyana Pilot Project on the use of photovoltaics (PV) and the PV Rural Electrification Feasibility Study in Manyana, Molepolole and Takatokwane (Zhou and Mhozya, 1996) were among other projects and studies designed to find out the use of solar energy in rural areas. Findings of these studies revealed that rural communities in the three villages would like to have modern energy supply in their households and public facilities. In addition to the Manyana Pilot Project and the Rural Feasibility Study, there has been a recent (September 2000) study by the BIDPA (2000) on the same subject at Motshegaletau village in the Central District.

Household energy use patterns in rural areas in Botswana

Zhou (2001) states that rural economic status is mostly determined by the economic activities being conducted in the rural areas. CSO (1995) and Zhou (2001) state that the occupations of rural people include paid employment, self-employment, family businesses, land and cattle posts and housework. These activities determine income levels and the development of modern energy in rural areas. According to the Botswana Government (1997), the majority of the rural poor and the low-income groups in rural areas have been shown to be incapable of affording the initial costs of wiring or buying material for electricity provision, even in areas where electricity is available (BIDPA, 2000). The government recognizes this fact and notes that despite the massive rural electrification campaign, the use of electricity in most households has not been successful. This means most rural households have been unable to have electricity connections in their households (Botswana Government, 1997).

Recent studies indicate that rural households in Botswana use more than one fuel to meet their energy needs (BEMP, 1996; Zhou, 2001). Some of the fuels that are used include fuelwood, paraffin, LPG, electricity, candles, coal, cow dung, crop residues and renewable technologies. Table 11.2 shows the proportions of households using some of the energy fuels/sources in Botswana.

Energy in rural areas of Botswana is used for various purposes, including cooking, lighting, water heating, space heating and cooling, beer brewing and ironing (BEMP, 1996; Kgathi and Mlotshwa, 1997; Zhou, 2001). Rural households tend to use a combination of fuels for various purposes. For example, Zhou (2001) found that 28.2 per cent of the rural households in Botswana use fuelwood and LPG for cooking. However, the BEMP (1996) study and the Rural Energy Needs and Requirements in Botswana study by Zhou (2001) note that fuelwood dominates energy consumption in rural areas at the domestic level. It is mainly used for cooking and for water and space heating. The EECG/ADB (1995) study showed that paraffin is considered the main fuel used for

Table 11.2 Proportions of households (HHs) using various energy fuels/sources

Fuel/source	% of National HHs	% of Urban HHs	% of Rural HHs	Monthly expenditure (US$ – urban)	Monthly expenditure (US$ – rural)
Fuelwood	93.5	55	90	7	2.936–3.57
LPG	2.1	45	4	12.83	7.93
Paraffin	2.1	70	90	2.31	2.08
Electricity	2.0	24	3	27.3	14.72
Candles*	–	19	50	6.3	5.4
Coal	0.2	2	–	–	–
RETs	0.1	3**	–	–	–

Source: BEMP (1996) as cited by Zhou (2001)
* Considered a modern energy in Botswana
** These are mainly solar water heaters in houses

lighting by 90 per cent of the households in rural villages but has limited uses for cooking. The BEMP (1996) study found that very few households (4 per cent) use LPG in rural areas and it is used for cooking and rarely for lighting. Households in urban areas use about 3 per cent of the RETs, mainly solar water heaters in houses. The Botswana Housing Corporation (a parastatal company that enjoys a monopoly in building and provision of houses in urban areas in Botswana) has until recently been constructing houses with solar water heaters.

Using data from the Household Income and Expenditure Surveys and the country's Population Census of 1991, the Central Statistics Office (CSO) broke down information on rural energy use and the type of fuel used for specific purposes, as shown in Tables 11.3 and 11.4 respectively. Table 11.3 shows that firewood was the dominant fuel used for cooking in most rural households in 1985/6, 1991 and 1993/4. However, findings indicate that while firewood remains the main source of energy used in rural areas, the percentage of households using it has been in decline, while the use of gas and electricity has increased over the same period.

Table 11.3 Main source of fuel for cooking (% of households using fuel)

Fuel	1985/6[a]	1991[b]	1993/4[c]
Electricity	2.1	2.7	3.7
Gas	10.7	21.7	28.6
Paraffin	6.8	10.7	9.1
Firewood	80.1	64.3	58.5
Other	0.4	0.6	0.1

Source: CSO, 1995
a 1985/6 Household Income and Expenditure Survey
b 1991 Population and Housing Census
c 1993/4 Households Income and Expenditure Survey

Table 11.4 Main source of fuel for lighting (% of households using fuel)

Fuel	1985/6[a]	1991[b]	1993/4[c]
Electricity	7.5	10.1	11.5
Paraffin	58.5	64.5	71.5
Candles	14.2	11.8	5.7
Other	19.8	13.6	11.3

Source: CSO, 1995
a 1985/6 Household Income and Expenditure Survey
b 1991 Population and Housing Census
c 1993/4 Households Income and Expenditure Survey

Table 11.4 shows that paraffin was the dominant fuel used for lighting in the same period. While paraffin remains the major fuel used for lighting in rural areas, the percentage of households using electricity has been increasing.

The above information from the CSO (1995) is in line with the findings of EECG/ADB (1995); BEMP (1996); Kgathi and Mlotshwa (1997) and Zhou (2001). For example, Zhou (2001) found that about 91.5 per cent of the rural households in Botswana use fuelwood for cooking, while 84 per cent use paraffin for lighting. Coal as an energy source is hardly used in rural areas in both households and other sectors (*ibid.*), but efforts are under way to promote its use, particularly in government institutions to substitute fuelwood for cooking (MMEWA, 1999).

Household energy supply

The Energy Resource Limited study (ERL, 1985) evaluated fuelwood consumption as a dominant fuel in rural areas. The main objective was to provide quantitative and qualitative information on future energy supply and demand trends, as well as on the existing situation, to enable government to take the necessary steps at an early stage for developing and managing future energy resources. This study covered the whole of eastern Botswana and it noted that biomass in the sparse vegetation class is dominant in the region, followed by low woodland and mid-density woodland.

The ERL study was followed by a regional study by the Energy Technology Centre (ETC) for SADC (1987). This study determined fuelwood supply and demand for the SADC region, including Botswana. It was based on the analysis of satellite imagery supported by a review of available information from studies carried out previously in the country and in the region (Kgathi *et al.*, 1997). Findings from these studies have shown that the availability of fuelwood in the region is actually declining, and that Botswana is affected. This suggests that current studies should focus on alternative energy sources for rural areas.

In an attempt to make modern energy available in rural areas, the government adopted the Rural Electrification Programme (REP) in 1975. This scheme was further improved by the adoption of the Rural Electrification Collective Scheme (RCS) in the 1990s. The RCS involved the connection of villages currently being served by isolated generators to the national electric grid (Diphaha, 1992; Botswana Government). Despite government promotional initiatives, communities are largely ignoring the Rural Electrification Scheme (Botswana Government, 1997). This is because the initial costs of connection are generally not affordable by the majority of the rural people. In an attempt to make the rural electrification scheme work, government decided to spread the period of payment for connection over 10 years. Even after this encouragement, however, the total uptake of electricity by households has remained at low levels (24 per cent in urban areas and 3 per cent in rural areas) (Ramasedi, 1992; Botswana Government, 1997). The low village population densities, and their spread over a wide area, make it difficult for the rural communities to group themselves to take advantage of the RCS. Furthermore, low incomes in the rural areas and low cost in urban areas limit the ability of the people to take advantage of high quality electricity supplies on a cost recovery basis (Botswana Government, 1997). What emerges from the literature on modern energy in Botswana is that supply is largely centralized. This approach has so far resulted in a low electrification of rural areas. This suggests that other energy distribution options such as the decentralized approach should be explored to find out whether they are better placed to promote rural electrification.

Government participation in the promotion of modern renewable energy in Botswana is fairly limited. Attempts have so far been left to non-governmental organizations and parastatal companies such as the Rural Industries Innovation Centre (RIIC). Such attempts are through pilot projects that emphasize the use of solar energy at Manyana village in the southern part of the country and at Motshegaletau. The Manyana Pilot Project was launched in 1992. As one of its main objectives, the project aimed at determining the social accessibility and economic viability of PV systems and solar heaters in a village setting. PV electrification is intended to complement grid electrification (Botswana Government, 1997).

Rural household energy use and supply patterns in Botswana indicate that fuelwood is likely to continue dominating energy demands in the country in the foreseeable future. Although other modern energy sources such as paraffin, candles, gas (LPG) and batteries have been introduced in rural areas, such sources are expensive (BIDPA, 2000), so that households prefer to stick to or switch to cheaper fuels such as firewood. In villages where photovoltaic energy has been provided, such as Motshegaletau, only a few households (2 per cent) have been able to use it (as already indicated in the BIDPA, 2000 study). These findings show that targeting rural households as end users of modern renewable energy has so far been unsuccessful in Botswana – and points to the need to investigate whether adopting other targets – such as income-generating activities – will not yield better results in the production and distribution of modern energy in rural areas.

Energy use in rural small and medium-sized enterprises in Botswana

A few studies such as Groth *et al*. (1992), Kgathi and Mlotshwa (1997) and Zhou (2001) briefly touched on energy use patterns and supply for small-scale rural industries. However, all three studies were limited to identifying some of the enterprises typically involved and the use of fuelwood in such areas. For example, Groth *et al*. identified three major groups of rural industries in Botswana: sorghum mills, bakeries and crafts.

The same studies noted that commercial enterprises, government institutions and agricultural businesses in rural areas use similar energy fuels/sources to those used in households, though the proportions of sectors using the fuels and the end users vary. Fuelwood is used for commercial purposes like bread baking and beer brewing at household level. Government institutions and commercial businesses also use fuelwood for cooking (Zhou, 2001). Kgathi and Mlotshwa (1997) state that about 87 per cent of the institutions and small-scale industries in Molepolole and Khakhea use fuelwood for cooking purposes, as well as for space heating and other purposes such as roasting meat in barbecues and burning waste in hospitals.

Small and medium-sized energy supply in Botswana

What emerges from these studies is that the use of modern energy for commercial purposes in rural areas is generally low or non-existent. Most of the small-scale industries in rural areas still depend on fuelwood to meet their energy demands. It is yet to be established how modern energy, especially RETs, can be made available in rural areas for income-generating purposes. The lack of modern energy in small-scale industries in rural areas also suggests that rural energy research should focus on the role that income-generating activities could play in the production and distribution of modern renewable energy. As already noted, the situation in Botswana is such that government ministries and parastatal organizations (such as the Botswana Power Corporation) involved in the promotion of modern energy to rural areas have so far made little headway in the production and distribution of energy in rural areas. Research, therefore, should also focus on the ability of decentralized and private sector initiatives in the production and distribution of modern energy to rural households and for income-generating purposes.

Rural energy policy in Botswana

Research and data on energy planning and management in Botswana has been collected in the three phases of the Botswana Energy Management Plan (BEMP) (Zhou, 2001). The first phase of the BEMP (1987) sought to collect data on energy resources, energy technologies, and energy supply and demand, and to set up a database for energy planning. The second phase (1992/3) developed and refined the planning data and appraised projects in order to provide recommendations for energy policy. The third and final phase (1996) consolidated Botswana's Energy Policy within the institutional realities of the country (*ibid.*). As a result of these developments in energy research and development in the country, Botswana finally had her first Energy Policy in 1998.

Kgathi *et al.* (1994) note that Botswana's energy policy is based on the premise that market forces are not adequate for the allocation of resources in the energy sector. This is based on three main reasons.

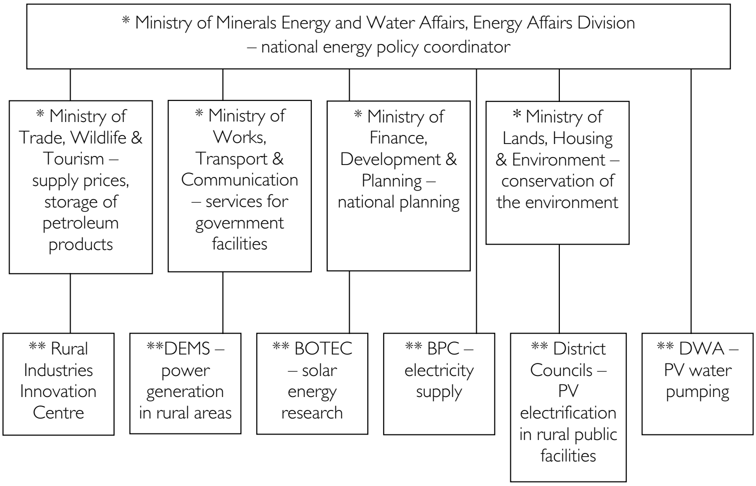
- Increased wood energy scarcity leads to environmental degradation and increased economic pressure on poor households.
- There is a need to take into consideration the potential for economic development of indigenous sources of energy as well as the strategic importance of certain energy sources.
- Botswana has a high dependence on imported energy (electricity and oil) and this makes the economy vulnerable (Botswana Government, 1985).

Botswana should aim at reducing the foreign exchange costs of imported energy as well as the economic and social costs associated with fuelwood.

From the available literature, it has been noted that Botswana has policies and programmes designed to promote the production and distribution of modern energy to rural areas. These programmes include the Rural Electrification Programme and the National Photovoltaic Electrification Programme. It nevertheless appears that greater emphasis is placed on modern non-renewable energy sources than on the promotion of renewable energy production in rural areas. This bias is perpetuated by the assumption that, in the context of Botswana's overall energy requirements, renewable energy technologies have only a limited contribution to make – despite optimistic assertions about their viability (Mosimanyana *et al.*, 1995). This view of RETs and conflicting policy plans on the production and distribution of modern energy to rural areas point to an information gap on energy for rural areas in Botswana.

Rural energy institutions in Botswana

The production and distribution of modern energy in Botswana is the responsibility of several institutions (Figure 11.1).



Source: UNICO International Corporation (2001).
* Supervisory institutions
** Implementing bodies
DEMS – Department of Electrical and Mechanical Services
BOTEC – Botswana Technology Centre
BPC – Botswana Power Corporation
DWA – Department of Water Affairs

Figure 11.1 Major energy institutions in Botswana

The Energy Affairs Division in the Ministry of Minerals, Energy and Water affairs (MMEWA) is the main energy institution in Botswana. The MMEWA is responsible for formulating, directing and coordinating national energy policy through the Energy Affairs Division (MMEWA, 1999). Energy studies to guide policy are commissioned by the Division (Zhou *et al.*, 1999). Although the overall production, distribution and management of energy issues is entrusted to the MMEWA, it shares implementation of energy programmes with other ministries, parastatals and NGOs. For example, the Botswana Power Corporation (BPC), a parastatal under the MMEWA, is responsible for electricity generation, transmission and distribution to the general public, supplying electricity to households, institutions and industries (MMEWA, 1999; Kgathi *et al,* 1997).

Other implementing institutions include the Ministry of Agriculture through its Crop Production and Forestry Department, responsible for forest and biomass management; the Ministry of Lands, Housing and Environment through the National Conservation Strategy Agency, responsible for conservation and environmental issues; the Ministry of

Works, Transport and Telecommunications through the Department of Electrical and Mechanical Services, responsible for the provision of power (by stand-alone diesel gensets and centralized power supply systems) to government institutions in rural areas where grid power is not economically viable for connections through the BPC; the Rural Industries Innovation Centre, responsible for developing tests and disseminating renewable energy technologies; the Botswana Technology Centre, responsible for research and information dissemination mainly on solar energy; and, finally, oil companies, responsible for purchasing and distributing petroleum products for commercial use as well as the management of government strategic reserves (MMEWA, 1999).

While Botswana has such energy institutions and policies in place, Kgathi *et al.* (1994) state that the current energy institutional framework is inadequate to cope with the management of the energy sector in Botswana. On the same note, there has been no study done to determine the main institutional arrangements and policies relevant to the production and distribution of modern renewable energy to income-generating activities and rural households in the country. There are only general strategies and programmes for rural energy development (such as the Rural Electrification Programme, established in 1975) implemented by either the BPC or the RIIC in Kanye.

Rural energy use in Africa: the case of Southern Africa

African countries generally use thermal and hydroelectric power. For example, Bassey (1992) notes that energy supplies in urban areas of countries in West and Central Africa are in the form of diesel and electricity generated from hydropower. Although hydropower is renewable and is generally used in some West and Central African states, its use in East and Southern Africa is fairly limited. Karekezi (1994) notes that, with the exception of biomass, renewable energy is presently a minor contributor to energy supply in East and Southern Africa, accounting for less than 2 per cent of the total supply. Lack of modern renewable energy in East and Southern Africa suggests a need to explore the potential of renewable energy sources and supply in the region.

The modern energy generated by African countries is generally used in mining activities, industrial sectors, urban households, and private and government buildings (Bassey, 1992). Although African countries have been able to produce modern energy to support economic development, most of it is used in urban areas. As a result, the majority of the rural communities are provided with little or no modern power supply. Bassey (1992) and Diphaha (1992) indicate that less than 10 per cent of the electricity generated in most African countries is used in rural areas where 80 per cent of the populations live. The shortage of energy in rural areas has left people living in these areas trapped in subsistence-level economies characterized by inefficient use of non-commercial energy, low agricultural productivity and poor standards of living (Best, 1992). It has led to the increased dependence on fuelwood by rural communities in order to meet their energy demands (Kgathi, 1992; Mosimanyana *et al.*, 1995). Zhou (2001) notes that rural fuelwood consumers mainly depend on collecting dead wood, but fuelwood scarcity may cause consumers to resort to cutting live trees – a scenario that Sekhwela (1997) confirms to be accurate in areas around rural settlements such as Molepolole. The cutting down of live trees for fuelwood has contributed to deforestation, even though it is acknowledged that the major cause of deforestation (95 per cent) is the extension of agricultural activities into wooded areas (Sekhwela, 1997). The depletion of wood resources in Botswana has actually become one of the major environmental concerns in the country (Botswana Government, 1990; Diphaha, 1992).

Best (1992) states that the shortage of modern energy in developing countries, especially in rural areas, is linked to inadequate policy and programmes. Policies and legislation are often government tools to stimulate rural commercial energy demand. Government can also encourage energy consumption through investment programmes such as rural electrification schemes, which often operate at financial loss until increasing demand can pay for the investment (Best, 1992). This suggests that African countries should identify ways that have the potential of promoting energy sources that might be readily available and affordable in rural areas. Solar energy sources are renewable and are said to be appropriate in rural areas of countries such as Botswana (Botswana Government, 1991, 1997). RETs have a large utility potential in agricultural, fisheries and forestry activities (Best, 1992). African countries have not yet taken advantage of these economic activities to promote the use of modern energy in rural areas. Research on energy supply in rural areas needs to assess the extent to which income-generating activities can promote the production and distribution of modern energy to rural areas.

Gaps in existing literature

In summary, it is important to underline the significant issues emerging from the reviewed literature – and also to identify some of the existing gaps.

1 As in most African states, modern energy used in Botswana is non-renewable; in this case, it is derived from coal. Most of this energy is used in urban areas with a small amount (10 per cent) being used in rural areas where the majority (80 per cent) of the people live (Diphaha, 1992). The lack of modern energy in rural areas has resulted in the rural communities relying more on fuelwood for their energy

needs. The dependence on fuelwood has led to increased pressure on and scarcity of wood resources, especially around rural settlements. This prospect of depletion has become a major environmental concern for Botswana (Botswana Government, 1997). The reviewed literature indicates that the production and distribution of modern energy in Botswana is centralized and mainly delivered by government-controlled parastatal organizations such as the BPC. Such initiatives have had few positive results, however – least of all in rural areas, where only 3 per cent of households receive an electricity supply (Botswana Government, 1997) despite the fact that the Rural Electrification Programme, implemented by the BPC, has been in place since 1975. Yet no study has been carried out so far to establish the limitations of public sector initiatives, centralized or decentralized, in the production and distribution of modern energy to rural areas. Related to this research gap is that of whether a decentralized private sector initiative is likely to deliver more efficient production and distribution of modern energy to households and income-generating activities in rural areas.

2 Best (1992) notes that RETs have a large utility potential in agricultural, fishery and forestry activities. What this suggests is that income-generating activities in rural areas have the potential to promote the delivery of modern energy to rural areas. The available literature (Groth *et al.*, 1992, for example) indicates that small-scale industries found in rural areas in Botswana include sorghum mills, crafts and bakeries. The literature also shows that the majority of these small-scale industries do not have modern energy and therefore use fuelwood to meet their energy demands (Groth *et al.*, 1992; Kgathi and Mlotshwa, 1997; Zhou, 2001). It has also been shown that initiatives in the promotion of modern energy in rural areas mainly target households – with a very low rate of success, partly because rural households cannot afford the initial costs of electric wiring or buying electrical wiring equipment (Botswana Government, 1998; BIDPA, 2000). Yet, again, no study has so far been conducted to establish the likely rate of success if the focus of promoting modern energy production and distribution in rural areas were to be shifted from households to income-generating activities.

3 Existing studies (UNICO International Corporation, 2001, for example) confirm that the distribution of electricity to rural areas through the national electric grid and through the Rural Electrification Programme has not achieved much in more than 26 years of existence. In response, previous studies have recommended the use of new and renewable sources of energy (NRSE) as an alternative form of modern energy for rural areas in Botswana. The limitations of these studies are that they are generic in nature (addressing the potential role of *specific* renewable technologies rather than the broad range of available RETs)

and do not explain the role of income-generating activities in promoting RETs in rural areas. Nor do they identify existing and potential components of RETs that are critical and need more attention than others in the delivery of such technologies for income-generating activities in rural areas. Clearly research is needed to address these problems if the distribution of RETs in rural areas in Botswana is to be achieved.

12

Study Findings and Conclusions

The primary objective of the medium-term study was to investigate the distribution of modern energy in rural areas with particular reference to Botswana. Findings for the three hypotheses are presented in this chapter.

Hypothesis 1: Decentralized private sector vs centralized public sector energy initiatives

Decentralized, private sector energy production and distribution have a better rate of success than centralized public sector initiatives in delivering modern energy to rural households and for income-generating activities.

This hypothesis suggests that decentralized private sector energy production systems are better than centralized public sector systems in the production and distribution of modern energy in rural areas. In trying to understand the energy distribution in Botswana, it is important first to understand the energy demand and supply in the country in an attempt to analyze the effectiveness of the centralised and decentralized institutions in delivering modern energy to rural households and income-generating activities.

Current energy supply and demand

In an attempt to address this hypothesis, an analysis of the latest available energy balance for Botswana is made. This exercise is important for this hypothesis as the flow of energy from origin, through transformation to final use in Botswana is investigated. From this, sources of energy, supplies and final consumption can be traced to determine which form of energy is actually reaching the rural population and how this energy is made available. The efficiency of each energy supply system – centralized and decentralized – will be evident as one traces the energy route. This analysis can provide an insight into the most efficient system of energy supply to rural areas. To investigate that, the 1997/8 energy balance as depicted by the Ministry of Mineral Energy and Water Affairs (Figures 12.1, 12.2), was considered (MMEWA, 2000).

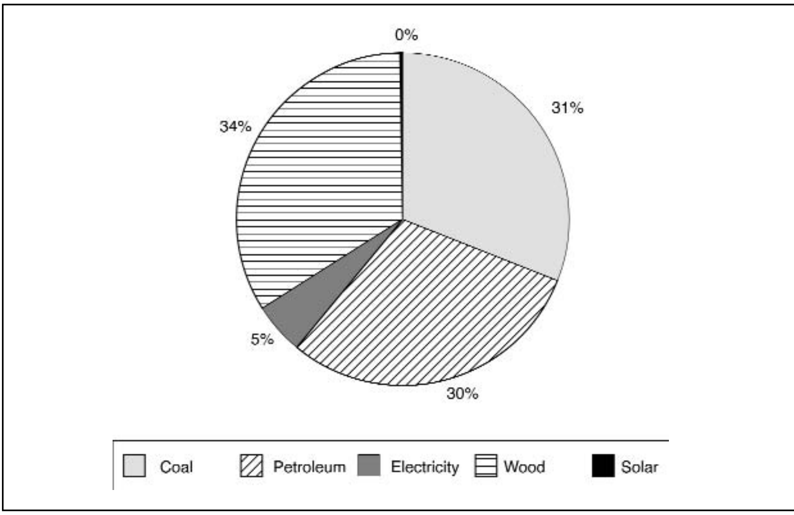


Figure 12.1 Primary energy supply 1997/8

Source: MMEWA, 2000

Figure 12.1 shows that the major source of energy supplied in Botswana is fuelwood, which contributed 34 per cent of the total primary energy supplied, followed by coal (31 per cent), petroleum (30 per cent), electricity (5 per cent) and solar energy, which contributed an insignificant amount of less than 0.2 per cent in 1997/8. As noted earlier, fuelwood is mainly used in rural areas where the majority of the people of Botswana live.

Final energy demand

During the 1997/8 financial year, the major consumers were residential (consuming mostly firewood), transport (mainly petrol) and industry (mainly coal and electricity), in that order. The energy demand pattern reflects the socio-economic structure of the country. As shown in Figure 12.2, the major consumers were the residential sector (43 per cent), which mostly used fuelwood, especially in the rural areas where most people live. Fuelwood is also used in government institutions and small and medium-sized commercial enterprises. Medium and high-income householders, most of whom live in urban centres, mainly use LPG and electricity for cooking and lighting. In rural areas, where fuelwood is mostly used, the degree of commercialization is very low, partly because fuelwood cannot support commercial enterprise on a larger scale. As a result, there are very few commercial activities in rural areas, as we have seen. The transport sector is the second largest energy consumer, using 23 per cent

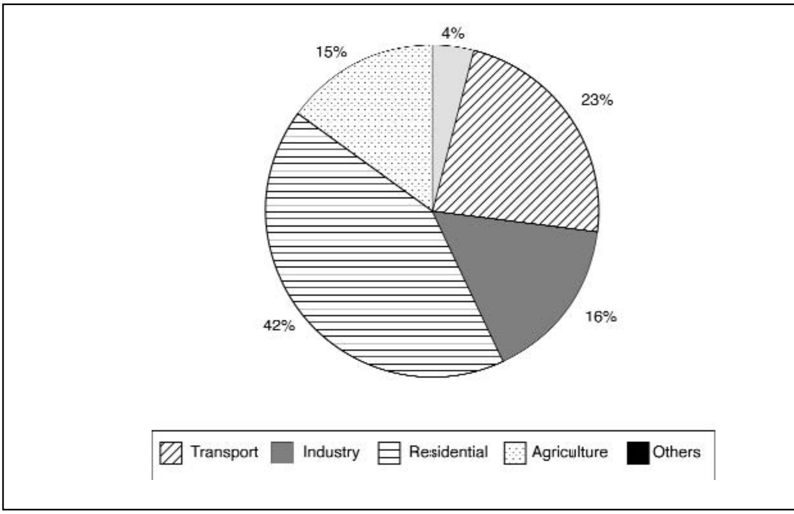


Figure 12.2 Final energy demand 1997/8

Source: MMEWA, 2000

of the total energy demand in the 1997/8 financial year (consuming mostly petroleum products).

The above energy balance indicates a significant use of petroleum products in Botswana. This cannot be attributed solely to their use in transportation. There is evidence that a substantial consumption of petroleum products is taking place in the rural areas – especially paraffin, candles and LPG. Petroleum products, and coal to a certain extent, are mainly supplied by private companies. Private companies such as British Petroleum, Engen, Shell, Total and Caltex supply petrol, paraffin, diesel and gas. Grid electricity, supplied by the centrally controlled parastatal BPC, is not yet adequately available in the rural areas.

Although care must be taken not to rush to conclusions, evidence does seem to be emerging that the private sector's method of distribution and production of energy sources is penetrating the rural areas more significantly than the centrally controlled one.

Modern energy distribution

We need to look at this increasing penetration of rural areas by the private sector in the context of the rural balance of energy consumption. Energy sources that are used in rural areas in Botswana include fuelwood, kerosene/paraffin, LPG and, to a smaller extent, crop residues and cow dung. Renewable energy sources, in the form of solar, wind and biogas, are in evidence but not widely used. Table 12.1 shows various fuel use

Table 12.1 Main cooking and lighting fuel use trends in urban towns and villages in Botswana (%), 1985–2000

	Cooking				Lighting				
Urban towns									
	Elec	Gas	Paraffin	Wood	Elec	Gas	Paraffin	Candles	Other
85/86	7	33	24	35	24	0	47	28	1
1991	8	46	28	18	26	0	56	16	2
93/94	11	50	22	16	27	0	58	0	14
2000	14	81	4	2	66	1	30	3	0
Urban villages									
85/86	2	11	2	86	8	0	78	11	3
1991	1	24	8	67	8	0	78	11	3
93/94	1	34	7	58	10	0	80	1	9
2000	2	59	5	35	29	1	64	6	0

Source: CSO (1995, 1999), as cited in Afrane-Okese and Zhou, 2001

trends, prevalent in both urban and rural households, reflecting the transition in the energy use patterns. The fuels shown in Table 12.1 are those mainly used for cooking and lighting in households.

Table 12.1 indicates that there has been a marked increase in the use of LPG as the main household cooking fuel from 1985 to 2000. Although there has been an increase in the use of electricity in urban villages, much of it is used in public institutions and only the elites have managed connections. Table 12.2 gives a detailed picture of the extent of use of the various energy sources as main sources for specific end uses in urban and rural areas.

As shown in Table 12.2 Afrane-Okese and Zhou (2001) found that fuelwood was the main cooking fuel for 78 per cent of the rural households, followed by LPG as a main fuel for 21 per cent of the households. Fuelwood and gas are the main fuels used for cooking, with totals of nearly 92 per cent and 44 per cent of the households respectively. Fuelwood and gas are also dominant for water heating and ironing for up to 89 per cent and 26 per cent of the rural households respectively. Afrane-Okese and Zhou further indicate that, for lighting in rural areas, paraffin was used alone by 29 per cent of the households but in combination with candles by 38 per cent. Paraffin was the main lighting fuel for 75 per cent of the rural households and candles are a back-up fuel for nearly 70 per cent of the households. While electricity is a popular energy source for lighting, the extent of use is limited by connectivity, which explains why only 11 per cent are using it.

From the above findings, it can be concluded that paraffin, gas and candles are some of the major modern energy fuels used in households in rural areas in Botswana. These fuels are distributed by the decentralized private sector. This shows that the private sector has a better delivery

Table 12.2 Percentage of households using specific energy sources as main sources for specific end uses in urban and rural Botswana

	Subsector	Elec.	Gas	Paraffin	Wood	Solar	Candles	Cow dung
Cooking	Towns	13.5	80.6	3.6	2.4			
	Villages	1.7	59.9	4.8	33.5			
	All urban	8.1	71.2	4.1	16.5			
	Rural	0.7	21.3	2.7	78.0	1.3		0.7
Lighting	Towns	57.3	0.6	39.7			2.1	
	Villages	29.5	0.6	63.6			6.1	
	All urban	46.0	0.6	49.4			3.7	
	Rural	10.8	2.5	75.3			4.3	
Water heating	Towns	30.3	40.0	9.9	9.2	10.6	21.1	
	Villages	6.6	24.5	4.4	58.4	6.1		
	All urban	19.1	32.5	7.3	31.6	8.4		
	Rural	1.1	11.4	2.7	83.0	0.2		
Space heating	Towns	35.2	1.6	1.9	5.1			
	Villages	12.6	1.6	0.5	48.5			
	All urban	24.8	1.6	1.3	25.1			
	Rural	1.3	0.9	0.4	44.5			
Space cooling	Towns	39.0						
	Villages	16.0						
	All urban	28.6						
	Rural	1.3						
Refrigeration (50% own it)	Towns	94.1	5.6	0.3				
	Villages	85.7	13.4	0.9				
	All urban	85.7	13.4	0.9				
Ironing (95% urban hhs have irons)	Towns	61.2	28.8	6.4	1.7			
	Villages	26.1	23.8	4.0	41.6			
	All urban	45.2	26.5	5.3	19.8			
	Rural	4.5	11.4	3.0	67.0	0.2		
Beer brewing	Rural	0.2	0.4	16.0				

Source: CSO (1995, 1999), as cited in Afrane-Okese and Zhou, 2001

approach in distributing modern energy fuels to rural areas. It can be assumed that the production and distribution of electricity to rural areas is likely to be efficient if carried out by the private sector.

The distribution of energy devices in the agricultural sector

The distribution and number of energy devices in Botswana's agricultural sector can be used to indicate the level of efficiency of the decentralized private sector in providing modern energy in rural areas. Energy use in the agricultural sector is mainly for water lifting for livestock and, to some extent, for irrigation. Table 12.3 shows the number of water-lifting technologies in Botswana. Diesel engines are widely used for water pumping, while a significant number of windmills have also been installed throughout the country. An estimated 15,000 boreholes have been drilled for agricultural purposes in Botswana, of which 90 per cent are privately owned (Mosimanyana *et al.*, 1995).

Table 12.3 shows that the private sector has been able to provide modern energy water-lifting devices and petroleum products such as diesel to agricultural consumers in rural areas. In addition to this achievement, the private sector also readily supplies diesel for about 5,900 tractors, mainly used for ploughing and transport in Botswana.

Table 12.3 Water-lifting technologies in Botswana

Technology	Estimated number
Windmill	250
Diesel	5,000*
Electricity	100
Solar	>70
Biogas	5
Hand pump	45
Animal-driven pump	5

* includes domestic use
Source: Zhou, 1995

Performance of the centralized grid system

While the private sector has managed to provide and distribute modern energy in rural areas, the centralized public sector have not achieved much success in providing electricity in rural areas through the national grid and the Rural Electrification Programme. By 2000, it was estimated that about 80 per cent of the rural households were still not connected to the national electric grid. Botswana's Rural Electrification Programme, started in 1975, is the main programme designed to promote rural electrification through the national electric grid in Botswana. This programme was targeted at major villages and rural electrification was generally the responsibility of the BPC. But as Table 12.4 indicates, only a total of 106 major villages across all the nine districts in Botswana were electrified by 1999, after almost a quarter-century of the Rural Electrification Programme.

In an attempt to increase the delivery of modern energy through the grid system in rural areas, government adopted the Rural Electrification Collective Scheme (RECS) in the 1990s. The scheme is administered by BPC's Commercial Department. The RECS involves the connection to the national electric grid of villages currently served by isolated generators. The scheme required potential consumers to form groups of at least four consumers within the vicinity of the village. At the initial stage, each member of the group was expected to contribute 10 per cent as down

Table 12.4 Number of electrified rural villages by districts, 1999

District	No. of villages	% of village
Central	35	26
Kgalagadi	8	23
Kgatleng	15	79
Kweneng	13	36
North East	12	38
North West	6	13
South East	5	100
Southern	12	17
Totals	106	

Source: MMEWA, 1999

payment; the remaining 90 per cent is loaned to the individual by government, which requires the individual to repay the loan over a ten-year period at interest of 9 per cent. However, the poor performance of the scheme, shown by the low rates of connection, led government to revisit it in 2000. It was decided to reduce the down payment from 10 to 5 per cent; the remaining 95 per cent is contributed by government, with the member having to repay over a 15-year period at an interest rate 1 per cent below prime. The new scheme does not require group formation and calls for a standard charge for all consumers within 500 metres of the distribution point.

The cumulative government expenditure on the RECS from its introduction in 1990/1 to December 1997 amounted to P(ula) 34,321,057 (US$5,720,176), which is an annual average of P4.9 million (US$81,667) for seven years (Zhou *et al.*, 1999). Despite the huge amount of money that government has so far spent on the scheme, it has not performed as expected. Table 12.5 shows that by the end of 1999 no more than 11,185 consumers in rural areas had benefited from the RECS and were connected to a source of modern electricity.

Findings indicate that, despite government initiatives in the promotion of rural electrification, rural communities are not taking advantage of the Rural Electrification Scheme (Botswana Government, 1999). This is because the initial costs of connection are generally not affordable for the majority of rural people. Despite terms of payment spread over a long period of time with government help, the total uptake of electricity by households has remained at the low level of 8 per cent. This means that the RECS, though highly commercialized, is failing to achieve the intended goals. Factors that contribute to the poor performance of the RECS include low income levels in rural areas. Rural householders who have been connected have incomes above those of the majority of the rural dwellers and comparable to those of urban dwellers. This means that although the RECS was intended to assist the majority of rural people with modern energy, it has benefited mostly the rural affluent and urban

Table 12.5 Number of schemes/consumers connected to the national grid, 1999

Year	No. of schemes	No. of consumers
1995	266	1,964
1996	350	2,924
1997	499	4,494
1998/9	1,016	11,185

Source: Energy Affairs Division (EAD), 1999

dwellers (most elites in Botswana have four homes: one in urban areas, another in their home villages and the last two at the cattle post and crop fields). This only serves to increase social stratification in the villages, and also benefits major villages more than small ones.

The RECS fails to consider the population dynamics that exist in Botswana: this is demonstrated by the fact that the BPC treats rural customers of different income levels on a similar basis and also operates on a commercial basis in order to sustain its operations. In this regard, BPC is operating both as a government agent and as private company. Because it has no obligation to provide electricity where it cannot make profits, it fails to provide power to most rural areas, where profits are not viable. The current BPC approach has resulted in the national grid being concentrated in the eastern parts of Botswana where most people live. Few of the rural centres in western Botswana have a modern energy supply.

Poor rural electrification in Botswana is also a result of low village population densities spread over a wide area, making it difficult for rural communities to group themselves to take advantage of the RECS or for BPC to invest in them, as they are not considered economically viable. Zhou (2001) notes that Botswana, like most of the region's countries, has low household connectivity to grid electricity due to limited household incomes. Connectivity to grid electricity for the total rural population was estimated at 6 per cent in BPC consumer data for December 2000, emphasizing again the inefficiency of the centralized public sector in delivering modern energy to rural areas when compared to the decentralized sector.

The Ghanzi and Maun case studies

The Ghanzi case study – the Botswana government supplied electricity through the Department of Mechanical Services (DEMS) in the Ministry of Works, Transport and Communication until 1996 – provides further insights into the comparative efficiency of the centralized and decentralized modern energy sectors. In Ghanzi government privatized modern energy distribution to Barlows Power Systems (BPS), an agent of the Botswana Earthmoving Machinery Company (BEMCO), in 1996. At the time of the handover in 1996, the Ghanzi power station consisted of three generator sets and two 500 kVA step-up transformers to 11 kVA. Three years after BPS took over, demand for electricity in Ghanzi was noted as high. As a result, in 1999 BPS and BEMCO installed three 1,000 kVA caterpillar diesel-generating sets and two 11 kV/400 V step-up transformers rated at 1,600 kVA each. Findings also indicate that there has been a steady growth in energy consumption since 1996. The maximum monthly demand for July 1996 was 810 kW; this increased to 930 kW in June 1999 (BPC, 2000). The growth of electricity consumption in Ghanzi was high, with average annual increases for 1998 and 1999 of 17 and 28 per cent respectively. Within a short time of its operation in the village, BPS had proved to be more efficient in the delivery of modern energy to consumers. Informal interviews with a selection of consumers to determine the state of general opinion on the quality of the electricity supply showed that quality had improved considerably from the time BPS took over in Ghanzi (BPC, 2000).

The high growth rates of consumption and consumers since 1996 indicate that as the private company made energy available, the demand for energy increased. The linking factor was probably an increase in the number of income-generating activities. As the number of consumers rose, the unit cost of electricity fell and energy became more accessible to more of the rural populace. The Ghanzi experience thus demonstrates that the private sector is capable of producing and distributing modern energy such as electricity to consumers more efficiently than the centralized sector. The fact that the centralized DEMS was unable to cope with the electricity demand in Ghanzi, leading to the award of electricity production and distribution to the private sector, shows that the centralized sector is not capable of efficiently supplying rural areas with modern energy. The increase in consumers, and especially of income-generating activities, with the corresponding increase in electricity produced and consumed in Ghanzi, are indications that the private sector is efficient in the delivery of modern energy in rural areas.

Related to the Ghanzi case is the power supply in Maun. Until 1995 Maun was not connected to the national grid; instead, from 1991 it had been supplied with electricity by a private company. Team Project had taken over the production and distribution of electricity in Maun in 1991 when DEMS proved unable to produce and distribute electricity efficiently in the village, as would turn out to be the case in Ghanzi. Findings indicate that Team Project was successful. Customer feedback on the quality of power was positive. There was an unexpectedly large load growth, mainly attributed to the higher reliability of supply by the private company (Botswana Power Corporation, 2000). The increase in the electricity consumer base, and especially in energy-based income-generating activities, led to Maun being connected to the national grid. Similar plans are under consideration for Ghanzi as soon as government is happy with the customer base in the village. Ironically, both Maun and

Ghanzi were previously considered unviable for connection to the national grid. The involvement of the private sector has made the two centres economically viable from the public sector perspective of the national grid.

DEMS – representing the public sector – has been unable to produce and distribute modern energy efficiently to rural areas such as Ghanzi and Maun for several reasons. DEMS produces electricity mainly for public institutions; other consumers are only connected if spare generation capacity is available. This approach has resulted in the centralized power systems being unable to contribute significantly to industrial or commercial development in rural areas (Botswana Government, 1991). Findings in both Ghanzi and Maun indicate that in energy distribution the private sector does not discriminate among consumers, as is the case with DEMS. The private sector provides electricity to all consumers, whether commercial, household or institutional. It is against this background that this study recognizes the value of the involvement of the private sector and decentralization in the production and distribution of modern energy to rural areas.

Coal utilization

A case study of coal utilization and distribution in two central government depots in Francistown and Gaborone by the private sector is yet another example of greater private sector efficiency in the delivery of modern energy to consumers. In 1997, a private company, Exim Enterprises, leased the two central government depots in Gaborone and Francistown. This was meant to sustain and advance coal distribution to the local market in the two areas. The Lease Agreement was for five years. By December 1999, two years after the takeover, the company had made remarkable improvements in the delivery of coal and service to consumers. It had introduced screens at the depots that enabled consumers to be provided with the correct size (pea size, for example) for their specific equipment (MMEWA, 1999). Although this example shows coal utilization in urban areas, it suggests that the private sector can be efficient in modern energy delivery even in rural areas, and for both domestic and commercial uses.

Conclusion

Findings in this study have shown that more than a quarter-century after the Rural Electrification Programme was introduced in Botswana, the rate of rural electrification is still very low at 8 per cent. By 1999 no more than 106 villages across all the districts in Botswana, and a total of 11,185 consumers, had been electrified. Even though the centralized grid-based system has made significant gains in the recent past, it has achieved little in terms of delivering modern energy to rural areas.

While centralized, grid-based rural electrification is currently performing poorly, the decentralized private sector has been successful in the production and distribution of electricity in rural areas. In areas where the private sector was provided with the opportunity to produce and distribute electricity, as in Ghanzi and Maun, it has managed to carry out the responsibility successfully, paving the way for connection to grid-based electrification. Although the private sector is efficient in the delivery of modern energy or electricity to rural areas, it nevertheless faces a monopoly competitor in the centralized, grid-based system as supported by government. Only in Ghanzi and Maun was the private sector ever given the opportunity to provide electricity to the public – and it proved efficient. The efficiency of the private sector in the distribution of modern energy to rural areas is further illustrated by the distribution of energy fuels such as paraffin, LPG and coal to rural areas. Findings indicate that the distribution of these energy fuels has been efficient and successful in rural areas.

This study therefore concludes that the decentralized private sector is better placed than the centralized public sector initiatives to produce and distribute modern energy in rural areas for both income-generating activities and domestic use. However, given the socio-economic status of the rural population, the role of government will still be important in providing the enabling environment within which energy can be made available to the rural populations. While this study acknowledges the role that the private sector can play in the efficient production and distribution of modern energy in rural areas, uptake rates in the case of electricity in Botswana are likely to remain low unless generous subsidies are forthcoming, especially for the rural poor.

Hypothesis 2: Income-generating activities vs domestic energy use

Income-generating activities have greater impact than domestic use in promoting the delivery of modern energy to rural areas.

Facts about rural areas in Botswana

The rural commercial/industrial sector in Botswana is composed of various activities ranging from general dealers, bars and restaurants, and garages and filling stations on the commercial side to welding and carpentry on the industrial side. Most of these activities are small enterprises and can generally form part of the potential market for rural electrification.

However, rural areas in Botswana are characterized by low-income groups who are mainly involved in subsistence arable or livestock farming. There is very little commercialization and the main energy source is fuelwood, which cannot support major commercial enterprises. Although most people in Botswana are rural-based, there is very little evidence of income generation taking place: hence access to and utilization of modern energy is limited (see Appendix VA). Urban centres have pronounced industrial activity; thus they consume more modern energy than the rural areas, even though urban populations are lower than those in rural areas. Most of the energy demand in urban centres is attributed to the high concentration of income-generating activities when compared to those in rural areas. It can be suggested, therefore, that income-generating activities can have a greater impact than domestic use in promoting the delivery of modern energy to rural areas.

Electricity tariffs for domestic and income-generating activities

In assessing energy consumption between domestic use and income-generating activities, tariffs are one of the tools that can be used. Tariffs can determine the scale of electricity consumption, depending on whether they are high or low. The level of tariffs in a sector (domestic, for example, or income-generating) will determine which sector provides the best entry point for modern energy use in rural areas. Generally, Botswana's electricity tariffs have been among the highest in the region (Zhou *et al.*, 1999), helping to deter high electricity consumption and also discouraging investment in the country, especially in rural areas. Table 12.6 shows electricity tariffs for Botswana in 1999.

Table 12.6 Electricity tariffs for Botswana in 1999 (in Botswana Pula)

Tariff category	Fixed charge	Energy charge	Demand charge
Home/household –230 V single phase or 400 V 3-phase	7.00	0.25323	Nil
Small business – <400 V and <35 KW	17.00	0.2618	Nil
Medium business->400 V and >35 KW	17.00	0.1342	32.13
Large business >11 KV supply	17.00	0.1210	30.24
Government/municipality/street lighting	17.00	0.3392	Nil
Water pumping	17.00	0.2669	Nil

Note: P6 = US$1
Source: Zhou *et al*., 1999

We can see that the household sector pays a lower fixed charge of P7 (US$ 1.17) per month than the P17 per month that is charged for other categories. However, households pay a higher unit price of P0.2523 t/kWh than large industries, which pay P0.1210 t/kWh. The fact that household tariffs are higher than those of industrial or commercial sectors or income-generating activities suggests that electricity for domestic use is unlikely to attract more consumers than commercial use. This point can be illustrated further: only 2 per cent of the households in Motshegaletau became connected to solar power, while a number of commercial centres showed interest in being connected to this source of electricity (BIDPA, 2000). Thus lower tariffs charged for income-generating activities in Botswana are likely to have a greater impact in promoting modern energy distribution in rural areas. As demonstrated by the Ghanzi and Maun case studies, income-generating activities increase the consumption of and demand for electricity. It can be assumed, therefore, that small-scale enterprises can pay electricity tariffs, even though these are described as high by Zhou *et al*. (1999).

Household income and expenditure levels in rural areas

Household income and expenditure levels can be used to determine the rate of modern energy distribution in both urban and rural households. Previous studies (Zhou, 2001, for example) have shown that household income levels in rural areas in Botswana are low and that household expenditure is accordingly geared towards food items. Table 12.7 shows the average monthly disposable cash income, total disposable income and expenditure for rural, urban villages and national households.

Table 12.7 Average monthly disposable cash income, total disposable income and expenditure for rural, urban villages and national households

Settlement type	Mean disposable cash income (Pula)	Difference = cash income – expenditure	Disposable income (cash + in kind)
Rural villages	441.4 (391.59)	49.81 (24)	641.2 (250)
Urban	1,524.9 (1258.18)	266.72	1,710.1
Urban villages	731.3 (672.44)	58.86	876.4
National (total)	833.1 (716.12)	116.98	1,015.9

Note: P6 = US$1
Source: CSO, 1995

Income level is one of the main determining factors in new investments like electricity connections in both urban and rural areas. Income levels affect the ability to pay for both the connection and the consumption of electricity. This suggests that even when target consumers are located under the grid, they may not get connected if the cost of electricity consumption and tariffs are high and prohibitive. Thus the fact that income levels for rural areas are low in Botswana suggests that households are unlikely to be able to afford the high prices charged for modern energy, since much of their income is committed to food items. Domestic demand for modern energy, therefore, is not the best option to use as an entry point in promoting the delivery of modern energy. However, other alternatives such as income-generating activities may offer a viable entry point, as demonstrated by case studies at Motshegaletau and Manyana villages.

Energy consumption for households and income-generating activities

Energy consumption for household and income-generating activities in rural areas can be compared to determine the sector that is likely to have

Table 12.8 Electricity consumption for domestic and commercial use in Botswana, 1994–9 (in 000 kWh)

Year	Domestic	Commercial
1994**	154,787	257,277
1995**	153,072	292,891
1996*	103,990	192,374
1997/8***	208,018	334,416
1998/9***	242,632	368,880
1999	142,043	192,246
2000	156,563	214,381
Totals	1,161,105	1,852,465

* 1996 covers July only
** covers January–December
*** covers BPC financial year. Note the usage of different financial year periods; hence the figures are not comparable within the years, except when they are of the same financial year.
Source: CSO, 2000

the greater impact in promoting modern energy delivery in rural areas. Table 12.8 shows electricity consumptions for commercial and domestic use in Botswana.

The information provided in Table 12.8 is generic in nature in that it shows electricity consumption for all commercial and domestic use in all of Botswana. It does not distinguish rural areas from urban areas. It indicates, however, that commercial activities or income-generating activities in the country have a larger energy consumption rate than domestic use. Since income-generating activities use more electricity, therefore, they provide a better entry point for the distribution of modern energy in a particular area. Income-generating activities thus provide an alternative target in promoting modern energy delivery in rural areas. This issue is further illustrated by the examples of the Motshegaletau and Manyana PV projects discussed below.

Case studies: Motshegaletau and Manyana PV projects

The case studies of the Motshegaletau and Manyana projects were used to determine whether domestic use or income-generating activities have a greater impact in promoting the delivery of modern energy in rural areas. The PV choice was offered to find out whether solar energy is an alternative energy source in areas where it is not viable to provide electricity through the grid-based system. Findings in these two case studies showed that income-generating activities have a better chance than domestic use of promoting modern energy delivery in rural areas. The findings for both studies are briefly summarized and analyzed below.

THE BIDPA (2000) STUDY IN MOTSHEGALETAU VILLAGE

The main objective of the study by the Botswana Institute for Development Policy Analysis (BIDPA) was to conduct a socio-economic impact assessment of the PV power station in Motshegaletau. Specifically, the study aimed at:

- assessing the socio-economic impact of the PV power station at both the household and the community levels;
- providing baseline information that may justify replicating the project in other similar rural villages;
- Determining the socio-economic benefits of the project in order to recommend the technology to both local authorities and government as a viable power-generating alternative to other traditional methods.

The BIDPA study in Motshegaletau concluded

> that the PV solar electricity has a potential to improve the lives of the people of Motshegaletau. However, at the current level of supply it does not meet what the community view as their most compelling need. This is the need to use such electricity for industrial purposes and therefore develop small businesses. This limits community development and even the national objective of employment creation, especially in the rural areas which is in line with the Industrial Development Policy. The community also felt that the electricity was limiting them from using stoves, heaters, electric irons and combined electric/gas refrigerators. (2000: 5)

The study went on to offer the following recommendation:

> it is important that for future PV mini-grid installations, industrial usage should be taken into consideration in terms of energy provision. This was evidenced by the limitations in electricity use brought in by the scope of the objectives of this project. BOTEC should also review the procedures for electricity connections and source more funds for this project in order to meet total energy demand…. (2000: 5)

It is evident from this study that income-generating activities create more demand for modern energy, making distribution more economically viable in rural areas. Findings of the BIDPA study in Motshegaletau village indicate that the establishment of the PV power station in the village created a demand for solar energy in income-generating activities, hence the increase in the number of business applications by small-scale business owners, encouraged by the readily available solar power in the village to establish businesses in the locality. The BIDPA study noted that

> Although the objectives of the project did not aim at community development, the perception of the people of Motshegaletau regarding this project was that it will bring industrial development to their village. They had hoped that it will enable them to use sewing machines, welding machines and ironing. (However, one of the benefits of the project was to provide basic lighting to the village). Small businesses that require the electricity only for light uses would benefit

> from the BOTEC solar power. There was a significant increase in the number of business plots requests since 1998. While this could not all be attributed to the advent of the electricity, it is possible that it had a significant contribution. (2000: 4)

The BIDPA study noted that some of the businesses that were not using modern energy in Motshegaletau village became connected and started using solar power. In doing so, business owners were able to realize better profits than when they were not connected. An example that the BIDPA study quotes is that of the Motshegaletau Bar that has been connected to BOTEC's solar electricity since 1999. The use of electricity has had a positive impact on the profits of this business enterprise. The electricity is used in the refrigerator for cooling the drinks, for lighting, and for the radio, which provides music for the customers. Before the connection to solar electricity, the bar was using a generator to provide electricity for these purposes. By comparison, the generator proved to be more expensive. Findings indicate that this business pays about P20 (US$3.33) per month for electricity. When the bar was still using a generator, the cost was P120 (US$20) per month for petrol and P10 (US$1.67) for transport. Besides low electricity bills for this bar, sales were reported to have increased. This was because the electricity is more efficient in cooling the drinks than the gas-powered refrigerator. This has resulted in customers from neighbouring villages like Moiyabana and Thabala coming to buy drinks at the Motshegaletau Bar. The use of gas-powered refrigeration is also more expensive than using BOTEC solar power. The bar in question used to spend about P88 (US$14.67) per month when it was still using a gas fridge. This included P78 (US$13) for a 19 kg gas cylinder and P10 for transport.

The Motshegaletau study also noted that the advent of electricity has attracted applications for business plots in the village since 1998, when the solar power station was constructed. The study notes that while the increase cannot all be attributed only to the advent of the solar electricity, there is compelling reason to believe that the availability of this electricity has contributed significantly to such an increase. Table 12.9 shows the number of business plot applications before, during and after 1998 (the year in which the electricity was introduced).

Although the demand for electricity for small-scale businesses was high in Motshegaletau, electricity use in the village was very low. The BIDPA study shows that out of a total of 112 households interviewed, only two used BOTEC's solar electricity. Two used solar home systems and one used a generator for electricity. This means that 107 (96 per cent) of the households in Motshegaletau did not use any type of electricity and that 98 per cent of the households did not use BOTEC's solar electricity although it was readily available in their village. This shows that households are not the best option as a target for the delivery of modern energy when compared to income-generating activities.

Table 12.9 The number of business plot applications in Motshegaletau, 1995–9

Year	Applications received	Applications approved	Type of business
1995	0	0	
1996	1	1	Football playground
1997	0	0	
1998	3	3	Restaurant, filling station and woodlot
1999	9	8	Butchery, bar, takeaway, 2 general dealers, community hall, horticulture, poultry

Source: BIDPA (2000)

Findings indicate that low income levels in Motshegaletau village, as shown in Table 12.10, prohibit connection of households to the available electricity in that village. About 82 per cent of the households in the village cited lack of funds as the main reason for not having electricity in their homes. Respondents noted that high connection fees, cost of wiring materials and the high cost of labour resulted in their failure to obtain a modern/solar energy connection.

Table 12.10 Levels of cash income per month for Motshegaletau households

Income level	Count (frequency)	%
None	10	9
Less than P100	25	22
P100–P300	43	39
P300–P500	9	8
Over P500	25	22
Total	112	100

Note: P6 = US$1
Source: BIDPA, 2000

The low income levels in Motshegaletau, as indicated by BIDPA (2000), are consistent with those reported by Zhou (2001), who notes that the current mean rural income averaged nearly P400/month and only 29 per cent of rural people earned a cash income above P500/month, as compared to 26.5 per cent during the 1993/4 Household Income and Expenditure Survey. The fact that rural household incomes in Motshegaletau are low means that most households in the village cannot afford modern energy. This also means that the domestic energy use of households is not the best target option in promoting the delivery of modern energy in rural areas. However, this situation can be reversed if the target is shifted from households to income-generating activities in rural areas.

The Manyana PV Project

The introduction of PV energy in Manyana village in southern Botswana boosted the participation of the rural people in income-generating activities. The Manyana Pilot Project Evaluation Report of 1994 found that residential systems in Manyana have significantly improved the capacity of the residents to engage in productive income-generating activities. The report notes that 97 per cent of all respondents felt that their household systems helped them to do productive work. An additional 30 per cent of the respondents use their lights for moneymaking or productive economic purposes. Table 12.11 shows some of the income-generating activities that were established as a result of the introduction of PV energy in Manyana village.

Table 12.11 Income-generating activities in Manyana due to introduction of PV power

Income-generating activities	%
Craft making (both for money and as hobby)	17
Knitting for money	6
Panel beating	3
Fixing radios and electronics	3
Hairdressing for money at night	3
Renting out room with PV systems for income	3

Source: Porter, 1994

The Manyana study also examined the impacts of PV lighting systems in the village. Findings of this study show that many people were using their lights for income-generating activities. Particular attention was paid to street lights, which were found to have spurred two income-generating activities: tuck shops and fund-raising for community groups. Respondents in this study noted that a few informal stands or tuck shops, which sell drinks and miscellaneous items, have developed. A vendor brings a box of his wares and sells them under an advantageously situated street light. The study also found that over 40 per cent of the respondents noted that community groups use street lights for money-making activities. Typically, they will host a concert, play or community choir event and sell baked goods during intervals in the performance. Community groups make between P100 (US$16.67) and P20 (US$3.33) at such events.

Apart from the streets lights, the Manyana PV project was mainly designed for low voltage for domestic use. However, it encouraged residents to use energy for income-generating activities as well. As a result, the use of the PV system for commercial purposes may suggest that a high voltage system is needed in the village. This, if introduced, has the potential to increase the demand for modern energy in the village.

CONCLUSION

This study has shown that rural income levels are low while electricity charges are very high. Most rural households have been unable to meet the initial costs for electric connection even where the national grid-based system passes near their houses. As a result, domestic use has so far been unable to promote the delivery of modern energy in rural areas.

On the other hand, findings in this study indicate that the introduction of modern energy and income-generating activities complement each other. It does not necessarily matter which comes first. The existence of one will stimulate the introduction of the other. An increase in income-generating activities can create demand for electricity, and vice versa. The development and growth of the tourist industry in Maun in the 1990s led to an increased demand for electricity in the village as more income-generating activities, especially in the tourist sector, were established. As a result, Maun was connected to the national grid in 1995. The introduction of modern energy technologies in a village can increase the establishment of commercial enterprises, as seen in the two studies at Motshegaletau and Manyana. It can be concluded that income-generating activities have greater impact than domestic use in promoting the delivery of modern energy to rural areas. It has also been noted that domestic use does not solve the problem of the low income groups in rural areas, while income-generating activities provide more income to the rural population and at the same time increase the demand for modern energy. In the light of these observations, this study concluded that income-generating activities have a greater impact than domestic use in the promotion of modern energy in rural areas.

Hypothesis 3: Prioritizing components for the promotion of RETs

Of all existing and potential components for the promotion of RETs geared to income-generating activities in rural areas, some are more critical than others and therefore need priority attention and action.

This study has already shown that that the majority of people in rural areas in Botswana live in scattered areas characterized by lack of conventional sources of energy such as electricity. The study has also shown that the national grid has only been extended to major villages in the country, leaving the majority of the rural areas unconnected. Studies have highlighted the fact that RETs offer an alternative solution in the distribution of modern energy to rural areas (Mosimanyana *et al.*, 1995; Zhou *et al.*, 1999). However, studies such as those by the Botswana Government (1997) have shown that attempts to promote renewable energy technologies in rural areas are constrained by the following factors:

- lack of qualified extension personnel to mount concerted campaigns on the use of solar energy as an alternative energy source;
- the relatively high initial costs of new and renewable sources of energy (NRSE) technologies;
- inadequate budgetary provision for the maintenance of NRSE installations in government institutions, due to perceptions that NRSE equipment does not require maintenance.

As a result of these constraints, it is crucial to assess the various possible components of RETs geared to income-generating activities in rural areas. These components usually include market research, financing mechanisms, provision of infrastructure, operations and maintenance, training (entrepreneurial, technical, managerial), quality control, resource assessment and statistical databases, institutional and policy framework and gender considerations. To determine which components are to be given priority, criteria for selection must be established. In this study, almost all of the above-mentioned components were assessed and the most critical ones were finally identified.

Market research

This is an investigation into what the market conditions for a particular technology are like, to be able to estimate demand for the technology. There is evidence that in rural Botswana, where there are very few income-generating activities, there is a latent demand for RETs that usually goes undetected until market research is undertaken. This is illustrated by the PV power station study in Motshegaletau. The initial project was geared to providing sufficient energy for lighting only. It was only after the study was undertaken taken that it was revealed that there was a demand for small-scale business enterprises in the village. Without market research, the demand for new energy technologies will not readily be known and hence nothing will be undertaken.

A feasibility study by Zhou and Mhozya (1996) in Manyana, Molepolole and Takatokwane villages assessed the market potential of PV electrification in these three villages. This was shown by acceptance of the solar PV lightning system, while approval of the credit scheme was expressed through willingness to take out loans. Findings indicated that about 77 per cent of those interviewed were willing to utilize the loan scheme to pay for a PV solar system. In this study, results showed the part that market research can play in delivering RETs for income-generating activities in rural areas.

Financing mechanisms

Given the low income levels of the rural population, the high initial cost of obtaining modern energy, and the inability of the rural population to afford the alternative modern energy sources, a financial mechanism is needed to facilitate the purchasing of energy. This has been the case with rural connections to the national electric grid but the lesson learned there has not been applied to RETs. For example, the Energy Affairs Annual Report of 2000 (MMEWA, 2000) notes that the Rural Electrification Collective Scheme, initiated in 1988, was amongst other things intended to:

- counter and lessen the burden of having people pay total upfront costs before connection;
- ensure that interested people participate (and pay) over stipulated periods whilst using the electricity service;
- implement the government desire of having as many people as possible connected by using affordable means of payment through group participation.

Rural electrification is expected to trigger development in rural areas in various ways. It is intended to provide energy services that improve household welfare and stimulate activities in production and commerce, and also to facilitate development of the agricultural base by keeping the rural populace in their villages.

We have seen that the Rural Electrification Programme initially required potential customers to form groups of at least four members within the same vicinity in the village. In April 2000, government approved the reduction of down payment from 10 to 5 per cent. As mentioned earlier, each member of the group contributes 5 per cent as down payment, whilst the remaining 95 per cent is contributed by government, with the member having to repay over a 15-year period at the prime rate of interest minus 1 per cent. The introduction of the standard costing in most villages positively contributed to the increase in the number of customers, as it does not require group formation and calls for a standard charge for all consumers within 500 metres of the distribution point. Findings show that over 80 per cent of the rural customers who have used the same scheme for electrification would not have managed without this financial assistance. Expenditure (notably by government) on energy reflects how much priority is accorded to the development of the various energy carriers. The Rural Electrification Programme in Botswana is budgeted for by government under its Rural Power Supplies and BPC budgets.

Table 12.12 shows the budget allocation for the various energy sources in Botswana in two national development plans: NDP 7 (1991/2–1996/7) and NDP 8 (1997/8–2002/3). The table shows that Rural Power Supplies, a bureau that supports rural electrification, has been accorded a significant budget in both NDPs, amounting to 62 per cent and 88 per cent respectively of the total energy development expenditure. Renewable energies, mostly solar, which are supposed to complement grid electricity in rural electrification, have received the least financial support during the two NDPs.

Table 12.12 Energy expenditure in NDP 7 (1991/2–1996/7 and NDP 8 (1997/8–2002/3) (in Botswana Pula million)

Project name NDP 7 (91/2 prices)	91/2	92/3	93/4	94/5	95/6	96/7	Total
Coal Development MR 104	0.45	2.05	1.00	0.50	0	0	4.0
BPC Financing MR 113	0	4.00	4.00	3.0	3.00	1.00	15.00
Renewable Energy Supplies MR 116	0.25	0.75	0.75	0.75	0.50	0.50	3.50
Rural Power Supplies MR 124	2.50	7.50	4.00	4.00	6.00	9.00	37.00
Total	**3.20**	**14.30**	**9.75**	**8.25**	**9.5**	**10.50**	**59.50**
NDP 8 (97/8 prices)	**97/8**	**98/9**	**99/00**	**00/1**	**01/2**	**02/3**	**Total**
Coal Development MR 104	2.00	2.00	2.00	2.0	2.0	5.00	15.00
Renewable Energy Supplies MR 116	0.65	0.97	0.25	0.25	0.25	1.34	3.70
Rural Power Supplies MR 124	24.00	25.00	25.00	25.00	25.00	11.00	135.00
Total	**26.65**	**27.97**	**27.25**	**27.25**	**27.25**	**17.34**	**153.70**

Note: P6 = US$1
Source: Zhou *et al*., 1999

Table 12.13 Number of PV installations by districts, 1999

District	%	Number of installations
Kgalagadi	8.5	22
Central	53.1	137
Kgatleng	0.4	1
Gantsi	7.7	20
Southern	16.3	42
Kweneng	8.5	22
Chobe	2.7	7
North East	0.8	2
Ngamiland	1.2	3
South East	0.8	2
Totals	**100.0**	**258**

Source: MMEWA, 2001

The information in Table 12.13 reflects the high proportion of subsidy support granted through the RECS to promote connectivity to the national electric grid; by contrast, support for the promotion of PV energy has been limited. This has contributed to the low installation or distribution of RETs in rural areas for use in households and income-generating activities. The small number of PV installations in the country shows the low rate of RET delivery in rural areas. From the time the PV programme started in 1997 to the end of 1999, the programme had made only 263 installations throughout the country, mostly for household use although some are for small businesses such as poultry farming.

Clearly an appropriate financial mechanism can make a significant impact with respect to the promotion of energy distribution in rural areas. This issue is currently not adequately addressed in the promotion of RETs for income-generating activities in rural areas in Botswana.

Training and capacity building (entrepreneurial, technical and managerial)

The Botswana Government (1997) recognizes the fact that lack of training and capacity building is one of the factors that hinders the promotion of RETs in rural areas. This fact is also noted by Porter (1994) in the Manyana Pilot Project Report. Porter's study found that the users received no formal training from the Energy Affairs Division on how to use and maintain their PV systems. Solar West (the company providing PV devices) was said to have undertaken a brief 15-minute training for each new user; in interviews with users, however, none of them mentioned any training. Porter noted that the lack of training contributed to greater dissatisfaction with the systems because consumers were never made aware of the limitations of the systems in terms of applications and power output. In addition to the lack of training for PV users, the Botswana Government (1997) noted that the use of solar energy as an alternative source of energy in the country is constrained by lack of qualified extension personnel to mount concerted campaigns on the use of solar energy as an alternative energy source. This indicates that there is currently a shortage of suitably qualified trained personnel in Botswana.

Recent studies (UNICO International Corporation, 2001, for example) indicate that rural district councils in Botswana have taken the decision to promote the use of solar energy devices to rural areas under their jurisdiction. However, the major problem that this study notes is the severe lack of trained manpower for maintenance, repair system design, sizing, product evaluation and specification in the NRSE area, and specifically in solar energy technology, which represents the bulk of NRSE usage in the country. All sectors – manufacturers, suppliers and installers, consumers and maintenance departments – experience the lack of manpower.

Findings in this study therefore, indicate that while renewable technologies are considered appropriate for rural areas in Botswana, and almost all the district councils in the country have taken a decision to expand the use of solar energy in their respective districts, the shortage of manpower in PV technology remains a major barrier to achieving this goal. Table 12.14 shows the total number of trained PV personnel in Botswana in 2001.

Table 12.14 Total number of trained PV personnel in Botswana, 2001

Type of personnel	No. of personnel
Artisans/technicians	200
Supervisory/training staff	40
Decision-making staff	30
Professionals	10
Totals	280

Source: UNICO International Corporation, 2001

The UNICO International Corporation (2001) notes that the necessary training facilities in relation to PV systems in Botswana are far below the satisfactory level. Technological training in relation to NRSE is rarely incorporated into existing training facilities programmes in Botswana, and training facilities dedicated to PV systems are hard to find. UNICO also observes that lack of trained manpower has led to large-scale failure and malfunction of the devices, resulting in large monetary losses in repairs and replacements. This has led to the imposition of restrictions on the usage of devices by some organizations such as the Botswana Housing Corporation, which has taken a decision to abandon PV devices in its houses. A parastatal like the BPC, the Botswana Housing Corporation is funded by government to build and provide housing throughout the country. UNICO notes that in order to minimize losses due to failure and malfunction of NRSE devices currently in use, to support the envisaged expansion of their usage, and to support the commercial sector, trained manpower will be needed at the following levels of responsibilities:

1 *technical*: to maintain, repair and provide upkeep of the systems;
2 *professional/supervisory*: to design and size the systems and to provide effective leadership;
3 *decision-making*: to conduct evaluation and specification.

MMEWA's Energy Affairs Division is responsible for working out the policy of promoting PV system electrification at central government level. Other important institutions or stakeholders in developing a training policy in the promotion of PV electrification systems are BOTEC and the RIIC. At the moment, however, no concrete and constructive policy has been developed to address the shortage of personnel to be engaged in the PV electrification programmes. Besides, these institutions, together with the manufacturing sector, also require trained manpower at the professional level with research and development capabilities.

This suggests that to encourage income-generating activities based on accessibility to renewable energy sources, there is need for training to develop entrepreneurial, technical and managerial skills for the sustenance of enterprises. This will probably result in their ability to expand and hence improve their income positions; ultimately, this will increase the demand for renewable energy in rural areas. As the demand for energy increases, the unit cost of energy will drop, resulting in more households being able to afford modern renewable energy.

Operations and maintenance

The sustainability of rural energy technologies is critically dependent on the operation and maintenance system that is in place. This is evident in previous renewable energy projects in rural areas of Botswana. The lack of an operations and maintenance system has been highlighted in NDP 8 as one of the main causes of failure of RETs in rural Botswana.

As already noted, the failure of renewable energy in rural areas in Botswana, especially in government institutions, is associated with a lack of qualified extension personnel to mount concerted campaigns on the use of solar energy and inadequate budgetary provision for the maintenance of NRSE installations in government institutions, due to perceptions that NRSE equipment does not require maintenance. This situation has contributed to the low distribution of renewable energy in rural areas.

Quality control

Quality control is an important component is ensuring that RETs provide the desired services. This is reflected in studies on RETs in Botswana. People are normally reluctant to acquire new technologies without a strong assurance of good quality equipment.

In order to determine the quality of PV equipment at Manyana Village, Porter (1994) interviewed the maintenance officer for Manyana, a representative from Solar West, and also the PV distributor that installed the residential and clinic PV systems. This was also carried out to determine the frequency of failures of the system components and possible causes of these failures. Additional information on the state of current system components was collected during a visual and electrical inspection of the clinic and residential systems by the consultant (Porter).

Findings indicated that tubes, lamps and charge controllers were the most common components to fail in the Manyana systems. The report notes that failures with the charge controllers were quite alarming in view of the expense of the item (P280 or US$46.70) and the shortness of the warranty (one year). A charge controller failure for a rural family purchasing a system on a credit basis would be devastating. Not only would it be difficult to raise the funds for the replacement, but the family's faith in the PV technology might well be destroyed, causing the family to default on the loan. The only conclusion to be drawn is that the Botswana

Bureau of Standards needs to work with government to establish quality standards for PV producers. The quality of the tubes, lamps and charge controllers makes the project problematic for the people of Manyana, and the quality of equipment needs to be assured for the sustenance of the project.

Resource assessment and statistical database

Limited access to information on the country's resource base is the major barrier to a wide promotion of RETs and a major cause of contradictory and inconsistent information on RETs. The accessibility of credible information will always play an important role in RET promotion in rural areas.

Gender issues

In relation to Botswana, Afrane-Okese and Zhou (2001) note that decision makers in the household are usually the household heads, and that policies will have to be targeted at them in order to be effective. The gender of the household heads could influence decisions made concerning energy use and appliance acquisition. Gender analysis of the urban household income data shows that female-headed households are in the minority in urban Botswana (about 39 per cent). However, the majority of these female-headed households are amongst the poorest in urban Botswana. More than half of them are in the lowest income group, while only about a third of the male-headed households are in this group. This is an indication of serious gender inequality, with consequent negative effect on the power of these female-headed households to purchase energy services. Clearly it will be useful for energy policies targeting poorer households to target the female-headed households that constitute the majority in the poorest income group.

Further findings by Afrane-Okese and Zhou indicate that in rural areas the majority of the households were female-headed (54 per cent) compared to male-headed (46 per cent). As in the urban situation, these households are known to have lower incomes than their male-headed counterparts. This makes their situation even worse than the urban female-headed households, since lower rural income levels mean that they are less able to afford modern energy services. These findings also show that about 45 per cent of the rural households surveyed had household members who never attended school and another 36 per cent who had only primary education. The remaining 19 per cent had secondary education. This situation implies low income levels in the majority of households in the rural villages.

As shown in Table 12.15, the study by Zhou and Mhozya (1996) of PV electrification in Manyana, Molepople and Takatokwane indicates that more male than female respondents were willing to pay for solar PV systems. This fact supports the generally accepted view that income levels for male-headed households are better than for female-headed

Table 12.15 Willingness to pay for solar PV systems by gender

Sex of respondents	Households willing to take loan	Households willing to buy PV system + NY
Male	200	174 + 51
Female	111	95 + 36
Total	311	269 + 87 (= 356)

Note: NY – not yet but willing to buy
Source: Zhou and Mhozya, 1996

ones, placing the former in a better position than the latter to afford solar PV systems.

In a study by Zhou (2001), women were found to be mostly involved in self-employment, family business and housework, the latter implying that women are the main users of energy in rural households. Considering the rural cash income distribution, the majority (30 per cent) earned between P50 and P200 (US$33.33) per month in 1993/4. For that same income category, more females (30.9 per cent) earned this income than males (28.8 per cent). If women's ability to acquire modern energy is taken into consideration, especially their predominantly low incomes, it is appropriate to conclude that issues of gender imbalance contribute to the low distribution of modern energy in rural areas.

Gender imbalances in Botswana can thus be said to be affecting income levels and through these the distribution of modern energy, especially in rural areas. This means that gender inequality should be addressed in order to promote the distribution of RETs in rural areas, especially for income-generating activities.

Institutional and policy framework

The shortage of modern energy in developing countries, especially in rural areas, is often linked to inadequate policies and programmes: government's tools to stimulate rural commercial energy demands (Best, 1992). In Botswana, several institutions, policies, strategies and programmes are meant to promote the production and distribution of modern energy in both rural and urban areas. The Energy Affairs Annual Report of 1996/7 states that the production and distribution of modern energy in Botswana is the responsibility of several institutions. However, the main responsibility is carried by MMEWA's Energy Affairs Division. MMEWA is responsible for formulating, directing and coordinating national energy policy through the Energy Affairs Division (MMEWA, 1999). The Energy Affairs Division thus coordinates energy matters and commissions energy studies in the country (Kgathi *et al.*, 1999). Although overall production, distribution and management of energy are entrusted to MMEWA, it shares the implementation of energy activities and programmes with other ministries, parastatals and NGOs such as the RIIC.

Botswana's energy policy was adopted in 1998, but earlier findings by Kgathi *et al.* (1994) indicate that the policy is based on the premise that market forces are an inadequate mechanism for the allocation of resources in the energy sector. This premise has three main supports: (1) increased wood energy scarcity leads to environmental degradation and increased economic pressure on poor households; (2) there is a need to take into consideration the potential for economic development of indigenous sources of energy as well as the strategic importance of certain energy sources; and (3) Botswana has a high dependence on imported energy (electricity and oil) and this makes the economy vulnerable (Botswana Government, 1985). Kgathi *et al.* state that Botswana's energy policy therefore aims at reducing the foreign exchange costs associated with imported energy as well as the economic and social costs associated with fuelwood.

In relation to renewable energy programmes meant for the production and distribution of modern energy to rural areas, the National Photovoltaic (PV) Electrification Programme is being promoted in rural areas through a credit scheme under the National Photovoltaic Rural Electrification Programme. However, solar PV electrification is not as heavily subsidized by government as the grid electrification programme; as a result, solar electrification presently achieves less access/connectivity than grid electrification, even in non-electrified rural villages. An effective policy is required to make solar and grid electrification complementary.

Summary of components for RET promotion

Table 12.16 provides a summary of possible components for the promotion of RETs geared to income-generating activities, based on the Motshegaletau and Manyana–Molepolole–Takatokwane studies. The table is a critical analysis of how each component was reflected in the two case studies assessed. It should be noted that the components identified were not always referred to directly in the two case studies. However, these components emerge clearly under analysis, which makes it possible to rank the level of their importance. It is important to note that all the components indicated in Table 12.16 are essential in the provision of RETs in rural areas. The overall ranking in each of the two studies indicates that some are of greater importance than others, and hence deserve more attention. The analysis of various components in Table 12.16 is discussed below.

Quality control

Quality control measures are meant to ensure that the rural energy technologies provide the desired services and are not regarded as inferior products. Sometimes rural populations may not acquire new technologies just because they are not convinced that they are reliable. Quality control is ranked high in importance in the Manyana study, while in Motshegaletau it was moderately ranked. Overall, the importance of

Table 12.16 Summary of possible components for promoting income-generating RETs, based on the Motshegaletau and Manyana, Takatokwane and Molepolole studies

Components	Motshegaletau PV study (successful)	Manyana, Molepolole and Takatokwane PV study (moderately successful)	Level of Importance (high, moderate, low)
Quality control	moderate	high	moderate
Resource assessment and statistical database	high	moderate	moderate
Market research	high	high	high
Financing mechanism	high	high	high
Training and capacity building	low	high	high
Operations and maintenance	moderate	high	high
Gender considerations	moderate	high	high

quality control in all the studies was moderately ranked. However, it became clear in all the studies that in order to instil confidence in the introduction of new energy technologies, quality control is a priority.

Resource assessment and statistical database

The overall assessment of the importance of resource assessment was found to be moderate when all studies are considered. In the Motshegaletau study, however, it was ranked high. Therefore, accessibility of information on RETs can be regarded as moderately essential in the promotion of RETs in rural areas in Botswana.

Market research

Market research was critical in all studies since it was ranked high in all studies. It provided essential information on latent demand that was critical in the provision of energy rural areas. As a result, market research proved to be vital in the promotion of RETs in rural areas.

Training and capacity building

The importance of training and capacity building was rated high in all the studies, as indispensable for the high utilization of new technologies.

Operations and maintenance

Operation and maintenance encourages sustenance and reduces the failure rate of the operation of RETs in rural areas. It also brings efficiency of the new systems and hence is ranked overall as of high importance.

Gender considerations

Gender considerations can be ranked highly from the two studies. There are more female-headed households in rural areas than in urban areas. Since successful dissemination depends on improving the involvement of women in the use of modern energy in rural areas, this component is also essential.

Financial mechanisms

Financial mechanisms are essential in enabling rural populations to purchase modern energy and are accordingly ranked high in the studies. Of course, the main constraint on the rural population in attaining modern energy is lower income, and financial mechanisms are not always able to overcome this most fundamental barrier.

Conclusion

This study has demonstrated that the majority of the population of Botswana live in small and scattered rural areas where the modern conventional energies – especially electricity, coal and petroleum products – are not readily available. The use of renewable energy devices is, therefore, considered to be a feasible solution in the absence of rural electrification in Botswana, especially in areas where the extension of the national electric grid is considered not economically viable. Its potentials are demonstrated by the widespread use of solar energy devices throughout the country and the planned expansion of their implementation. Its potential is further demonstrated by the decision of most district councils in rural areas to expand the usage of solar energy devices to rural areas under their jurisdiction. In addition, major organizations in some sectors, such as the Botswana Telecommunications Corporation, already rely heavily on solar power.

While the introduction of RETs in rural areas remains important for households and income-generating activities, progress in the implementation of the PV programme in Botswana is slow, such that only 300 installations have so far been made in 86 villages around the country, with a total of 42.75 kWP since its initiation in 1997. While solar PV electrification remains in the shade of the government's more vigorous subsidization of its grid-based rural electrification programme, solar electrification will continue to achieve less access/connectivity than grid electrification, even in non-electrified rural villages.

While RETS offer a better alternative as an energy source, the major problem that this study notes is the severe lack of trained manpower in the NRSE area for maintenance, repair system design, sizing, and product evaluation and specification. This is specifically evident in solar energy technology, which represents the bulk of NRSE usage in the country. All sectors – the manufacturers, suppliers and installers, consumers and maintenance departments – experience the lack of manpower.

This study concludes that even though there are particular components of RET promotion in Botswana that need attention and priority, these components are closely linked to each other and the removal of one may result in the collapse of the system. However, components that need more attention in the distribution of RETs in rural areas include *market research, financing mechanisms, operations and maintenance, training (entrepreneurial, technical, managerial) and quality control.* These components, therefore, should be given priority in the promotion of RETs geared towards income-generating activities in rural areas.

13

Final Policy Recommendations

This chapter presents policy recommendations for the three hypotheses tested in the medium-term study. The adoption and implementation of these recommendations might help to solve the problems of lack of modern energy in rural areas that have been identified in this study.

Hypothesis 1: Decentralized private sector vs centralized public sector energy initiatives

This study has shown that decentralized energy supply can be a better approach than the centralized delivery of modern energy for domestic use and income-generating activities in rural areas. The following policy recommendations are intended to articulate this finding.

- The production and distribution of modern energy to rural areas should where appropriate be decentralized and handed over to the private sector. The role of government should be limited to facilitation and regulatory interventions in the form of policies and acts. However, government should have connection targets set for the private sector as part of the effort to promote the production and distribution of modern energy to rural areas.
- Financial schemes for private energy providers should be put in place in order to afford them the opportunity to produce and distribute modern energy in rural areas. Financial schemes or a levy should also be put in place for the rural communities to afford them the opportunity to be connected to modern energy.
- Public awareness should be awakened through campaigns promoting the decentralized private sector energy initiatives in rural areas.

Hypothesis 2: Income-generating activities vs domestic energy use

Findings for this hypothesis have shown that in the past targeting households in the promotion of rural electrification has had insignificant results. A change in the strategy is crucial if the delivery of modern energy in rural areas is to be effective. In relation to this hypothesis, this study suggests the policy options outlined below.

- Encouraging income-generating activities in rural areas should be the number one priority in government's strategy for bringing modern energy to rural areas. Government initiatives should target SMEs, which have a profit maximization motive, rather than targeting domestic consumption just for welfare reasons. Income-generating activities increase the demand for modern energy in rural areas and thus create a base upon which modern energy, especially electricity, can be extended to households. Income-generating activities empower the rural population by improving their ability to purchase modern energy technologies, and also provide the necessary demand for that type of energy.
- The government should continue to sponsor research into appropriate energy sources for the rural population. It is the responsibility of government to generate and disseminate information on the modern sources that are needed in rural areas. This responsibility cannot be left to the private sector in its attempt to create a market for energy consumption in rural areas.

Hypothesis 3: Prioritizing components for the promotion of RETs

Findings in this study have shown that even though the Botswana government has a National PV credit scheme that requires a down-payment of 15 per cent with the rest paid in four years at an interest rate equal to the prime rate, the payment conditions are still too high for potential customers and rapid dissemination has not been attained. By lowering the down-payment and prolonging payment terms, it might be possible to attain rapid dissemination comparable to recent grid connection increase. Users should maintain the PV system by themselves if they are technically capable, or else conclude maintenance contracts by paying additional fees to the system suppliers or maintenance service companies. A high degree of user awareness is required to operate a PV system sustainably. Otherwise, the system will be abandoned and the payment will fall into arrears. The constraints associated with the low population density, the low skill levels of villagers, and the remoteness of the rural communities ensure that the profitability of maintenance work will be poor and that sufficient services cannot be expected.

Findings have also shown that in the past experience of developing countries such as Botswana user maintenance of PV systems has rarely been successful, and that frequent visits and diagnoses by trained maintenance personnel are very important. To overcome the constraints mentioned, the institutional approach most likely to succeed appears to be the provision of PV-based electricity on a fee-for-service basis by a utility rather than through the sale of hardware to individual consumers. The fee-based approach would require that the utility own and maintain the SHS installed in its customers' premises. Trained staff would visit the customers regularly to service the systems, carry out repairs, and collect a service fee. The main aim of the fee would be the recovery of the utility's operating costs, including a capital recovery charge. The establishment of a head office would manage the accounts, inventory, procurement and training.

The study has shown that there are components of RET promotion for income-generating activities in Botswana that need to be given priority and attention. However, for this to be possible, specific recommendations are made below.

- Government should establish a National PV credit scheme with more relaxed terms of payment as compared to the current system, which expects consumers to pay within four years. This should include the creation of a levy as a way to subsidize the potential rural beneficiaries.
- A training policy on PV electrification should be adopted in order to address the current problems of installation, repair and maintenance of PV devices in rural areas.
- Efforts should be taken to increase public awareness of the relevance of PV electrification in rural areas. Where PV systems are being used, manuals and brochures should be written in both Setswana and English.
- The Botswana Bureau of Standards should set up guidelines for PV electrification devices in order to make PV providers supply quality products to consumers, especially those in rural areas who in most cases do not know how to read and write.
- An effective policy is needed to ensure that both grid-based and PV rural electrification in Botswana come under a single rural electrification system. This will enhance the idea that the systems can complement each other in promoting rural electrification, and create a selection criterion for villages that qualify for connection through either the grid-based system or renewable energy such as solar power. The current approach is that the grid-based system and solar electrification are implemented independently of each other.
- An effective institutional and policy framework for PV electrification should be established to facilitate the promotion of PV electrification in rural areas.
- Solar water heaters seem to have a wider market and usage, not only in rural areas but in urban areas as well. Consideration should be given to their development countrywide.
- Wind energy was widely used in the past for agricultural purposes. Although it currently competes with petrol and diesel pump engines for watering livestock, it is important that it should be developed further, with other sectors such as irrigation included in its use.

Part V Select Bibliography

Afrane-Okese, Y. and Zhou, P. P. 2001. *Urban and Rural Energy in Botswana: Needs and Requirements. Synthesis Report*. Gaborone: EECG Consultants.

AFREPREN, 2003. *African Energy Data and Terminology Handbook*, Nairobi: AFREPREN.

Bank of Botswana, 2000. *Annual Report and Economic Review 2000*, Gaborone: Bank of Botswana.

Bassey, M. W. 1992. 'Renewable Energy Research and Development in West and Central Africa', in M. R. Bhagavan and S. Karekezi (eds), *Energy for Rural Development*. London: Zed Books, pp. 89–107.

BEMP (Botswana Energy Master Plan) 1987. *Summary Report*. Gaborone: Ministry of Minerals, Energy and Water Affairs.

—— 1993. *Summary Report*. Gaborone: Ministry of Minerals, Energy and Water Affairs.

—— 1996. *Final Phase*. Gaborone: Ministry of Minerals, Energy and Water Affairs.

Bhagavan, M. R. 1999. *Reforming the Power Sector in Africa*. London and New York: AFREPREN/Zed Books Ltd.

BIDPA 2000. *The Photovoltaic Power Station in Motshegaletau: a Socio-Economic Impact Assessment*. Gaborone: Botswana Institute for Development Policy Analysis.

Botswana Government 1982. *Energy Development in Botswana*. Gaborone: Ministry of Mineral Resources and Water Affairs.

—— 1985. *National Development Plan 6, 1985–1991*. Gaborone: Government Printer.

—— 1990. *The National Conservation Strategy*. Gaborone: Government Paper No. 2 of 1990, Government Printer.

—— 1991. *National Development Plan 7, 1991–1997*. Gaborone: Government Printer.

—— 1997. *National Development Plan 8, 1997–2003*. Gaborone: Government Printer.

BPC 2000. *The Ghanzi Report on Power Distribution*. Gaborone: Botswana Power Corporation.

CSO (Central Statistics Office) 1995. *Household Income and Expenditure Surveys,* Gaborone: Government Printer.

—— 2000. *Statistical Bulletin*. Gaborone: Government Printer.

—— 2002. *Population and Housing Census of 2001*. Gaborone: Ministry of Finance and Development Planning.

Diphaha, J. 1992. 'Promoting Alternative Energy in Botswana: the Case for Subsidies', in M. R. Bhagavan and S. Karekezi (eds), *Energy for Rural Development*. London: Zed Books, pp. 108–18.

Dithale, N. 2003. *Country Validation Data – Botswana*, Nairobi: AFREPREN.

EECG/ADB 1995. *The Domestic Energy Consumption and Its Impact on the Environment in Botswana. Final Report*. Abidjan: African Energy Programme and African Development Bank.

EIU 2003. *Country Report: Zambia*, London: Economic Intelligence Unit.

ERL (Energy Resources Limited) 1985. *Study of Energy Utilization and Requirements in the Rural Sector of Botswana*. Gaborone: Ministry of Mineral Resources and Water Affairs.

ETC Foundation, 1987. *Woody Energy Development: Biomass Assessment. A Study of SADCC Region*. Leusden: ETC Foundation on behalf of the Southern African

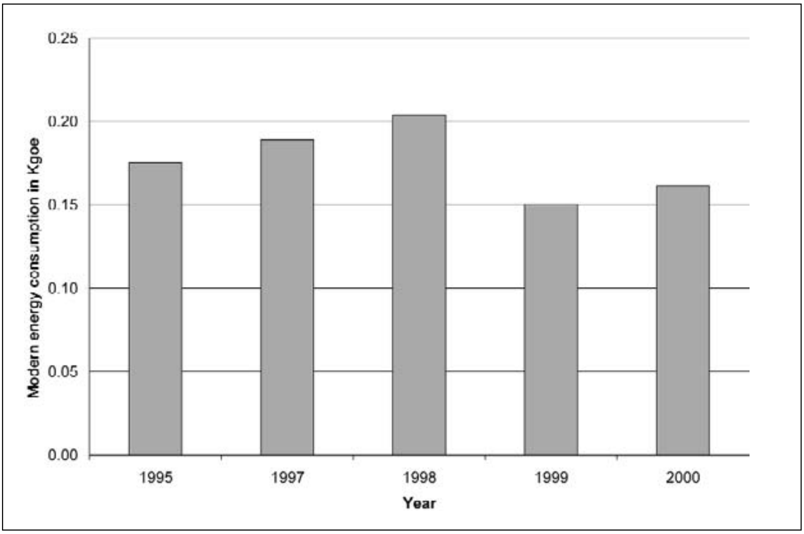
Development Coordination Conference (SADCC), Energy Sector.
Groth, A., Jefferies, K., and Woto, T. 1992. *SADCC Rural Industries and Energy Programme, Botswana*: *Country Report*. Kanye: Rural Industries Innovation Centre (RIIC).
JICA (Japan International Cooperation Agency) 2002. *Interim Report for the Master Plan Study on Photovoltaic Rural Electrification in the Republic of Botswana*. Tokyo: UNICO Electricity Power Development.
Karekezi, S. 1994. 'Dissemination of Renewable Energy Technologies in Sub-Saharan Africa'. *Annual Review Energy Environment*: 393, 398, 409, 411, 413.
Kgathi, D. L., 1992. 'Household Response to Fuelwood Scarcity: Implications for Energy Policy'. PhD thesis, University of East Anglia.
Kgathi, D. L. and Mlotshwa, C. V. 1997. 'Fuelwood Procurement, Consumption and Substitution in Selected Areas of Botswana: Implications for Theory and Policy', in D. L. Kgathi, D. O. Hall, A. Hategeka, C. V. Mlotshwa and M. B. M. Sekhwela (eds), *Biomass Energy Policy in Africa: Selected Case Studies*. London: Zed Books.
Kgathi, D. L., Sekhwela, M. B. M., Tietema, T. and Mpotokwane, M. A. 1994. 'Biomass in Botswana', in D. O. Hall and Y. S. Mao (eds), *Biomass Energy and Coal*. London: Zed Books, pp. 17–67.
Mbaiwa, J. E. 2004. 'Enclave Tourism and Its Socio-Economic Impacts in the Okavango Delta, Botswana'. *Tourism Management*, forthcoming.
Mosimanyane, M. T., Zhou, P. P. and Kgathi, D. L. 1995. 'Renewable Energy Technologies in Botswana – The Case of Wind Energy for Water Pumping', draft report, SEI/AFREPREN/FWD, Nairobi.
MMEWA (Ministry of Minerals, Energy and Water Affairs) 1997. *Energy Affairs Department, Annual Report 1996/97*. Gaborone: Government Printer.
—— 1996. *Energy Statistics 1995/1996*, Energy Affairs Division, Ministry of Minerals and Water Affairs, Gaborone.
—— 1998. *Annual Report 1998*, Energy Affairs Division, Ministry of Minerals, Energy and Water Affairs, Gaborone.
—— 1999. *Energy Affairs Division, Annual Report 1999*. Gaborone: Government Printer.
—— 2000. *Energy Statistics 1997/98*. Energy Affairs Division. Gaborone: Government Printer.
NRP 2000. *Study of Fuelwood/Woody Biomass Assessment around Mochudi and Bobonong: Final Report*. Gaborone: Ministry of Minerals, Energy and Water Affairs.
Perkins, J. S. and Ringrose, S. M. 1996. *Development Cooperation's Objectives and the Beef Protocol: the Case of Botswana. A Study of Livestock/Wildlife/Tourism/ Degradation Linkages*. Gaborone: University of Botswana.
Porter, J. 1994. *Manyana Pilot Project Evaluation*. Gaborone: Renewable Energy for African Development.
Ramasedi, B. 1992. 'Rural Electrification in Botswana', in V. Ranganathan (ed.), *Rural Electrification in Africa*. London: Zed Books, pp. 112–40.
Sekhwela, M. B. M. 1997. 'Environmental Impact of Woody Biomass Use in Botswana – the Case of Fuelwood', in D. L. Kgathi, D. O. Hall, A. Hategeka, C. V. Mlotshwa and M. B. M. Sekhwela (eds), *Biomass Energy Policy in Africa: Selected Case Studies*. London: Zed Books, pp. 64–124.
UNICO International Corporation 2001. *Progress Report for the Master Plan Study on Photovoltaic Rural Electrification in the Republic of Botswana*. Tokyo: UNICO International Corporation Electric Power Development Company.
Zhou, P. 1995. 'Energy and Agricultural Linkages in Botswana – 1995'. Paper presented at ISES Conference, Gaborone.
Zhou, P. P. 2001. *Rural Energy Needs and Requirements in Botswana*: *Final Report*. Gaborone: EECG Consultants and Rural Industries Innovation Centre (RIIC).
Zhou, P. P. and Mhozya, X. 1996. *Photovoltaic Rural Electrification Feasibility Study in Manyana, Molepolole and Takatokwane, Botswana*. Gaborone: Energy Affairs Division, Ministry of Mineral Resources and Water Affairs.
Zhou, P. P., Ramaphane, K. M. and Mhozya, X. 1999. 'Evaluation of the Rural Electrification Collective Scheme (RCS) – Botswana: Draft Final Report'. Gaborone: EECG Consultants.

Part V Appendices

VA.1 Selected trend data: Botswana

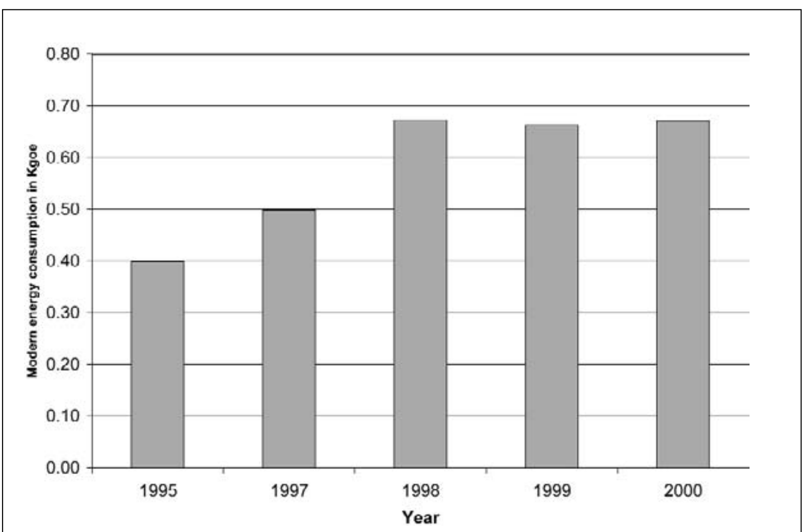
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
National population (millions)	1.35	1.39	1.43	1.46	1.50	1.53	1.56	1.59	1.68	1.70
National population growth rate	3.1	3.0	2.9	2.1	2.7	2.0	2.0	1.9	2.5	1.0
Rural population (millions)	0.729	0.737	0.758	0.760	0.780	0.785	0.800	0.816	0.862	0.876
GDP (US$ million)	4,413	4,501	4,662	4,899	5,239	5,449	5,639	6,120	6,330	7,000
GNP *per capita* (US$)	3,300	3,200	3,100	3,360	3,410	3,270	3,070	3,040	3,300	3,100
Total modern energy consumption ('000 toe)				860		1,030	1,150	920	1,020	
Modern energy consumption *per capita* (kgoe)	391	388	380	589.0	526.7	470.6	538.5	578.6	600.0	
Total energy production ('000 toe)			820	840	710	760	800	890		
National debt (US$ million)	612	660	691	703	613	562	516	649	738	370
Merchandise exports, f.o.b (US$ million)	1,744	1,722	1,874	2,160	2,233	2,069	1,711	1,388	1,521	2,314
Installed capacity (MW)	197	197	197	155	155	132	132	132	132	132
Electricity generation (GWh)	1,128	1,197	1,241	1,310	1,409	1,538	1,644	1,760	1,995	2,158
System losses (%)	16.9	16.7	17.3	14.1	6.3	6.9	6.4	10.7	8.7	11.1
Rural population with access to safe water (%)	91	91	91	91	91					

Sources: Ditlhale, 2003; Mbaiwa, 2003; AFREPREN, 2003; World Bank, 2000; World Bank, 2003



VA.1.1 Total modern energy consumption (Kgoe) vs GDP (US$) (Modern energy consumption per US$1 of GDP)

Source: AFREPREN 2003



VA.1.2 Total modern energy consumption (Kgoe) vs merchandise export (US$) (Modern energy consumption per US$ of merchandise export)

Source: AFREPREN 2003

Part VI

ETHIOPIA

Wolde-Ghiorgis Woldemariam

COUNTRY PROFILE

Ethiopia

SELECTED INDICATORS

Population (millions): 65.40 (2001)
Percentage of population rural: 84.10 (2001)
Land area (km^2): 1,097,000
Capital city: Addis Ababa
GDP growth rate (%): 7.70 (2001)
GNP *per capita* (US$): 100 (2001)
Official exchange rate: Birr 8.80 = US$1 (June 2003)
Economic activities: Agriculture, forestry, fishing, manufacturing, mining
Energy sources: Biomass, natural gas, hydro
Electricity consumption *per capita* (kWh): 22.1 (2001)
Electricity generation (GWh): 1,812 (2001)
System losses (%): 22 (2001)
Electrification levels (%)(2001): National: 13
Rural: 0.7
Biomass consumption as a percentage of total energy (%): 93.05 (2000)
Poverty levels 1998:
- (%) population living below US$1 a day: 81.9
- (%) population living below US$2 a day: 98.4

Sources: Wolde-Ghiorgis, 2003; Kebede, 2003; Teferra, 2002; AFREPREN, 2003; EIU, 2003; World Bank, 2000; World Bank, 2003

14

Introduction

Rural energy situations and trends in Ethiopia

The background to energy initiatives and the provision of modern energy services for rural development in Ethiopia is multi-faceted because it is so deeply rooted in poor socio-economic conditions compounded by severe underdevelopment. Energy problems and supply deficiencies are best understood as complex socio-economic conditions wired into extreme poverty and under-development.

Utilization levels of modern fuels in the rural areas of Ethiopia are among the lowest in the world. Electricity consumption is limited to no more than 1 per cent of the rural population and only 10–13 per cent, nationally. Electricity is therefore largely unknown in Ethiopia among the vast rural population (currently over 56 million as of 2003). Consumption of petroleum products in rural Ethiopia is also mostly limited to the use of kerosene for lighting in wick and lantern lamps.

Modern energy impacts on rural-based enterprises in Ethiopia are thus insignificant in relation to the energy requirements of the relatively vast rural population. The only exception is a slow but steadily growing trend toward the use of modern energy in flourmills powered by diesel engines or electric motors. The consequences of dependence on traditional energy sources are alarming trends of desertification in many parts of the country. Only semi-arid vegetation and grass remain for pasturing and the nomadic modes of economic livelihood. The only significant sources of biomass fuels and trees are presently found in the south-western region of the country.

The rural energy issues facing the country could not be seen in true perspective in the 1980s. Consequently, even the most minimal adjustments and options are yet to be mapped and planned. Ethiopia is faced with the double challenge of guaranteeing energy security in parallel with food security for a large and growing population. Despite repeated droughts, the food supply problem appears to be reaching a promising stage through the experience gained from extensive agricultural extension packages. The national energy issue in general, however, and the rural energy problem in particular are just beginning to be considered as the core hindrance to poverty reduction. As indicated above, key indicators and measures of development associated with poverty alleviation strategies reflect the negative impacts of the absence of modern energy supplies in the country. It can be argued that lack of modern energy services alone could not have been the causes of underdevelopment in the past. Still, it can also be contended that the rural energy feature has not been recognized and fully considered in various voluminous studies. While the need for a national energy policy was addressed in broad terms in 1994 (key aspects of the existing energy policy are summarized in Appendix VIA.1), references to the rural energy problem are still too broad and unfocused.

15

Study Findings and Conclusions

Hypothesis I: Decentralized private sector vs centralized public sector energy initiatives

In comparison with the experiences of other less developed countries, rural electrification in Ethiopia has been slow and unfocused in many respects. First the prevailing trends will be examined, to be followed by assessments of the involvement of the public and private sectors. A summary of technological options and cost considerations has also been given. Although new approaches are being considered, the rationale employed by the utility in considering diesel generation in the past has also been addressed briefly here.

Trends in decentralized rural electrification: preliminary qualitative assessment

There are small power-generating plants widely distributed in the rural areas of Ethiopia. These have been built, and are owned and maintained, by private suppliers. Except for a few photovoltaic units belonging to donor-driven projects, all decentralized electric supplies use diesel generators in the 10–50 kW capacity range. These serve remote rural towns, both market and administrative centres, that have not been considered financially viable targets for electrification by the utility. Voltage supply levels can at best energize incandescent lamps. Despite the high cost of electricity (sometimes five times higher than the national tariff), the private suppliers have been making profit on their investments. RETs based on micro/mini hydropower, wind generators and PV systems, owned and operated by the private, decentralized sector, are as yet non-existent in the rural areas of Ethiopia.[1]

1 The utility is yet to be engaged in electricity generation using a mix of energy sources other than medium-to-large-scale hydropower and diesel generation options. A pilot-scale project on geothermal generation commissioned in 1998 is still under test. Despite high initial costs, there is sufficient experience in operating and maintaining small-scale hydropower units within the capacity range 250 kW–10 MW. The viability of micro hydropower units (1–100 kW), as well as wind generators and PV systems should be tested soon. This could be done with isolated and off-grid trials; if successful, RETs could later be interconnected either with the main grid or within new mini-grid subsystems.

Centralized public sector power generation and distribution

Rural electrification schemes implemented by the public sector (that is, by the utility) have benefited those connected at a subsidized cost. Even so, it cannot be said that these have been successful, for two main reasons. First, a cross-subsidy is borne by a larger-scale hydropower source (450 MW) *vis-à-vis* a smaller-scale (total installed capacity 50 MW) diesel generation source. Second, problems in maintaining fuel supply to remote sites, compounded by non-availability of spare parts, have been a major hindrance. Constraints have therefore limited the slow expansion of rural electrification programmes to load centres serving settled populations of 5,000 inhabitants and above. Further, grid-based rural electrification extensions have been restricted to an average maximum distance of 200 km from the interconnected system (ICS). Around generating stations within the self-contained system (SCS), the distance limitation is 15 km or so. There are small-scale hydropower plants (Yadot, in south-eastern Ethiopia, 250 kW; Dembi in south-western Ethiopia, 400 kW; and Sor, in central-west Ethiopia, 500 kW). All other generating stations in the SCS networks have been based totally on diesel generation. Gradually, many of the diesel stations nearer to the ICS have been connected to the grid by medium voltage distributions using 15 kV lines. These are limited to a maximum distance of 60 km from the nearest ICS substations. Using 33kV distribution transmission lines, the Ethiopian Electric Power Company (EEPCO) is planning to extend grid extensions to load centres as far as 100 km away from the ICS grids.

Other grid extension methods for serving rural settlements are also being considered, although these do not appear to be more economical than conventional grid extensions. Whatever systems or sources of generation are being considered, however, it is apparent that the rural poor will not be the beneficiaries. Low-income rural communities in scattered traditional villages and settlements will have no chance of receiving electricity supplies from the private or public sectors within the foreseeable future. Rural electrification – whether through decentralized or centralized generation approaches – cannot benefit the rural poor population of Ethiopia. In any case, the rural houses of those at present outside the electrification networks will continue to be built in the traditional manner, mostly as huts with thatched roofs over walls that combine small stones with dried mud bricks.[2]

[2] From the safety point of view, consultants and experts assert that electricity supplies from private or public systems cannot be delivered to huts with thatched roofs. So, the alternative is to think of installing photovoltaic panels on top of thatched roofs, as has been done successfully in West African countries. One problem with this approach is that the electricity supply becomes too expensive for lighting purposes. This option must therefore be recommended only for providing power for health and educational services, as well as for radios and, possibly, black-and-white TVs.

Wind vs diesel in rural electrification: technologies and costs

In comparison with diesel generation, wind energy has the merit of being attractive for electricity generation provided its limitations and potential benefits are both well understood. Using key technical parameters and cost considerations as bases for comparison, it can be established that wind generation is a favourable option. Table 15.1 provides a list of the

Table 15.1 Summary of comparisons between diesel and wind generators for rural electrification

Description	Diesel generator plants	Wind generator plants
Energy source	Diesel fuel oil; non-renewable.	Wind energy; renewable.
Technology, complexity & lifetime	Standard technology, but prone to wear and tear; on average ten years.	Well established and continually being improved for electricity generation; indefinite lifetime.
Parallel operation option of single units	Method available at a common bus bar for two or more diesel generators.	Method also available for wind farms of many single units.
Dependability of reliable power generation and operation	Diesel generation is dependable at any time of operation, subject to availability of fuel.	Dependable generation of electricity possible only when wind speed is above cut-in speed (e.g., 3.5m/s) and below cut-out speed (e.g., 15 m/s), mostly during daytime.
Minimum number of consumers	Diesel generation for rural electrification based on a minimum number of consumers in an adminis-trative centre or a market town that would guarantee pay-back of investments and operational costs within a period of ten years.	Minimum number of 50 to 100 consumers would be needed; investment totally dependent on type of rural or semi-rural settlement near a medium-sized plant; there could be a need for a sub-transmission system from generation station to distribution centre. Pay-back period for investments on wind generator and energy storage systems could be shorter if number of consumers exceeds 100.
Cost components (unit costs in US$/kW and US$/kWh	US$850–US$1,000/kW US$0.25–0.35 per kilogram of fuel oil; energy cost US$0.10–0.15/kWh.	US$800–US$1000/kW; energy cost US$0.10–0.15/kWh.

Source: Wolde-Ghiorgis, 2002

main features needed for choosing between diesel generation and wind generator plants.

The main limitation of electricity by wind generation is that wind speed is intermittent and highly dependent on daily statistical averages. Experience has shown that wind energy is preferably harnessed using at least two or more wind generators safely spaced in a wind farm. For the purpose of providing electricity to households, using wind energy from a single generator could be unviable and unreliable. Energy storage systems will be required if the generated electricity is to be utilized during night-time hours for lighting requirements. Despite these constraints, once its availability is established, wind energy nonetheless has an obvious claim to being the second-best option after diesel generation. In Appendix VIA.4 (p. 288), data are provided for a selected number of windy sites in Ethiopia. From these, sites suitable for introducing rural electrification using wind generators are indicated in Appendix VIA.5 (p. 289). The exploitation of wind energy will need to be taken as seriously in Ethiopia as in many other developing countries (Rajsekhar, 1999; Lew, 2000). While it is too early for EEPCO to be engaged fully in wind generator plants as a power producer, there are still sound grounds for seriously considering rural electrification schemes based on wind energy as alternatives to diesel generation at remote sites.

Rationale employed by the Ethiopian Electric Light and Power Authority (EELPA) in the past in opting for diesel generation

Cost and peak load factor considerations

From the 1960s to the 1980s, EELPA's alternative to grid extension as a means of rural electrification was to consider diesel generation. This was done either through direct intervention or by allowing independent producers. The rationale employed in taking decisions was to start from economic evaluations, whether in identifying prospective sites or in finally settling on the generating capacity. The two interrelated issues were therefore cost and peak load factor considerations. As distribution within local areas was in any case limited, transmission costs were not regarded as a critical issue. The cost of a rural electrification scheme was taken as US$0.12/kWh generated, excluding costs of transportation and fuel (World Bank, 1975). Some basic and detailed research will need to be conducted in the case of the experience of EELPA. None of the diesel station installations were based on cost recovery considerations, making them unattractive for village electrification. As to load factor (ratio of demand to generating capacity), it has remained below economic justification in the range 10–50 per cent. Actually, this range is typical for any rural electrification project (*ibid.*). With unrecoverable costs and low load factors as limiting factors, rural electrification in Ethiopia using diesel generation has therefore remained very slow. Consequently, critical scrutiny must be trained on the rationale employed in the past for relying only on grid extension or diesel generation. This will mean considering alternative schemes such as the harnessing of wind energy resources around sites with acceptable load factors. Again, there could also be instances for considering whether PV systems would be appropriate sources of electricity for needed applications.

Rural electrification: preliminary appraisal of RETs vs grid extension and diesel generation

Rural electrification provides the social and economic benefits of electric service to those deprived of it because they live outside existing service areas. Rural electrification provides long-range economic and social benefits to the national GDP by increasing the productivity of the rural sectors, including agriculture and related cottage industries that may be located in many administrative regions. To a less developed country like Ethiopia, that nevertheless possesses plentiful renewable energy resources, rural electrification is essentially one new field of investment among other initiatives to invest in new areas, particularly areas where living standards and productivity are very low. While rural electrification is gaining the attention of decision-making authorities and the support of the national utility, a number of questions are also emerging. Key questions are:

- What are the prospects of investments in rural energy development?
- What project justification procedures are appropriate given that investments will be aimed at income-generating activities and sustainable livelihoods?
- In justifying or rejecting a rural electrification programme or project, is the economic rate of return a relevant factor?
- If so, how can the investments be made cost-effective?
- What pricing and financial policies are appropriate, based on the experiences of other developing countries that have successfully planned and implemented rural electrification?
- If a rural electrification programme is going to be successful in Ethiopia, will it require new concepts as to organization, financing and management?

These are questions that have not been answered fully by the findings of the present study. Nonetheless, from the findings of a preliminary project design study dedicated to answering the questions, the prospects are that all RET options are feasible in comparison with the diesel option (Sharew *et al.*, 2001).

Electricity has not been extended into most rural areas of Ethiopia because the economic criteria cannot be satisfied in scattered and less-settled rural areas. The investments required have been too high to permit service to scattered settlements in villages and semi-urban administrative centres. To address this problem, an attempt has been made to compare the diesel generation option as a basic standard to grid extension, micro/ mini hydropower generation, wind power generation and applications of PV systems. For these four alternatives, preliminary and broad findings have been obtained, as discussed for each case below.

Grid extension option from a hydropower-based ICS for rural electrification in Ethiopia: a public initiative

In the eastern, central, southern, north-western and northern regions of the country, rural electrification through grid extension using 15 kV lines has been implemented. Rural towns within 50 km of the grid have been connected. Towns that were formerly served with diesel generators have also been connected to the national grid, and a new 33 kV medium voltage is being implemented to extend electrification up to 100 km from the grid. Outside this range, the only alternative for expansion is diesel generation. But this option has not been encouraging in view of the constant increase in fuel prices, and maintenance and operational problems. New options like the use of shield wire and capacitive coupling have been considered, but these schemes are yet to be implemented successfully. Of the two latter options, only the shield wire option will be implemented on the western end of the interconnected system (Ghedo–Nekempt–Ghimbi). The same option was also to be utilized on the Gilgel Gibe–Addis Ababa 230 kV transmission line in the course of 2003.

To determine demand, standard load forecast calculations are carried out for the residential and non-residential consumer requirements, and basic load forecasting methodologies are followed. Key factors like population size (greater than 5,000), household and industrial loads, and street lighting have been selection criteria. Inevitably, the population size criterion has excluded many rural settlements and villages, as the populations of most neighbouring rural communities rarely exceed 1,000 inhabitants: costs of grid extension equipment and transmission subsystems would not be justified at that level of uptake. This reasoning has also hindered the progress of the overall national electrification programme. To overcome the problem of finance, two recommendations for overcoming the recognized constraints are:

- encourage mobilization of community organizations, peasant farmer associations and high-population villages to raise money in saving accounts within specified periods of time; and

- promote the theme of sustainable rural livelihoods, so that non-profit and international organizations become actively engaged in rural electrification projects with cost-recovery financing schemes.

These are approaches that have been pursued successfully in many other developing countries. The fact remains, though, that costs may not be recovered easily and within short periods of time. Even so, rural electrification by grid extension or diesel generation is likely to remain, largely as a public initiative. This needs to be undertaken by the national utility in cooperation with the federal and regional governments on an equity basis. To overcome and/or minimize financial losses significantly, rural electrification by grid extension should perhaps be used strictly for powering electric pump sets for irrigation purposes. Lighting loads should be supplied by RETs or even by small diesel generators.

Micro/mini hydropower option: public/private initiatives

Agricultural production in Ethiopia, traditionally an agrarian country, has been and still is carried out mainly in areas remote from the national grid. Rural settlements are also found in locations that cannot viably be supplied from the ICS. Ethiopia is endowed with substantial micro/mini hydropower resources that could be harnessed (Wolde-Ghiorgis, 2001). Ideally, micro/mini hydropower resources at conveniently located sites would support rural development by providing one reliable source of electric power. Such units would form self-contained systems. Whether to use micro (1 kW–100 kW) or mini (100 kW–1 MW) generating capacity would be determined by sustainable demands for electric power. The enhancement of rapid local and regional agro-industrial development could be the deciding factor for investment. For the country in general, there is a need to introduce small-scale or cottage industries to supplement and support agricultural development.

The lesson from other developing countries (such as Nepal) is that micro/mini hydropower units can play a vital role in transforming rural life (Khennas and Barnett, 2000). In spite of the presence of viable potential, the investment needed for micro/mini hydropower schemes remains too high, however, for rural communities. The experience of developing countries that have succeeded in launching micro/mini hydropower schemes through cooperative efforts also provides lessons on harnessing this energy source. Funding could be sought either from government sources or through loans from banks and non-profit organizations.

Wind generation: public/private initiatives

Wind energy potentials in some parts of Ethiopia have been found to be viable for electricity generation (Wolde-Ghiorgis, 1988). There are wind energy resources that are also definitely adequate for water pumping applications in wider areas (CESEN, 1986b). It has been confirmed that there are indeed sites suitable for wind power generation (Sharew *et al.*, 2001). The issue, again, is how to seed initiatives in Ethiopia to introduce the technology of small-scale (100 W–10 kW) wind power plants. Such projects can be launched as pilot projects or demonstration units for the benefit of rural communities, as successfully achieved elsewhere (Piscitello *et al.*, 1998). Preliminary research on economic factors and technology options has provided the following options:

- Over a 20-year period, diesel generation is more expensive than wind power generation. Further, it is possible to reduce the investment cost on a wind energy development programme (for both power generation and water pumping applications).
- Assembly of wind turbines can be undertaken locally.
- Some components like inverters, battery charge controllers and even batteries can also be assembled locally and manufactured to reduce taxation rates.
- Importation of wind generators and more complex control units can be made exempt from taxes.
- Coordinating communities for the implementation of rural electrification around sites with the potential for wind energy could be established.
- Job opportunities could be created for people in rural communities after training for installation and maintenance work.
- Loans with minimum interest rates and longer pay-back periods can be extended to legally organized communities.
- Pilot projects could be designed and built to familiarize rural people with the benefits of utilizing wind energy.
- Interest and support from non-profit (or non-governmental) organizations could be canvassed for rural electrification programmes and projects.

The role of the public utility (EEPCO) could be decisive in accelerating the utilization of wind energy for power generation. Possibly the Ministry of Agriculture (MoA) might also promote the active involvement of regional rural agricultural bureaus, which could be urged to include the use of wind pumps for irrigation within the agricultural packages in a successful extension programme. The preliminary study also demonstrates that international experience exists for facilitating the needed technology transfer, provided there is policy support.

PV option: public/private initiatives

The preliminary study on the PV option has shown that low-power PV generation is viable in the rural areas of Ethiopia. Applications are for water pumping, lighting, refrigeration and communication. As noted earlier, two key problems have been identified: high costs of PV units, and a need for battery storage in lighting applications. Critical examination of standard studies of PV applications has led to the following recommendations as the major outcome of the study (Foley, 1995):

- Financial mechanisms should be developed in Ethiopia to facilitate long-term loans to cover investment costs.

- Pilot projects at very low power rates (50 W–250 W) will need to be prepared to train rural communities in using PVs.
- Taxation on PV units and components has to be reduced to encourage the use of the technology, which is expensive.
- In the long run, local enterprises could be encouraged to assemble and manufacture components of PV systems, as they do in many other developing countries.

In relation to the PV pumping systems, village communities succeeded in installing 1,000 PV pumps as part of a project that was funded by international donors (Mali/UNDP, 1999).

Conclusions: decentralized vs centralized modern energy supplies

Decentralized private sector energy production and distribution in Ethiopia have a better rate of success in delivering modern energy for economic activities and household uses. Even so, the ongoing trends seem to show that it is only the relatively higher-income rural people that are the beneficiaries. The vast majority of low-income rural people appear to remain permanently dependent on biomass energy sources. Therefore, the question of non-use of modern energy services by the rural poor population of Ethiopia will remain. Consequently, it is difficult for the poverty of the rural poor to be reduced when access to modern energy services is limited in rural areas.

For rural communities, available quantitative data indicate that the private energy sector is more successful than the public sector in the provisions of modern energy services. Nevertheless, there is the clear danger that without favourable policy directives or price controls, the issue of minimum equity may not be addressed. In the foreseeable future, rural people on very low incomes will not benefit from the successes of private energy provision.

Hypothesis 2: Income-generating activities vs domestic energy use

Impacts of modern energy uses in selected rural settlements

To make a meaningful but qualitative appraisal of the impacts of modern energy services on income-generating and domestic activities in the rural areas of Ethiopia, it was necessary to resort to:

- reports and bulletins of the Central Statistics Authority (CSA) of the government of Ethiopia; and
- a survey study of modern energy services in selected rural settlements.

Both data sources were found useful for two reasons. The CSA reports and bulletins provide indicators that can be used directly and indirectly to estimate the impacts of modern energy services on the daily lives of rural communities. While the quantitative indicators have not been directly related to energy utilization patterns in rural areas, qualitative findings of direct interest have been deduced from direct and indirect impacts of modern energy services. These are presented below (pp. 240, 242). Then, in the examination of a field survey, similar findings have been deduced (p. 243).

Qualitative analysis of direct and indirect impacts on income-generating activities

CSA reports and bulletins (2000) point to eight impacts of modern energy services on income-generating activities.

1 IMPACTS ON INCREASED NUMBERS OF FLOUR AND OIL MILLS IN RURAL AREAS OR IN NEAR RURAL TOWNS

Direct impacts (positive). In relation to the drudgery of rural life, it can be asserted that the impacts of flour and oil mills are positive for the following reasons:

- Faster and more refined grinding of cereals and peppers has been made available to rural women and communities (CSA, 1997).
- Desired quantities are milled at affordable costs and at sites located not far from villages.
- Higher-quality processed edible oils have been provided for both rural and urban communities.
- Both flour and oil mills are profitable to the private owners (CSA, 1997).
- Financial benefits to commercial establishments – small-scale enterprises such as food and beverages trading houses – during dry and rainy seasons have been improved.
- Storage of unmilled cereals and grain in traditional stores, prone to attacks by rats and insects, has been reduced.

Indirect impacts on socio-economic activities (positive). There are also indirect positive impacts on social activities, the important ones being the following:

- There is a saving of time and energy – for women, who grind cereals, and for men, who pound oil seeds – that can be devoted to home-based handicrafts and improved child care.
- Supplies of food and traditional beverages for catering to rural customers are significantly expanded.
- The quality of household life among well-to-do villagers has been significantly improved.
- The slow but steady trend towards modernization has been facilitated.

2 Impacts on relatively improved modern transport systems (positive)

Fleets of diesel-powered buses and lorries for transporting goods and passengers from rural to urban centres have increased steadily. These much-needed transport system improvements, together with expansions in rural road infrastructure, have had positive direct and indirect impacts.

Direct impacts on income-generating activities (positive). Direct positive impacts of modern energy services on the income-generating activities of the rural poor include the following:

- Agricultural products (cereals, oil seeds grains, vegetables, cash crops) are transported much faster than when farmers use donkeys, horses, mules, camels and human power. Products move in greater volume to nearby towns and more distant markets located in major urban centres.
- Transport of goods to and from villages have also been partially solved, despite lack of all-year and all-weather rural roads.
- Although too small in comparison with other developing countries, increased expansion of trade among inter-urban and inter-regional market centres is taking place.
- There are increases in exports of cash crops such as coffee (CSA, 2001c).
- Easier and faster travel is offered to urban and rural dwellers who use buses and hired lorries to and from market and rural towns. Legal processes, the sale of produce, attendance at health centres and the purchase of needed (and affordable items) are thus made easier.

Indirect impacts on socio-economic activities (positive). Five indirect impacts of modern energy services on rural socio-economic activities are clearly positive:

- Improved social contact among family members, clans and friends is facilitated by modern transport services.
- Faster transportation of patients to health centres is being made possible.
- Expansion of trading and trade centres is also dependent on uses of petroleum products (CSA, 2000d).
- Greater migration of rural youth into urban centres seeking higher educational opportunities is a continuing trend.
- Improved banking and telecommunication services are steadily growing in rural areas (CSA, 2000d).

3 Impacts of modern energy services on agricultural activities and production

Key indicators show that the impact of modern energy use on agricultural production has been significant in the richer farmlands. A significant number of renewable and non-renewable energy technologies are being used in agro-industrial enterprises in various parts of Ethiopia.

4 IMPACTS OF MODERN ENERGY SERVICES ON RETAIL PRICES AND TRADES

Monthly average retail prices of goods and services in rural areas are monitored by the CSA regionally and nationally (CSA, 2000b; CSA, 2001a). The price fluctuations are mainly dependent on supply and prices of petroleum products, monitored every three months in line with international oil prices. The impact of modern energy services is significant, in that market prices of goods and services vary with prices of petroleum products.

5 IMPACTS OF MODERN ENERGY SERVICES ON SMALL-SCALE ENTERPRISES

The only source of useful data is a CSA report on cottage/handicraft manufacturing industries survey (CSA, 1997). Results from the report indicate that modern energy services have had a significant impact on direct production of goods. The outputs are dependent on the skills of craftsmen in addition to the working materials. Modern energy uses also have a significant impact on the growth of commercial establishments focused on food and beverages supplies.

Qualitative analysis of direct and indirect insignificant impacts of modern energy uses on domestic activities

On domestic activities, the following four insignificant impacts of modern energy services have been assessed.

1 ABSENCE OF VISIBLE IMPACTS ON DOMESTIC USES

In rural Ethiopia there have been neither serious efforts to introduce improved wooden stoves, nor noticeable innovations promoting modern energy services and technologies to rural communities with the aim of improving efficiency and energy conservation. All modern energy improvements (disseminations of improved charcoal and wood stoves, for example) are focused on main urban centres. Kerosene stoves are little in evidence except in semi-urban centres, because prices are beyond the reach of most rural poor people.

2 BARELY TANGIBLE IMPACTS ON DOMESTIC LIGHTING IN RURAL AREAS

The CSA reports give ample figures and data on the use of energy sources for lighting in rural households. These range from traditional fuels to indigenous candles, modern candles and the kerosene and diesel used for lighting with wick, lantern and pressure lamps (CSA, 2001a). Electric lighting in rural households is very rare.

3 INSIGNIFICANT IMPACTS ON IMPROVEMENT OF QUALITY OF RURAL LIFE: REFRIGERATION, RADIO, TV, AND SUPPLY OF POTABLE WATER

The use of refrigerators, radios, TVs, and domestic appliances (pressing irons, for example) is still uncommon among rural communities in Ethiopia. Settlements that are relatively richer or nearer to major urban centres do own some of these amenities. However the CSA report regarded them as insignificant.

4 OVERALL ADVERSE IMPACTS ON THE ENVIRONMENT DUE TO LACK OF MODERN ENERGY SUBSTITUTES FOR TRADITIONAL ENERGY SOURCES
Ethiopia's total dependence on traditional energy resources is exhausting its fragile ecosystem. One cannot overemphasize the point: the need for cleaner energy substitutes and supplements is pressing. Decreasing wood resources may result in Ethiopia facing an energy crisis that will be difficult to reverse and control effectively. Adverse impacts on the environment and ecosystem are obvious, and yet nothing serious or tangible is being done to reverse an alarming situation.

Impacts of modern energy services on rural life: a case study

A case study of the impacts of modern energy services on rural settlements in Ethiopia has been attempted using a semi-qualitative approach. It is based on a field survey of rural electrification with rural industries and other modern energy services. The survey was conducted to examine the broad impacts of modern energy services on socio-economic conditions (Tesfaye, 2000b). The physical features and climatic conditions in the different regions of Ethiopia vary greatly; it would not be possible to expect similar impacts everywhere. Rural areas nearer to urban centres have much easier access to modern fuels (kerosene, diesel oil, and even electricity). In localities far from centres of distribution for petroleum products and electricity the impact of modern energy supplies is limited. Between the two extreme situations there are rural settlements that offer varying levels of modernization for comparison.

Features of the settlement area selected for impact assessment

The surveyed villages and rural towns are located in the southern region of Ethiopia within an agro-climatic zone classified as cool highland where the altitude is above 1,500 metres above sea level, mean annual temperature is 25^{O}C, and mean annual rainfall is 1,500 mm. The economy is based on smallholder farming where farmers own one hectare or less and cultivate cereals and a local banana-like tree whose roots are ground and baked as bread. Some sub-districts are also producers of coffee and fruits earning cash income for households considerably higher than other rural areas. There are urban centres whose economies are based on agriculture and the rural population for inputs and markets.

There are varied services in the rural towns, including food and drink houses, mills and handicrafts, which need agricultural inputs, and markets for services provided from and to the rural population. As shown in Table 15.2, five settlements were first chosen for the field survey, but one was omitted from household sampling. A total of 62 households, ten commercial establishments (providers of services like drinks, food, overnight accommodation), and four grain-milling enterprises were included in the overall survey. Two settlements are rural towns and the other two are villages. All are in the same region, about 300–350 km south of Addis Ababa, and within 20–40 km of Awassa, the regional capital of the Southern Nationalities and Peoples Region, one of the 11 regions of the Federal Government of Ethiopia. From the vegetation point of view, this is one of the few areas remaining in Ethiopia that has not been severely degraded ecologically and environmentally by deforestation.

Table 15.2 Impacts assessment: important features of the surveyed settlements

Settlement features	Settlement type				
	1 Rural town, and area capital	2 Market town	3 Village	4 Village	5 Rural, scattered
Name	Gesuba	Gunino	Borja	Bokola	Lasho
Population	4,000	3,000	~ 1,000	~ 500	NA
Agro-economic activities	Subsistence	Subsistence	Cash	Cash	Subsistence
Houses/households	700	500	~ 200	~ 100	~ 200
Distance from local capital (km)	0	15	15	20	15
Distance from nearest town (km)	0	0	10	3	15
Distance from all-weather road (km)	7	11	1	0	0
Number of grain mills	7	0	1	None	None
Other small-scale industries	None	None	None	None	None
Rural hotels	7	7	None	None	None
Foods and beverages houses	66	65	10	15	1
Shops	~ 5	14	~ 5	5	1
Clinics	1	1	None	None	None
Schools	2	1	1	1	None
Number of sample households	19	17	11	None	15

Source: Tesfaye, 2000b, with some adaptations from Wolde-Ghiorgis, 2000.

The main features of the survey area in terms of the availability of modern energy services and the existence of productive activities are summarized below (Tesfaye, 2000b).

- Two of the settlements are within an area that produces cash crops including coffee, fruit and a mild tranquillizer plant. The plant leaves (chewed for the juice) are harvested for export and domestic consumption. The other three settlements are dependent on subsistence farming based on small farms.
- Except in the hotels, no settlement has access to electricity, publicly or privately owned – although one of the towns at one time had a diesel generator that is no longer functional.

- No settlement has a petroleum distribution station. Fuels were being distributed through retailers who buy from distribution stations in the major towns and sell to rural people.
- The only industrial activity in the settlements, was grain milling which was confined to the larger towns.
- Social services, including schools and clinics, are also available only in the larger towns.

Using detailed questionnaires for households, the prevailing energy consumption patterns in the settlement areas were examined. The resulting impacts on (1) productive and (2) domestic activities are given below.

1 Impacts on income-generating activities in the selected settlement area: a qualitative appraisal

As indicated earlier, the key impacts of interest within the context of income-generating activities are:

- grain milling using diesel-powered mills;
- commercial establishments; and
- social welfare services.

Significance of the impact of modern energy for grain milling on development in the selected rural area. Rural women in Ethiopia grind cereals and grains into edible flours manually, using stones. The indigenous grinders are present in each rural household. Women also pound red pepper needed for preparing the stew that goes with the local bread types. At the end of the nineteenth century, great efforts were made by the government of Ethiopia to introduce modern and conveniently located flourmills. But success has largely been confined to major urban centres by the higher poverty levels of rural communities. Agricultural processing industries (grain mills, oil mills and coffee hullers) have remained the dominant small-scale industry subsector. In general, though, in rural areas grain grinding, even now, is done at home (Abegaz *et al.*, 1990).

In the surveyed settlements, the only small-scale industries found were thus grain mills. Although the larger towns also have bakeries and wood-working workshops, these are small, and are usually classified as part of the informal sector. Seven grain-milling enterprises were found in Settlement 1 (Geshuba town), but 12 mills were in operation as some of the establishments own more than one mill. The second settlement (Gunino town) has 11 mills, but the third (Borja village) only one. Not all these mills were operating during the field survey. The main features of the diesel engines, capacities and constraints are outlined below (Tesfaye, 2001).

- Capacities of engines range from 17.6 kW (23.5 HP) to 52.5 kW (70 HP).
- All grain mills operate under full capacity, limited by market size and the lack of spare parts.

- Diesel fuel consumptions reportedly ranged from 20 litres per day to 800 litres per day, depending on the capacity of the establishment.
- Milling charges vary from 4 Birr (US$0.53) per 100 kg to 15 Birr (US$2) per 100 kg, varying with the seasonal incomes of rural communities.
- The harvest season (December–January) is the peak milling period, when both grains and cash are available to customers in the towns and the rural settlements around them.
- Then the milling operation decreases to the rainy season (June–August) when competition among the millers to attract customers is said to be very fierce.

There are rising commercial constraints, as grain mills are now being installed in nearby rural areas and millers in the towns are losing market. New millers are also installing machines in the town and competing for the limited market.

The survey found that grain mills account for 87 per cent of the total number of employees and 67 per cent of the capital employed in small-scale industries. These are the only types of industries using mechanical power in the settlement area. The other industries (bakeries, for example) use manual power, tools and woodfuel for heat. From the qualitative findings indicated above, it is concluded that the selected area has demonstrated a significant impact of modern energy and technology on economic activities closely related to the agricultural resources of the selected survey area.

Significance of the impacts of modern energy on commercial establishments in the selected rural settlement area. The typical commercial establishments in semi-urban and rural towns in Ethiopia are centred around food catering, the sale of beverages, lodging services and tailoring. There are also trading activities involving the processing of agricultural products like oil pressing and coffee washing, as well as the drying and cleaning of animal skins for further processing into leather goods. It is certain that trends of modern energy use are having impacts on the improvement of the quality of services and supplies. In general, it can be said that the impacts of modern energy services on commercial establishments in the selected settlements are significant and positive.

Impacts of modern energy uses on social welfare services in the selected rural settlement area. Social welfare services include the provision of improved health services, greater educational opportunities (at the primary level), and water supply for human and animal drinking. The preliminary study could not focus on the impacts of modern energy services on such facilities, owing to a general lack of awareness of the benefits of access to modern energy services in the rural areas of Ethiopia. Still, it can be said that the rural communities are moving away from traditional medicinal practices and resorting to better health services. In general, government and non-governmental organizations run health facilities at zero or nominal fees. Increased numbers of children are also going to the primary schools. Water supply for drinking remains unchanged by the use of modern energy: water is still hauled by women and children from shallow wells or seasonal streams. While the survey did not establish whether a piped water supply is being provided, it can only be available in commercial establishments. Water for animal use is also found in surrounding streams or ponds. We may conclude that modern energy provision is likely to have impacts on social welfare services in the selected settlement, without bringing these services up to accepted standards.

2 Impacts of modern energy on domestic activities

Tangible impacts of modern energy on rural lighting. With no electricity supply in the settlements, lighting was found to be mainly dependent on kerosene, although candles are also being used in the towns. Lighting is required in the evenings for social activities. Wick and lantern lamps are utilized for three to five hours of an evening after dark descends. The survey noted that quality and duration of light was dependent on the availability of cash to a given household. Cash incomes rise during the harvest season and after the sales of cash crops. Then incomes decline when there are slumps in the food and beverages business, or overall trading activities. In larger towns, where incomes are regular and higher, the use of lamps becomes uniform through the seasons of the year. The mean monthly volume consumed and the amount spent on kerosene by households in the surveyed settlements varied. It ranged from two litres and Birr 5 (US$0.58) for the scattered settlements, to 4.8 litres and Birr 12 (US$1.40) in the largest settlement. The government fixes the price of kerosene in urban centres. Secondary retailers, who buy fuel from distribution stations in barrels, supply petroleum products to smaller towns.

At the third stage, small retailers in the selected area buy kerosene from the secondary retailers. They then sell kerosene in quantities of a third of a litre or less. Monthly kerosene consumption for those using lanterns and pressure lamps was found to be ten litres at a cost of about Birr 20 (US$2.34). The commercial establishments buy their lighting fuel in larger volumes than households and therefore at lower cost. Some of the hotels also own small gasoline generators of 2.5 kW capacity or slightly larger, providing electric light for 10–20 rooms. There was no use of solar torchlight, batteries or PV panels for lighting. The impacts of modern energy on rural lighting in the selected rural study area were therefore tangible. With the planned extension of the supply of electricity from the national grid by EEPCO, the administrators in the settlements are hopeful that a viable rural electrification project will soon be implemented. The necessary applications and financial contributions that are required have already been completed.

Insignificant impacts of modern energy on quality of household facilities. In all of the surveyed households (and in the settlements), the impact of modern energy services is limited to kerosene use for lighting. Wood is used for cooking in settlements, and both wood and charcoal are used for cooking in the rural towns. In the rural settlements, women and children collect wood from distant sources, usually once or twice a week. It is also purchased in some rural settlements. The average wood consumption is about 1 kg per day per person, using unimproved three-stone stoves. In the towns, with the use of improved charcoal stoves, about 20 kg of charcoal is used per household. This is equivalent to about 160 kg of wood. Expenditure per month on traditional fuels ranges from Birr 5 (US$0.58) in scattered settlements to Birr 70 (US$ 8.18) in rural towns. Use of kerosene and improved wood or charcoal stoves wwas not observed during the survey period.

Insignificant impacts of modern energy on the quality of life of the rural poor. The general absence of improvements in the quality of rural life through modern energy use was reflected in findings for the selected settlements. However, as the selected area is relatively richer than other rural settlements, there are a few radio owners and some TV owners in the local hotels. The impacts are insignificant, however in comparison with those found in urban centres. In households, there is the additional inconvenience of smoke from the open-hearth fires and from wick lamps (especially when diesel oil is used). Lack of electric lighting has been noted, and one should also note the hazard of installing electric wiring in small, window-less huts with thatched roofing. Therefore, the viewpoint commonly held is that electricity is only appropriate for dwellers in urban or bigger houses. The supply of potable water is the responsibility of women, along with the collection of firewood and in addition to the routine handling of household chores.

Conclusion: comparative impacts of modern energy on rural areas

The use of modern energy services in rural Ethiopia has a greater positive impact on income-generating activities than on domestic uses. This is so despite inattention to the rural energy problem in the country for three decades, particularly after the increase in oil prices in the 1970s. Elements of modernization have filtered slowly into the domestic sector through the use of modern fuels for lighting. The proposition has therefore been proved, for the following three reasons:

- Agro-based, small-scale industries (flour and oil mills, for example) have been expanded and successfully operated as business ventures, benefiting entrepreneurs and rural communities.
- With the expansion of rural road infrastructures, transport facilities and systems have been built, assisting the distribution of appropriate petroleum products in many rural areas.

- Trends in the establishments of rural commercial enterprises have reflected the provision and distribution of modern energy services, especially petroleum products.

On the other hand, except for the diffusion of kerosene for rural lighting, domestic activities have remained practically untouched by modern energy services. Four separate indicators can be identified to exemplify this absence of a positive impact:

- lack of dissemination of improved wood and charcoal stoves in rural settlements;
- inadequacy of rural electrification schemes, even at project levels, using non-renewable and renewable energy sources;
- absence of modern energy substitutes or supplements (such as imported or locally mined coal) for decreasing traditional energy sources; and
- insignificant improvement in the quality of life in terms of entertainment, social services, education, and communication, in contrast with rapid developments in these aspects of life in the advanced developing and developed countries.

Based on the qualitative findings, two main conclusions can be drawn.

- Although on the whole the provision and distribution of modern energy services are far below the needed quantities and volumes, the impacts on income-generating activities are greater than those on domestic uses.
- Impacts on rural development have been inconsequential in comparison with the results achieved in many developing countries because the provision and distribution of modern energy services to the rural areas of Ethiopia have not been substantive.

Hypothesis 3: Prioritizing components for the promotion of RETs

Farmers, village artisans and rural women in developing countries do not promote RETs: this also affects rural Ethiopia. Just as applications of fertilizer to infertile and semi-arid farmlands have yielded increased production through successful extension programmes, so the use of modern energy for motive power, heat and lighting can be expected to bring significant changes in socio-economic benefits (Wolde-Ghiorgis, 2000). Beyond the economic benefits and poverty reduction, no doubt improvements will follow in the quality of rural life. However, prioritizing the promotion of RETs needs to be tied both to viable productive activities and to the availability of renewable energy resources.

Despite the availability of renewable energy sources, the use of appropriate RETs is practically absent throughout rural Ethiopia. Very few mini-hydro plants have been built and operated by the utility. Some wind pumps have also been installed and managed by donor agencies, and there are also a number of isolated PV units. There are no noticeable RETs in the country, nor is there a national programme for promoting RETs in rural communities. So, using available data and studies, an attempt has been made to to show that the prioritization of RETs can be justified at this stage of economic development in Ethiopia. This can be realized only if their application can be tied to needed developments in agriculture, agro-industries, rural industries, cottage industries and commercial services. The analysis to be presented is thus a combination of needs (for modern energy inputs or services) and productive activities. The findings to be derived can be refined and improved by using more relevant data on modern energy production and distributions in wider rural areas.

Prioritizing the promotion of RETs in agriculture

Rural income-generating activities are critical for developmental reasons. The most important of these is agriculture. Inputs to the sector in the form of fertilizer and high-yield seeds have been growing rapidly in the last decade, with reportedly marked improvement in productivity. Even higher yields and marketable output are possible with mechanical inputs for cultivation, irrigation, and crop preservation. While the dissemination of RETs has not gone as fast as needed, it is possible to prioritize applications, as discussed below.

Cultivation

Improved energy inputs for cultivation may be made with either transitional or modern technologies. In the former, productivity gains are possible by enhancing productivity of human and animal power through more appropriate tools, such as more efficient ploughs; in the latter case, motorized cultivators running on petroleum fuels are a substitute for animate energy, with much higher yields. RETs are not seen as viable substitutes for commercial cultivation in Ethiopia.

Irrigation

Development of surface and sub-surface water for agriculture is recognized as fundamental for increasing farmers' incomes and ensuring the food sufficiency of the country. To date, about 11 per cent of the cultivable area in the country is utilized and only 1 per cent of that by irrigation (CSA, 2001b). Little effort has been made to develop the country's water resources for this purpose. To ensure food security for farmers and food self-sufficiency for the country, aggressive interventions are required in the development and dissemination of water development technologies – as mentioned above, this would complement and extract full value from other inputs such as fertilizer and high-yield seeds. With irrigation, grain production can further be increased, with potentially double and triple cropping, and with cash crops including vegetables and fruits. For the livestock sector, too, pumped water would mean increased productivity in cattle. Water-pumping technologies, however, have not been as aggressively promoted as fertilizer, although they may actually be more important because they not only improve but also ensure production. In many parts of Ethiopia seasonal rains have become unreliable. Sometimes farmers' risks may actually increase with higher inputs of fertilizer when it fails to rain, in addition to crop losses.

Experiences in India and Pakistan shows that the demand for pumped water increases fast. Demand has been met almost exclusively with diesel pumps, requiring considerable investment on pumps and fuel.[3] This route may be insupportable for Ethiopia, where practically all modern capital and recurrent inputs are imported. The best means would be to develop indigenous energy resources and technologies. The renewable alternatives for pumping are human/animal, solar and wind energies. Pumps using human and animal power are appropriate for low water demand, mainly for pumping village potable water from shallow and low-depth wells. On the other hand, wind and solar pumps can be used for larger water demand, and electric pumps can be used to tap deep wells.

Solar energy availability is above 5 kWh/m^2 in the highlands, where farming is generally practised. In the lowland pastoral areas insolation is even higher. The average insolation for the dry months, where irrigation water would be needed, is close to 6 kWh/m^2. However, PV pumps are competitive with diesel pumps only for demand up to 3 kWh/day (even at high diesel prices of US$0.5 per litre), which is adequate for potable water supply purposes.

Wind energy potential in the pastoral farming areas is high, with average wind speeds above 3.5 m/s at heights of 2 metres above ground. Wind pumping may be the least-cost option for potable water and irrigation pumping in the livestock farming areas of Ethiopia, including Somalia, the Afar, and Borena. Large-scale development of improved agricultural machinery would mean large capital and recurrent expenditures on devices and energy (tractors, pumps, harvesters and diesel).

DRYING

Drying of crops is one method of preserving quality and extending the life of produce; another method is refrigeration. Crops are usually sun dried in the open air. According to Kristoferson and Bolkalders (1991), this method of drying has serious disadvantages among which are:

- product quality is not optimized, as temperatures cannot be controlled;
- crop may not be protected from rain, dust, rodents, birds and insects.

[3] For example, in Pakistan it has been estimated that 30 per cent of all petroleum fuel consumption in the country went for tractors and irrigation pumps. Irrigation pumps have been shown to account for 20 per cent of the petroleum fuel consumption (Tesfaye, 2000b).

Due to these and other shortcomings of the traditional method of drying, controlled drying is essential, and is customarily effected by the use of fossil fuels or electricity. These are, however, not accessible or affordable on most small-scale farms, where production and hence the demand for energy are low. The use of solar dryers is, therefore, very appropriate.

As the important agricultural products in Ethiopia are cereals for domestic consumption and coffee and tea for export, appropriate drying technologies for these should be developed and disseminated. As the disposable cash income of subsistence farmers is limited and dryers are used only intermittently at low capacity, they need to be cheaper and easy to construct with local materials.

Illustrative comparisons of the traditional direct solar dryer and the cabinet and indirect chimney type dryers are made in Table 15.3. As shown in the table, the thermal efficiencies used for the traditional solar dryer and for the cabinet dryer are from actual experiments conducted on similar dryers (Bassey and Schmidt, 1986).

Table 15.3 Illustrative comparisons of the performances of traditional and improved solar dryers

Dryer application	Energy rate	Traditional sun dryer	Cabinet dryer	Traditional sun dryer	Cabinet dryer	Indirect chimney
Crop to be dried		Maize	Maize	Coffee	Coffee	Coffee
Drying period		Aug-Oct	Aug-Oct	Apr-May	Apr-May	Apr-May
Available solar energy	kWh/m^2/day	5.1	5.1	5.8	5.8	5.8
Efficiency of dryer (at 22–30°C, relative humidity 55–65%)		15%	25%	15%	25%	30%
Effective available energy	kWh/m^2/day	0.8	0.8	0.9	1.4	1.8
Moisture content to be reduced from–to:		22–13%	22–13%	55–11%	55–11%	55–11%
Drying area and duration required % (improved dryers compared to traditional dryers)		100%	60%	100%	60%	50%

Source: Tesfaye, 2000b

Solar dryers have advantages in space saving and in the preservation of important qualities in crops, and they can be used during the wet season. However, for most subsistence farmers in Ethiopia these advantages may not be significant in current circumstances: they do not have constraints of space, their production is not high, and the crops they produce are not especially prone to losing nutrients and other qualities. It seems unlikely, therefore, that smallholder farmers will adopt drying technologies widely at present. But with more diverse production, including vegetables and fruit, and with out-of-season production possibly with the help of pumps, the need and demand for faster drying and for quality preservation will become important. The case for large private or government exporters of cash crops, such as coffee and tea, however, is different from that of subsistence farmers. These large-scale farmers have the capacity to invest in direct or indirect solar dryers with auxiliary commercial energy systems. As the volume of production handled by them is high, and as the products will need to be of good quality for export, improved solar drying can be used beneficially.

Livestock water supply

Ethiopia has one of the largest livestock populations in Africa and a sizeable proportion of the rural population derives its livelihood from livestock rearing. Livestock farming in Ethiopia relies on fodder from natural vegetation and on seasonal rains. Fodder cropping is not practised and water harvesting is not widespread (UNDP/RRC, 1984). This system of production suffers from constraints of forage and water during the dry season, which is exacerbated when the rains fail. Furthermore, overgrazing and rangeland encroachment by sedentary farmers contracts the land and water resources available to pastoral communities.

In the rangelands, drought alternates with normal seasons and the need for security reserves of water and fodder is essential. Boreholes for water reserves could be located at strategic points. Without such security, people and cattle move around for often low and sometimes uncertain gains. In the process, useful time is wasted and production is lost. Livestock farming areas of Ethiopia lie in the lowlands of the east, south-east, south and west respectively, on the borders with Eritrea, Somalia, Kenya and Sudan. The location of these areas places them beyond easy access to electricity and petroleum fuels. On the other hand, solar and wind resources are more available here than anywhere else in the country. In the Afar and Somalia regions in the east and south-east, solar insolation is 6 kWh/m^2/day, and wind speeds are in excess of 5m/s. Wind pumps are the cheapest options for sites where mean wind speeds exceed 3.7 m/s for the critical months in the year (Argaw, 1992). As illustrated in Table 15.4, wind pumping is thus cheaper than diesel in the pastoral areas of Ethiopia. Wind pumps have the added advantage that local production is possible. PV pumps, for which the most costly components are panels and either direct current or alternating current pumps, will be useful.

Table 15.4 Comparison of diesel and wind pump costs

Cost items	Cost in US$/m^3 of water pumped	
	Diesel	Wind pump (@ wind speed v = 3.7 m/s)
Annualized investment cost	0.16	0.30
Annual fuel cost	0.20	–
Operation & maintenance cost	0.06	0.06
Total cost	0.42	0.36

Note: Fuel price = US$0.30 per litre
Source: Argaw, 1992

Energy demands for other services in the livestock sector include the processing of milk and meat, refrigeration, and transport to market. Meat processing is carried out mainly in large, mostly urban-based industries and commercial energy is used. Milk is processed using human power at the household level. With increasing urbanization and larger markets, centralized processing may become dominant. Hydropower-based and PV technologies will be viable for decentralized generation of electricity.

Limited roles of RETs in the development of agro-industries

The application and prioritizing of suitable RETs was considered by selecting coffee and tea plantations and production as vital agro-industries. Findings are summarized below.

COFFEE PLANTATIONS AND ENERGY USE

Smallholder farmers mostly handle coffee production in Ethiopia. There are also two large government-owned coffee plantations in the south-west of the country. Close to 4,400 tons of processed coffee was produced in 1993 on 11,000 hectares of land by these two plantations, as shown in Table 15.5. Energy service requirements in coffee plantations are diverse and include the following energy supports:

- energy required for the production of coffee for inputs such as land preparation, irrigation water, and crop protection;
- energy requirements for post-harvest operations that include pulping, fermentation, washing, pre-drying, drying and hulling (ARDCO, 1995);
- transport and other services.

Cultivation and irrigation in the plantations is powered by diesel engines, post-harvest processing by diesel, electricity or solar energy. For the coffee plantation shown in Table 15.5, pulping and hulling are done with electric mills. The cleaned coffee is dried using thermal energy from dryers working on diesel and also with solar energy. The demand for electricity and petroleum fuels is high in coffee plantations. Coffee plantations are far away from central electricity supplies and the enterprises need to install large diesel generators for both productive purposes and general use by employees. Plantations are usually situated close to adequate water sources so as to benefit from irrigation. Many workers are employed, as either permanent or seasonal labourers. There is a high demand for electricity, but limited financial and technical resources restrict the scope of diesel-based generation. The availability of hydropower resources make such plantations prime targets for micro/ mini hydropower development.

Table 15.5 Energy use in the Bebeka coffee plantation (south-west Ethiopia), 1993

Production (Farming activities)	Unit	Estimates Raw	Processed	
Production (washed coffee)	Tons	8,553	1,426	
Production (dry coffee)	Tons	2,135	712	
Production (total)	Tons	10,688	2,137	
Fuels used	**Diesel**	**Gasoline**	**Electricity**	**Wood**
Unit	**Litres**	**Litres**	**KWh**	**kg**
End uses				
Farm machinery	85,372			
Tractors	68,737			
Other	16,635			
Pumps	11,773			
Driers	1,561			
Coffee pulper (wet)			18,897	
Coffee pulper (dry)			9,434	
Trucks & other vehicles	180,234	38,769		
Other uses	8,345		608,980	331,240
Total	287,285	38,769	637,311	331,240
Electric generators	250,811			

Source: ARDCO, 1995

Tea farms and energy use

There are three large government tea farms in Ethiopia. An energy demand survey made in one of these plantations in 1993 is shown in Table 15.6. The energy inputs and processes include:

- diesel for tractors and pumps;
- electricity for pumps and pre-drying of fresh tea (20–30 per cent of the moisture in tea is removed);
- electricity for crushing tea; and
- wood-fired boilers for drying at 80–120^{o}c.

The last process (drying with wood boilers) is highly energy-intensive. For every kilogram of dry tea leaves, the boilers consume 1.7 kg of wood. To meet this high requirement for wood, the tea plantations also keep

Table 15.6 Energy use in the Gumero tea plantation, 1993

Area cultivated:	860 ha
Eucalyptus plantation:	730 ha
Production (made tea):	1,056 tons (estimated from boiler wood input: 1.7 kg of wood per kg of produce)

	Fuel			
End uses	Diesel (litres)	Gasoline (litres)	Electricity (kWh)	Wood (kg)
Farm machinery	86,400	0	0	0
Tractors	86,400			
Pumps	960		3,312	
Fans			190,085	
Crushers			NA	
Boilers				1,795,250
Trucks & other vehicles	42,000	29,700		
Other uses	19,480	843,330		
Total	148,840	29,700	1,036,727	1,795,250
Electric generators	408,000			

Source: ARDCO, 1995

large fuelwood plantations. For the data given in Table 15.6, the ratio of tea area cultivation to fuelwood area is about 1 : 1.2. Although wood produced in the plantations is sustainable, tying up such a large area for energy production is constraining expansion of the area for tea production. Modern energy (oil) can be a substitute for boiler wood, as the boilers installed in the plantations are dual-fuel boilers acquired with such constraints in mind. Fuel oil requirement for oil-fired boilers is about 0.2 litres per kg of dried tea leaves. Like coffee plantations, tea plantations are also usually situated close to rivers and can develop mini-hydro sites for electricity production.

Applications of RETS in launching the development of rural industries

Small-scale industrial operators are concentrated in the larger rural towns. In the villages, only informal, very low-scale operations are carried out. The demand for industrial services in the villages is limited both in quality and volume of products. This usually translates into lower energy demand or intensity for village operations compared to towns. Qualitative comparisons of uses of non-renewable and renewable energy technologies for rural industries are illustrated in Table 15.7.

Formal small-scale industrial activities in rural areas are licensed enterprises, as opposed to informal, unregistered and unlicensed, home-based industries. These consist of grain and oil mills, coffee dehullers, sawmills, wood and metal workshops, auto garages, bakeries, and brick and block making. From one sample survey, there was one grain mill for 2,500 people, with mills accounting for two thirds of the total number of small-scale industries (ARDCO, 1995). This corresponds approximately to 1.5 industries for 2,500 people (or 0.6 industries per 1000 people). Extended to the whole country (for a rural population of 55 million), this corresponds to about 30,000 small-scale enterprises in rural and semi-urban areas.

Table 15.7 Qualitative comparisons: uses of non-renewable and renewable energy technologies in rural industries

Industry	Town (T) or Village (V)	Formal (F) or Informal (I)	Energy used	Renewable energy technology options
Grain and oil mills	T, V	F	Diesel	Micro-hydro electric or mechanical
Coffee processing	T	F	Diesel	Micro-hydro electric or mechanical
Lumber mills	T, V	F	Diesel	Micro-hydro electric or mechanical
Brick and	T			
block making	T	F	Wood	Improve efficiency of kilns
Bakeries	T, V	F, I	Wood	Improve efficiency of ovens
Wood & metal workshops	T, V	F, I	Manual	Micro-hydro electric
Auto garages	T	F	Manual	Micro-hydro electric
Pottery	T, V	I	Wood	Improve efficiency of kilns
Blacksmiths	T, V	I	Charcoal	Micro-hydro electric
Charcoal production	V	I	Wood	Improve efficiency of kilns
Textile making, knitting	T, V	F, I	Wood	Improve efficiency of stoves?

Source: ARDCO, 1999

Energy services are required in the small-scale industries for motive power and indigenous thermal processes. Typical energy use for each industrial type is shown in Table 15.7. Where available, motive power demand is met by electricity, which is only accessible in the larger towns, and is generated mainly by diesel engines elsewhere. Wood and charcoal provide thermal energy for ovens, kilns and bellows. Brick and block making, auto garages, and wood or metal workshops operate mainly in the large regional centres (in towns such as Jimma, population 90,000). The demand for these services exists only in urban areas. Rural homes are mostly made of mud, and rural people cannot afford relatively higher-quality wood and metal products. With an improving transport infrastructure, these industries may flourish in rural areas with greater access to energy. There will also be better markets for wood and metal products, as well as services to vehicles.

To summarize, the important rural industries in Ethiopia are: (1) grain and oil mills; (2) coffee processing; (3) bakeries; (4) sawmills; and (5) brick and block making. Their key features in relation to the use of modern energy services (from non-renewable and renewable energy sources) are discussed in turn below.

1 Grain and oil mills

Ethiopia is a country of subsistence farmers, most of whose products (as high a proportion as 80 per cent) are consumed by local people. Grains are still hand-ground in many rural households. Since the end of the nineteenth century, there has been a gradual shift to the use of mechanical mills (first introduced in the mid-nineteenth century) in rural areas. Further widespread use of mills began in the 1940s and the shortage of female slave labour for hand grinding is given as a major factor for this shift (Aredo, 1997).

The first technology adopted for milling in the country was the water wheel. It is estimated that there may have been hundreds of these mills operating in the country during the 1950s. During the second half of the twentieth century diesel mills began to replace water mills as the population became more urbanized and water mills became less accessible.

Today grain milling continues to be an important rural enterprise. It is still the first rural enterprise that springs up and accounts for more than two thirds of all industries in rural areas. Although data are not available on the current number of grain mills operating in rural areas, the total could be as high as 15,000. In some rural towns the market for them is saturated and few operate at full capacity (Tesfaye, 2000a). The technology of choice for mills in rural areas today is diesel. Energy use by rural diesel grain mills is about 5,000 litres per year for those operating at full capacity, as shown in Table 15.8. This means that most grain mills operate at half capacity or lower, with a consumption of about 2,500 litres per mill per year. Annual processed volume of grain per establishment is about 1,200 quintals (1 quintal = 100 kg).

Oil milling is another important agro-processing industry in the country. The number of oil mills is only one sixth that for grain mills. Oil milling is mainly an urban operation. A survey conducted in 57 rural and semi-urban and five urban settlements has shown that more than 85 per cent of oil mills were operating in the urban settlements (ARDCO, 1999).

Table 15.8 Sample diesel fuel use by grain mills in rural areas

Settlement	Energy use Litre per year	Energy intensity Litre per 100 kilogram
Rural scattered	5,802	2.0
Rural village	4,355	1.7

Source: ARDCO, 1999.

Oil mills in rural areas operate on diesel and annual consumption is about 4,000 litres. Fuel requirement for a quintal of grain input is not available for diesel mills, but electricity consumed per quintal of oil seed input in the larger towns is about 0.4 kWh.

The renewable energy options for grain and oil milling in rural areas include water mills, electricity from micro-hydro, wind or PV. We have seen that the use of mechanical power from water mills in Ethiopia goes back to the mid-nineteenth century. Currently, there is renewed interest in this form of energy and some NGOs are installing water mills in rural areas.

Of about 30 micro/mini hydropower plants for generating electrical power in Ethiopia, more than two thirds are non-operational, and some of those that are working provide lighting services alone. The larger mini-hydro sites of the power utility provide general electric services for urban areas in the south-west. The current contribution of micro-hydro electric power to rural grain milling is insignificant.

Windmills have also been used in Ethiopia in the past, according to a recent study (Aredo, 1997). A tax decree issued in 1925 classified existing mills into three types in order of importance and widespread use: (1) water mills; (2) electric or gasoline mills; and (3) wind and animal-driven mills. The distribution of windmills must have been very limited as they are listed after electric mills. Electricity was then available in only five towns and service was provided only to noblemen and the main churches (Tesfaye, 2000a).

Experience with PV mills in Ethiopia is limited to a single unsuccessful case. A PV system installed in 1988 included a 2 kWp PV mill, in addition to lighting for 400 households and a 4 kWp pump. The plant was then expanded to 10.5 kW capacity and later to 21 kW. Because the PV mill used direct current, its motor frequently failed during its brief life. The mill had been operational for less than a year when it stopped functioning towards the end of 1991.

The renewable energy options of highest viability for milling in rural areas are water mills and micro-hydro electric power. Milling in rural areas is a private, small-scale enterprise which means investment capacity is limited, and this excludes the PV option. Wind milling, although potentially low-cost, suffers from limited local experience and a relatively limited resource base. Water mills and micro-hydro systems have distinct advantages. This is because experience with them has a long history, technologies are familiar to operators and users, and the resource base is indigenous and widely available. Comparing the water mill and micro-hydro options, the former are well adapted to less accessible rural areas, and the latter to villages and towns.

Grain and oil milling industries account for close to three quarters of the small-scale industries in rural areas and their importance is therefore quite high. The industry is a high priority area for developmental reasons. It is the principal field of rural enterprise and employment. The service provided has positive impacts both economically and socially, as it frees women from a strenuous and time-consuming labour of grain grinding and pounding activities.

The distribution of milling enterprises will expand, since at present less than a tenth of the rural population has access to the service (UNDP/World Bank, 1986). This expansion in the rural areas has a considerable potential impact in economic terms – for a start, the import of fuel is bound to be high if the service is to be met by diesel engines alone. On the other hand, water mills and micro-hydro systems will have cross-sectoral direct benefits to the owners and operators. Both the rural and urban manufacturing sectors will provide technology and parts, thus creating additional employment and linkage to the manufacturing sector.

2 Coffee processing

Coffee is a very important commodity in Ethiopia for both internal consumption and export. Annual production is estimated to be about 250,000 tons and exports amount to 116,000 tons (1999/2000). Revenues from coffee export stood at Birr 2.1 billion (US$260 million) in 1999/2000, and accounted for 54 per cent of all exports (National Bank, 2001). Unlike other large coffee-exporting countries, small-scale farmers largely produce Ethiopian coffee as the main crop for cultivation. Because coffee farming is distributed among tens of thousands of small producers its processing is also distributed, though not as widely as its production. Coffee is processed in three ways.

- Farmers process coffee using sun drying in the open air, then the husk is removed by pounding. Quality of output from this process is quite low and the product is either consumed on-farm or sold locally for domestic consumption.
- Government, private wholesalers and coffee producer associations collect coffee from farmers for either the domestic or export markets. Mills in rural or urban areas process it mechanically.
- Large government coffee farms process their coffee on-farm with mechanical mills.

Coffee is cleaned using two methods. In the dry method, mills remove the husk and internal mucilage from dried coffee. In the wet method, the husk from fresh berries is removed with special mills and what is left is removed by fermentation (UNDP/World Bank, 1986). The quality of wet-processed coffee is superior to the dry-processed product. Coffee processing by mechanical mills in rural areas – a potential rural growth industry – currently mainly uses the dry method. However, efforts are being directed to expanding wet-processing capacity, and the number of such plants is increasing (Kebede, 2001a). The total number of coffee processing plants was 892 in 1999, of which dry coffee processors numbered 388, with a processing capacity of 270,000 tons. There were 504 wet processors, with a processing capacity of 65,000 tons.

The capacity presently available in installed coffee mills is adequate for processing current production (250,000 tons of production, 235,000 tons of processing capacity). However, farmers are still processing a considerable proportion of coffee produced manually, and mills utilize only part of their capacity. Unless demand from the domestic and external market expands, the change in the industry will only be replacement of dry processors by wet processors.

Findings from a sample survey carried out in the south-west of Ethiopia are shown in the Table 15.9. The mills surveyed were in relatively large rural towns, one served by grid electricity and the other by a diesel generator. It is estimated that about half the mills in operation are situated in rural areas. With further substitution of wet mills for dry mills, the number of rural mills will be higher than urban-based mills.

Diesel is the source of energy for many rural coffee mills. Substituting wet processors for dry processors will further increase diesel requirements. Wet processing is best done close to farms where berries are available in a fresh form. The only viable renewable energy alternative for diesel in rural mills is micro-hydropower. Micro-hydro is specially suited to this industry because with the wet processing method a large and continuous water supply is required. For this reason such mills are often situated on the banks of rivers. Where other markets are available for electricity besides the mill, hydroelectric plants may be viable. Where demand is limited to the mill itself, water mills will be the least-cost option.

Table 15.9 Energy use for coffee processing in two towns in the south of Ethiopia (dry processing), 1994

			Town Mettu	Town Mizan	Capacity utilization	Energy use
Electric	Capacity	KW	23	NA		
	Production	kg/hour	950			
	Operation	Hours/year	3,456			
	Energy use	kWh/year				38,636
Diesel	Capacity	KW		23	44%	
	Production/operation	kg/hour		NA		
	Energy use	Litre/year				18,225

Note: The Mettu mill operates 16 hours/day for 5 months and 8 hours/day for the remaining 7 months of the year. The Mizan mill operates for 6 months of the year only.
Source: ARDCO, 1995

3 Bakeries

Bakeries account for 14 per cent of industries in rural areas, which makes them the most numerous industries after grain mills. There could be as many as 3,000 rural bakeries. In rural areas commercial food preparation is mainly a town and village activity, and bakeries are situated in the larger rural towns. In the rural setting bakeries produce bread, whereas in the larger towns pasta is produced. Rural bakeries are small in capacity and use wood for their ovens. Wood consumption per establishment is 10–30 tons per year (ARDCO, 1999). Adequate data are not available on specific fuel consumption for baking in rural Ethiopia.

The volume of wood consumed by the baking industry is quite large, with an estimated annual consumption of 20 tons of wood per bakery. With 3,000 bakeries, annual wood consumption could reach 60,000 tons. Unlike wood used for cooking in households, which is mostly residue or small branches of trees, wood used in bakeries is usually large-diameter wood from the trunk or main branches of trees. This has serious implications as trees have to be harvested either wholly or partially, destroying their regenerating potential. The bakery industry is, therefore, a prime target for conservation measures. Experience in Asian countries indicates that the efficiency of rural baking stoves could be increased by up to 25 per cent using simple thermal management techniques. Such measures include lowering baking frequency (by increasing batch size or baking layers in the oven) and using dry wood (ARDCO, 1999).

4 Energy use in sawmills

There are 39 sawmills operating legally, with mean capacity in each plant estimated at about 3,000 solid cubic metres. But actual performance is only about 1,000 cubic metres. The number of illegal lumber processers is much higher than this, but capacity would be much lower. Licensed sawmills use petroleum fuels for the harvesting and transport of logs, and electric or petroleum-driven machines for saws. Unlicensed operators cut and shape lumber using handsaws. Energy use in two lumber mills is shown in Table 15.10.

Harvesting and transport are not viable applications for RETs. Processing, however, is currently done with electricity in areas that have access to grid electricity or diesel generators. Installed capacity for some of the mills visited for the above survey ranged from 20 to 80 kW. Legal lumber mills are therefore relatively large production units. In areas where a few such processers are in operation, the demand for them alone might justify the development of micro-hydro units.

Table 15.10 Sample energy use by sawmills, 1994

Lumber used (m^3)	Energy use	Unit	Town 1 Gore	Town 2 Dembi Dollo
Felling/cutting (dozers)	Diesel	Litres	NA	2.39
Transport	Diesel	Litres	NA	4.77
Processing	Electricity	kWh	104	
Processing	Gasoline	Litres		0.60

Source: ARDCO, 1995

5 Brick and block making

Brick making is another energy-intensive industry. On average, 250 tons of wood are consumed per establishment (ARDCO, 1999). Although the survey was conducted in different settlements, 19 of the 20 brick producers were concentrated around one major regional town, Jimma (population 90,000). Demand for bricks is confined to large towns, since rural homes (and many urban homes) are made of mud and wood. Another reason for such a large concentration of brick makers in this particular town is that fuel (wood) is available and cheap in the area, which includes the last remnants of the natural forests of the country.

The specific fuel consumption for brick kilns in Ethiopia is about 1.1 kg of wood per kilogram of brick. The thermal efficiency of rural brick kilns in Asia is said to be around 10 per cent. These kilns are said to suffer from heat loss with flue gases, from the cooling of fired bricks, and from poor firing practices. With more efficient kilns, heat from flue gases is used for preheating. Heat from the cooling area is used to preheat air required for burning the fuel. One such kiln is the so-called *Bull's Trench kiln* which has a 40 per cent efficiency. It has a lower fuel requirement than the rural kilns presently in operation (1,850 kJ per kg of fuel against 3140 kJ per kg of wood). Still, fuel requirements are high and fuel costs account for as much as 50 per cent of industrial costs in the brick industry. Measures to conserve wood in the industry will therefore be readily accepted by operators and forest experts.

Likely uses of RETs in cottage industries: the informal sector

Informal manufacturing activities are significant income earners for both urban and rural people in Ethiopia. A sample survey conducted in 1996 has shown that there were more than 276,000 such establishments in urban areas alone (CSA, 1996). Although the survey is supposedly for urban areas, it included rural towns with populations of only a few thousand. The number of such home manufacturers in rural towns is estimated to be 187,000.

Cottage industries operate informally, meaning that they are not registered or licensed. The operators often have other more important sources of income, one of which, in rural areas, is usually farming. Such income-generating activities are undertaken mainly to augment income. Employment is either part-time, seasonal (for farmers), or for women. Productive units are too small to yield incomes.

The informal manufacturing activities in rural areas are textile production, blacksmithing, woodworking, bakeries, pottery, and charcoal burning. As illustrated in Table 15.11, energy demand in these activities is for human power and biomass fuels for the dyeing of fabric. Charcoal is also used by blacksmiths for hand-operated bellows; bakers use wood ovens; and potters and charcoal producers use wood kilns.

In terms of number and the volume of energy used, blacksmithing and charcoal burning are the most important indigenous activities in rural

Table 15.11 Biomass energy use in informal industries (kg/year per establishment operator)

Settlement area	Fuel	Blacksmiths	Charcoal making*
Rural	Fuelwood	–	10,800
Rural towns	Charcoal	2,672	–

* Wood demand is computed from losses in charcoal making for one traditional charcoal maker over one year. The earth-mound kiln has approximately 10 per cent efficiency by weight, and a charcoal burner makes about 1,200 kg of charcoal.
Source: Kebede, 2001b

areas. Data on the number of blacksmiths operating in rural areas are not available. But it is estimated that about 100,000 people are engaged in the charcoal-making business (some as a full-time activity but most seasonally). One way of improving energy services for these industries would be through the provision of modern energy to replace human power: electric tools for wood and metal workers, together with the substitution of coal or petroleum fuels for biomass energy in ovens and kilns. Electricity from micro-hydro plants is the only viable option for replacing human power in cottage handicrafts.

Technical improvement of biomass ovens and kilns for bakers, potters and charcoal producers, will also have quite a large conservation impact. Metal or brick kilns for charcoal are estimated to increase yields from the present 10 per cent to 20–30 per cent (by weight). Annual charcoal consumption is estimated to be around 230,000 tons (Kebede, 2001b). A complete shift from the traditional earth mound kiln to the metal or brick kilns would save close to 1.2 million tons of wood.

Renewables and RETs for commercial services

In rural towns in Ethiopia the retailing of consumables, commercial beverages and food preparations are sources of income for a considerable portion of the population. There is a high concentration of such service providers in rural towns. The 1996 informal sector survey in urban centres and rural towns revealed that there were nearly 245,000 such units throughout the country. If the main urban areas are excluded, the number is about 155,000.

Biomass fuels are used for the preparation of beverages and meals in teahouses, bars and restaurants, as shown in Table 15.12. Fuel is used mainly for cooking meals and for making local drinks (boiling and distilling). The scale of operation of these informal establishments is very small. Energy used is about two to five times that in households and the stoves used are the same. It is therefore feasible to promote biomass-converting household stoves to these commercial establishments.

Subject to the availability of biomass resources, improved stoves are available for immediate dissemination to commercial establishments in urban centres, but not for rural areas. An improved baking stove (the

Table 15.12 Biomass energy use for beverage and food preparations in the central region of Ethiopia (kg/year per establishment)

Area	Fuel	Beverage	Food
Rural	Fuelwood	2,872	1,032
	Charcoal	1,092	
Rural towns	Fuelwood	4,577	5,555
	Charcoal	825	2,575

Source: EESRC, 1994. Data converted by author to kilograms/year from data presented in MJ/year.

Mirte Mitad) and a charcoal stove (the Lakech) have been disseminated in urban areas as well as in some rural towns. The acceptability of these stoves has been high in commercial establishments because their volume of energy use is higher than the typical household level. Biomass-conserving stoves have been disseminated to larger, formal-sector commercial establishments in rural towns as well to smaller units operating informally in the villages.

RETs like micro-hydro or PV can provide electricity to commercial establishments for entertainment and refrigeration. Where micro-hydro resources are available, it is usually the cheaper and more versatile source. In areas where financial and other resource requirements are limited, larger commercial establishments may be able to install PV home systems for entertainment and light. The investment required for a home system is about US$500 (Birr 4,500) for a 100 Wp unit, which is within the capacity of such establishments. Savings on kerosene for pressure lamps would be significant.

Comparison of RET projects and critical components: a qualitative assessment

Energy policy in Ethiopia favours the harnessing of all types of renewable energy sources, although it does not go into the details of implementation (MME, 1994). However, no decision has been taken to focus on any small-scale RETs, except to state that priority will be given to hydropower exploitation. Nor has any preliminary programme of energy development been devised by a research centre or academic institution to investigate closely the exploitation of available and potential energy resources. Financial incentives to commercialize renewable energy sources are yet to evolve. In the absence of clear directions, then, it is probably unrealistic to compare RET projects and critical components in Ethiopia.

Nevertheless, a recent exploratory study comparing RET projects and their components has been conducted (Sharew *et al.*, 2001). Taking economic and financial considerations into account, the study compared viabilities of micro-hydro power, PV, wind generators and grid extension with diesel generation for prospective sites (Table 15.13). Preliminary

Table 15.13 Comparison and priority settings for RET dissemination for income-generation in rural areas

Technology	Sector and application	Resource	Cost	Reliability	Transferability	Priority	Viability	Rank
PV	*Agriculture*							
	Irrigation water pumps	++	+	++	–	3	2	5
	Livestock water pumps	++	+	++	–	3	3	6
	Commerce							
	Light & communication	++	+	++	–	1	2	3
	Refrigeration	++	+	++	–	1	2	3
Solar dryers	*Agro-industry*							
	Crop drying	++	++	++	++	1	2	3
Wind: pumps and generators	*Agriculture*							
	Irrigation water pumps	+	+	+	++	3	2	5
	Livestock water pumps	++	++	+	++	3	3	6
	Commerce							
	Light & communication	–	–	–	+	1	1	2
Micro-hydro: Mechanical and electric power	*Agriculture*							
	Irrigation water pumps	++	+	++	++	3	2	5
	Livestock water pumps	++	+	++	++	3	3	6
	Rural industry							
	Grain and oil mills	++	++	++	++	2	3	5
	Coffee mills	++	++	++	++	2	3	5
	Bakeries and brick kilns	–	–	–	–	1	1	2
	Commerce:							
	Light & communication	++	++	++	++	1	3	4
	Refrigeration	+	++	++	++	1	3	4
Biomass	*Rural industry*							
	Bakeries and brick kilns		++	++	++	1	3	4
	Charcoal making	Conserve	++	++	++	3	2	5
	Commerce							
	Cooking and baking		++	++	++	2	3	5

Notes: Transferability includes suitability for local production, skills and back-up services required. Resource, cost, reliability, and transferability are marked as: – (poor), + (good), and ++ (very good). Priority and viability are marked as: 1 (low), 2 (medium), 3 (high), 4 (very high), and 5 (highest rank).
Source: Adapted from Wolde-Ghiorgis, 2002

results of this study have shown that none of the RETs can be more viable than diesel generation under the conditions listed below.

- Demands for modern energy services for income-generating activities and effective uses of the RETs in the selected or identified rural areas are established.
- Performance-based financial incentives are to be employed to encourage efficient projects.
- Directions of financial incentives are realistically set with consideration of potentials for changing market conditions.
- Capacities for administration, maintenance and repair of viable RETs are to be reliably built.

Taking the development of a micro-hydro project, the above factors can be qualitatively assessed for two main reasons. First, Ethiopia has abundant hydropower potential. Second, even if it is too risky both in terms of guaranteeing reliable water supply and in securing needed financing sources, micro-hydro is a versatile RET. Its applications are useful for rural income-generating activities and the improvement of the quality of rural life. Water turbines are needed for pumping water for irrigation, which has rarely been done in the country. The mechanical power of simple water wheels, which can be harnessed to drive flour mills, is another plausible application. It will significantly improve the daily drudgery faced by rural women in grinding grains manually. Small-scale hydroelectric plants, which have also been utilized with limited success, can drastically change rural modes of living. Besides, hydro resources in Ethiopia are concentrated in the highlands, where traditional farming for crop cultivation has been practised for centuries. Development of hydropower can further contribute to better water management, a serious problem in the highlands during periods of drought. Wide-scale development of water technologies will therefore have productive linkages.

In terms of evaluations of demand for micro-hydro development, there is, however, a critical source of disagreement that originates from the common stand taken by consultants and energy experts. The point of contention has been the narrow definition of energy demand, which is strictly interpreted to mean a mix of affordability and energy requirements. Even potential, suppressed demands or aspirations for micro-hydro energy sources are not recognized in assessing demand for mechanical power or electricity in the rural areas. This rigid stand will need to be reconsidered. Learning from the experiences of developed countries in the first half of the twentieth century, all that is needed is the provision of finance that will cover initial costs. If opportunities for micro financing at community levels are considered, the issue of affordability can be positively addressed. In line with the scope of the second factor, all that is needed is the incorporation of performance-based financial incentives in the implementation of the micro-hydro project.

Evidently, it is also necessary to develop the directions of financial incentives with the aim of creating sustainable market conditions. No local or external financing institution will throw scarce financial resources at risky or uncontrollable projects. Also, although the technology is simple and rugged, without the necessary capacity for managerial operations, maintenance and repair, any micro-hydro project can easily fail. While technical capacity for the development of micro-hydro systems exists within the country's institutional base, it has not been developed and refined. Organizational and managerial capacities for mobilizing communities and potential investors to develop resources are also lacking or unknown. Consequently, the short-term impacts of micro-hydro development on rural income-generating activities may be uneven: it will take time for institutions and communities to move up the learning curve. In this regard, the Nepalese and Sri Lankan experiences (both positive and negative) in the development of micro-hydro schemes will need to be studied if useful lessons are to be learnt (Khennas and Barnett, 2000).

Some RETs geared to income-generating activities are more critical than others, and these should be given priority for greater dissemination. Three additional questions need to be considered carefully in the priority-setting process:

- What are the most critical RETs for use in rural Ethiopia? In answering this fundamental question, the technology matrix shown in Table 15.13 is a useful guide.
- What makes some RETs more appropriate than others? Resource? Size for wider energy services? Finance and financing mechanisms? Applications? These are questions that will need to be addressed in the context of the underlying factors: availability of renewable energy sources and reliability of technology.
- What are Ethiopia's priorities with respect to the most applicable RETs? What are the experiences of other developing countries? PVs in Kenya? Micro-hydro in Nepal? Again, these are questions that should be considered seriously if initiatives are to be taken to introduce RETs in the rural areas of Ethiopia.

16

Final Policy Recommendations

Based on the findings of the study, policy options and recommendations have been proposed based on the following:

- institutional and management framework;
- legal framework;
- economic and financial considerations; and
- human resources and technical capacities.

Hypothesis 1: Decentralized private sector vs centralized public sector energy initiatives

It has been established that modern rural energy supply and distribution in Ethiopia, using both centralized and decentralized options, has not met with significant success. Electricity supplies to rural areas from the centralized interconnected system are only reaching rural administrative or major marketing centres by means of 15 kV lines within 50 km from the grid, and recently introduced 33 kV lines up to distances of 100 km. Decentralized electric services have also been provided by isolated self-contained systems using diesel generator sets. With regard to the distribution of imported petroleum supplies, except for weak and dim lighting with kerosene lamps, households have not benefited from the use of modern fuel supplies (like electricity or coal) for cooking and productive activities. The basic conclusion drawn is therefore that modern energy options have no prospect of success. To alleviate existing and impending problems afflicting modern energy supply to rural areas and settlements, two policy recommendations are therefore being proposed.

Policy option 1: Medium and long-term options

Over both medium and long terms, rural energy supplies will need to be promoted and provided extensively and widely to rural areas in Ethiopia. Public and private sectors will need to be actively involved in both decentralized and centralized supply options.

Institutional and management framework

This policy option and recommendation will need to be considered at different levels of authority. First, it has to get the attention of concerned government authorities and bodies at both the federal and regional levels. At the federal level, the concerned bodies are the new Ministry of Rural Development (MRD), the Ministry of Agriculture (MoA), and the Ethiopian Rural Energy Development and Promotion Centre (EREDPC). The Agriculture Development Led Industrialization (ADLI) strategy is aimed at benefiting the vast rural population of Ethiopia through accelerated agricultural and industrial developments. So, for this reason alone, the legal authority of the EREDPC has at last been established. Regional Energy Bureaus (RBEs) will also need to be established to provide support at all rural and local levels. It is generally and implicitly assumed that energy projects do not include equity considerations and the alleviation of socio-economic conditions without some level of subsidy. It can also be deduced that modern energy services outside urban centres will need to be promoted vigorously to rural areas. Such measures will enhance both centralized and decentralized energy supply options for rural areas and communities, in line with the ADLI strategy. It therefore follows logically that improvements in the quality of rural life and poverty reduction can succeed sustainably with the use of clean and modern energy services. New policy directions in the rural energy subsector will then need to be promoted and enhanced by strengthening institutional frameworks at critical levels.

Legal framework

The necessary legal frameworks will need to emanate from the new ministries, authorities and bodies concerned, both at federal and regional level. Within the current ADLI strategy, there are no known legal frameworks that promote modern energy services to rural areas through centralized and decentralized options. Still, if the proposed policy option is found acceptable, then there should be no difficulty in working out the needed legal and regulatory supports.

Economic and financial considerations

In implementing the proposed policy option, it will also be necessary to take into account economic and financial considerations. These, however, will clearly be immense and unaffordable at federal and local levels of government, with the direct implication that the policy recommendation would be rejected at all levels of decision making on financial grounds alone. Still, in the context of a national energy problem with wide-ranging negative effects that are now being recognized, a solution might begin by seeking the support of financing institutions. There has been strong support for soft loans and grants for rural infrastructure, ranging from primary education and health services to road construction, and including village electrification. Water pumping and flour/oil milling in rural areas are promising for private, small-scale enterprises with limited investment capacity, but without the PV option. Support was started and provided for rural electrification as early as 1975 (World Bank, 1975).

Ultimately, though, financing institutions have to convince international consultants to make distinctions between least-cost and cost-effective energy projects for sustainable rural development. Experience has shown that the critical argument used against rural electrification in Ethiopia is that it is unaffordable in poor rural areas. This reasoning is actually based on the least-cost analysis routinely applied to major projects aimed at development in agriculture. But the approach has only resulted in aggravating the rural energy problem in the country. Without challenging the least-cost approach, it could also be argued that cost-effective energy projects in line with the proposed draft policy recommendation are viable. There will be economic benefits and impacts in the medium term (within less than ten years) and long-term benefits to the national economy and future generations. The proposed draft policy recommendation therefore calls for rural energy development to be regarded as an infrastructure-building process, in line with the priorities for rural development and poverty reduction.

Human resources and technical capability

The needed human resources and technical capability can be trained, provided the goals of the recommendation are accepted as lying within the ADLI strategy. Training programmes in the energy sector offered by the UNDP/World Bank and other donor organizations could be helpful in building the needed capacities at any desired level. The accumulated experience of existing staff could also easily be shaped and given the right direction. The current energy professionals are engineers, scientists, economists, accountants and lawyers. These are specialists and civil servants who are hardly able to appreciate the problems and constraints of rural development strategies, policies, programmes and projects. The involvement in policy formulation and implementation stages of qualified experts in applied sociology and rural development will be beneficial. Technical capability will also need to be strengthened at all levels.

Policy option 2: Short-term initiatives

On a short-term basis (within five to ten years) modern energy supply options will be provided and distributed to the rural areas and communities of Ethiopia. Public and private sectors will both participate, at reasonable prices and within recognized legal and regulatory frameworks. Modern energy supplies will include increased imported or locally produced kerosene for rural lighting and cooking. Electricity for rural small-scale industries and water pumping for drinking and irrigation will also need to be provided. Possibly, imported or locally mined coal will need to be considered for rural cooking after the raw coal has been *cleaned and processed into briquettes. Further, the number of commercial enterprises controlling the centralized petroleum supply depots in Addis Ababa should be increased. They should also be required to diversify their rural distribution services.*

Institutional and management framework

The policy recommendation on short-term rural energy initiatives is probably outside the jurisdiction of the EREDPC. Still, the Centre may be able to assume responsibility for enacting and modifying the policy. If this is not possible, a new body will need to be established by combining the resources of concerned ministries and enterprises. Participating ministries could include the MRD, the Ministry of Trade and Industry (MTI) and the Ministry of Mines (MM). Enterprises that could be actively involved are EEPCO, the Ethiopian Petroleum Enterprise (EPE), and the Ethiopian Electric Agency (EEA). Representatives of operating and new petroleum companies, as well as participants from research and training institutions, could be actively involved. Exact organizational structure can again be worked out if the viability of the proposed policy is seen to be acceptable. Further institutional and management framework details could be worked out by taking lessons from other developing countries.

Legal framework

A suitable legal framework is necessary to allow the creation of an autonomous body to oversee the distribution of energy to rural areas. Such a body will need to have regulatory and enactment powers. The actual administration of supply, distribution and possible revenue collection can be left in the hands of existing public enterprises and private traders. Initially, there could be challenging legal hurdles hindering smooth distributions to rural areas.

Economic and financial considerations

There are two economic and financial considerations that will need to be addressed carefully and broadly. First, there is the issue of working within or outside market forces for scarce and imported energy resources. This raises questions of welfare provision or subsidies if the poor are to be helped to be actively engaged in productive economic activities. Second, there should also be substantial investment outlays if energy supplies are to be increased by doubling either electricity generation or importation of petroleum products (and, possibly, coal at first). If the proposed policy recommendation is seen as falling within the ADLI strategy, there are definite possibilities for its immediate implementation. Incentives will need to be provided to private sector enterprises interested in the production and distribution of modern energy to rural settlements.

Human resources and technical capability

Appropriate managerial and technical skills will be required (a minimum number of 15 to 20 specialists). These will range from engineers and natural scientists to lawyers and accountants. Ideally, existing training programmes could be very useful if the right selection of candidates or new recruits is made and financing arrangements are secured from donor organizations. If such opportunities do not materialize readily, the next option will be to organize short courses locally in any institution of higher learning.

Hypothesis 2: Income-generating activities vs domestic energy use

From the key finding and two conclusions derived from qualitative testing, a single crucial policy recommendation emerges.

Policy option 3: Prioritizing income-generating activities

Learning from experience in the advanced developing countries, income-generating activities in rural areas will need to be prioritized over domestic uses in promoting modern energy services and supplies in the rural areas of Ethiopia. Cleaner energy supplements and substitutes will also need to be found as soon as possible as traditional energy use declines.

INSTITUTIONAL AND MANAGEMENT

The required institutional and management framework will be based at the highest government level in line with the strategies and objectives for national development. The international financing institutions will be included through their poverty alleviation strategies for poor rural communities. Without subsidies the institutional framework is definitely beyond the responsibilities and tasks of the newly established EREPDC.

HUMAN RESOURCES AND TECHNICAL CAPABILITY

The needed human and technical capability will have to be sought initially from advanced developing countries. It will be futile to expect national professionals to address the fundamental issues of sustainable rural development while the whole field of energy use and implications remains an unresolved problem facing the officials concerned at different levels of authority.

Hypothesis 3: Prioritizing components for the promotion of RETs

RETs are yet to be introduced to the rural areas of Ethiopia, where there are substantial resources of untapped mini/micro hydropower and wind energy, as well as plentiful solar energy. RETs could be utilized for water pumping and power generation, as well as photovoltaic systems for providing electrical and mechanical power for rural communities. Modern energy technologies could also have significant results in improving the efficiency of indigenous cottage industries. For 30 years RET installations appear to have been driven mainly by donors under bilateral cooperation programmes. The conclusion is that the benefits to be derived from using RETs have not been recognized. Two policy recommendations are therefore proposed for consideration.

Policy option 4: Priority setting for RETs

Policy makers have been focusing on the exploitation of the existing immense hydropower resources of the country via medium-scale and larger hydropower plants. National energy policy needs updating so as to include the development of small-scale hydropower plants as low as 1 kW (or even lower). Using cost-effective approaches, micro/mini hydropower units can provide modern energy services to rural productive activities. Next, priority ought to be given to wind energy converters in areas where there is wind energy potential but no hydropower resource base. Further consideration will also need to be given to the dissemination of PV systems, ethanol as a fuel for lighting purposes, and improved biogas plants.

Institutional and management

The proposed policy option for prioritizing RETs is not totally new to the Ethiopian Rural Energy Development and Promotion Centre (EREDPC). Its predecessors – the Ethiopian National Energy Committee (ENEC), the Ethiopian Energy Authority (EEA) and the Ethiopian Energy Studies and Research Centre (EESRC) were working along similar paths. The new draft policy option will still produce better results more effectively in comparison with previous approaches. There have been significant achievements during the last 25 years in terms of visible or sustainable outputs, but follow-up has been lacking. Extensive feasibility studies were conducted on micro/mini hydropower projects, but these were never elevated to the design and implementation stages. Biogas plants were investigated in detail, but simplified technical literature on their construction is yet to be prepared and distributed to rural communities for the benefits of potential users. Experiences gained from a relatively large PV plant in the late 1980s have not been disseminated for use by public energy sectors or private enterprises. Ethanol has been pushed constantly as an attractive source of useful energy, but no significant project has materialized. Regional energy bureaus will need guidelines from the federal agency, since significant experience has not been gathered in the regional capitals, except in three or four regions. For successful implementation of the draft option, these institutional guidelines will need to be provided by the EREDPC and the REBs.

Legal framework

If the institutional and managerial frameworks are strengthened and streamlined, there should be no legal obstacles to the implementation of the policy – although regulatory tax guidelines will need to be sorted out with agencies of the MTI at federal and regional levels.

Economic and financial considerations

Indigenous and modern small-scale productive activities in the rural areas of Ethiopia are underdeveloped, mainly because of their dependence on either traditional energy sources or inadequate modern energy supplies. Although the necessary studies of rural development and poverty reduction options are still to be conducted by experts and specialists, they are likely to recommend (1) the application of improved technologies and adequate energy supplies; and (2) the creation of improved on-farm and off-farm employment opportunities. These are clearly major issues and will require separate and extensive studies, drawing on the experience of developing countries that have successfully introduced and adapted RETs. Economic and financial inputs to back detailed professional studies will be needed simply in order to determine the pros and cons of utilizing RETs in improving rural productive activities in Ethiopia. The proposed draft policy option will need to be based on cost-effective approaches that would provide ultimate benefits and improvements in socio-economic conditions for current populations and future generations. The active involvement of international financing institutions and other donor organizations, as well as public and private banks, will be decisive in providing the needed loan and grant funding for investment initiatives.

Human resources and technical capability

If the required human resources and technical capability were already in place, the absence of RETs in rural Ethiopia, established in the present study, would not have been so glaring. It is clear that a new and systematic training programme will need to be launched to provide the missing skills and capacities at all levels, for two main reasons. First and foremost, specialists will need to be trained in all major types of RETs, reviving a programme first attempted in the early days of ENEC. The current situation is that too few individuals are in possession of technical information, while the expertise they have may be of use in limited ways only. It cannot be assumed that the fundamental principles of energy technologies for rural development, with their various capabilities and limitations, have been grasped and mastered.

Second, very little technical-scientific research is being conducted to keep abreast of the technological refinements or cost reductions that are continually being introduced in the RET industry. This explains why there are such huge gaps in development, and why the barriers being faced in introducing these energy technologies appear insurmountable. One may hope that the time has now arrived to examine critically the deficiencies in human resources and technical capability that inhibit the use of RETs to exploit the immense but untapped renewable energy resources of the country, using small-scale applications that will be of immediate use to dispersed and isolated communities. New and systematic RET training programmes will therefore need to be designed; scientific-technical research must be promoted; barriers and gaps in technology will have to be faced realistically and objectively.

It has been noted that there is ample technical capability, in facilities and human resources, to partially or wholly manufacture or assemble simple types of RETs, except for PV components and systems. The only limitation is that there is no clear-cut policy that sets out to encourage the assembly of RET devices for marketing in rural areas or, alternatively, provides tax incentives and grace periods to traders and importers to encourage the introduction of RETs at reasonable prices. To this end, the policy option outlined below has been formulated.

Policy option 5: Promoting capacity building in local manufacturing/assembling of RETs and components

As ample experiences in many developing countries have shown that all RETs need not be imported into a developing country, and since there are also local capabilities for manufacturing and/or assembling major components of RETs, incentives and opportunities will be provided by concerned bodies and authorities in Ethiopia to all local producers and traders who can wholly or partially manufacture, assemble or distribute RETs like wind pumps and generators, water turbines and generators, biogas digesters, and supporting structures for PV systems (electrical components, wires, storage batteries, etcetera), all to be designed, distributed and marketed for the benefit of communities, aiming at the exploitation of available renewable energy resources in line with development strategies.

Institutional and management

The whole policy formulation and enactment can possibly be brought under the federal government through the MTI, in cooperation with the trade and industry bureaus of the regional governments, in line with development strategies that encourage the establishment of micro and small-scale enterprises. There may be no need to promulgate new directives and regulations. The idea of giving priority to the development of locally manufactured RETs is the crux of this policy option.

Legal framework

Once the desirability of formulating and enacting the proposed option is accepted, the necessary legal framework can easily be formulated or streamlined. Private traders and producers have in the past been discouraged by legally enforced restrictions on imported PV devices. If the right incentives are provided, the active involvement of private traders and NGOs will be greatly encouraged.

Economic and financial considerations

Market forces will openly govern the economic and financial considerations in the implementation of the policy option. There could be financial risks at the initial stages, but these can be overcome by standard marketing techniques and appropriate managerial actions. Experiences from a great many developing countries have repeatedly demonstrated that applications like irrigation schemes and water pumping for drinking become established after a period of adjustment to the use of RETs. Many modern energy technologies turn out to be applicable fairly universally to the socio-economic conditions of rural communities. It is also clear that the introduction and promotion of RETs and modern energy supplies in rural areas will require new budgetary allocations at both the federal and regional levels.

Human resources and technical capability

While private traders will have no difficulty in handling the necessary business activities, practical training programmes at community level will need to be organized to remedy teething problems in the use of RETs. The welfare of rural women, for example, can be improved by using RETs planned and implemented through training courses and simple publications for trainers, sales-oriented advertisements and practical demonstration. Technical and basic managerial skills will need to be given to representatives of rural communities to build the competence of potential users, as RETs can be costly and difficult to repair once damaged or mishandled. There is wide experience to demonstrate that rural communities adapt easily to the uses and applications of RETs within very short time frames if training programmes are provided and efficiently administered.

Part VI Select Bibliography

Abegaz, Z. and Junge, B. 1990. *Women's Workload and Time Use in Four Peasant Associations in Ethiopia*. Addis Ababa: United Nations Children's Fund (UNICEF).

Acker, R. H. and Kammen, D. M. 1996. 'The Quiet (Energy) Revolution: Analysing the Dissemination of Photovoltaic Power Systems in Kenya'. *Energy Policy*, 24, 1: 81–111.

Acres 1994. Ethiopian National Rural Electrification Project, Final Report, Executive Summary. Addis Ababa: Ethiopian Electric Light and Power Authority (EELPA).

AFREPREN 1990. *African Energy Issues in Planning and Practice*. London: Zed Books, in association with the African Energy Policy Research Network.

—— 2000. Renewables and Energy for Rural Development Theme Group Country Reports. Nairobi: AFREPREN General Assembly, November, pp. 33–44.

——/FWD 2003. *African Energy Data Handbook*. Nairobi: Afrepren.

Anderson, D. and Ahmed, K. 1995. *The Case for Solar Energy Investments*. Washington, DC: World Bank.

ARDCO 1995. Survey and Analysis of the Upper Baro-Akobo Basin, Final Report, Vol. IVA, Energy Resources. Addis Ababa, May.

—— 1999. Oromiya Energy Resources Baseline Survey, Vol. 3, Annexes. Addis Ababa.

Aredo, D. 1997. 'Grain Milling Industry in Ethiopia: a Survey'. In *Small-Scale Enterprise Development in Ethiopia*, Proceedings of the Sixth Annual Conference on the Ethiopian Economy. Addis Ababa, November.

Argaw, N. 1992. 'Solar Energy in Water Pumping: Report on PV Pumping in Ethiopia'. Addis Ababa: unpublished.

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

Bassey, M. W. and Schmidt, O. G. 1986. *Solar Drying in Africa*. Proceedings of a Workshop held in Dakar, Senegal, 21–24 July. International Development Research Centre (IDRC).

Bhagavan, M. R. and Karekezi, S. 1992. *Energy for Rural Development*. London and New Jersey: Zed Books, in association with AFREPREN.

CSA 1996. Report on Urban Informal Sector Sample Survey. Addis Ababa: Central Statistical Authority.

—— 1997. Report on Cottage/Handicraft Manufacturing Industries Survey. Addis Ababa: Central Statistical Authority.

—— 1998a. Report on Urban Informal Sector Sample Survey. Revised Report on the 1995/6 Household Income Consumption and Expenditure. Addis Ababa: Central Statistical Authority.

—— 1998b. Agricultural Sample Survey 1997/8 (1990 EC). Report on Land Utilization, Private Peasant Holdings, Vol. IV. Addis Ababa: Central Statistical Authority.

—— 2000a. Ethiopia: Statistical Abstract 1999. Addis Ababa: Central Statistical Authority.

—— 2000b. Report on Monthly Average Retail Prices of Goods and Services in Rural Areas. Statistical Bulletin, 237–1. Addis Ababa: Central Statistical Authority.

—— 2000c. Report on Monthly Average Products Price of Agricultural Products in

Rural Areas. Statistical Bulletin, 239. Addis Ababa: Central Statistical Authority.
—— 2000d. Transport and Communications Statistics. Statistical Bulletin, 229. Addis Ababa: Central Statistical Authority.
—— 2001a. Monthly Average Retail Prices of Goods and Services in Rural Areas. Statistical Bulletin, 256–1. Addis Ababa: Central Statistical Authority.
—— 2001b. Agriculture Sample Survey 2000/2001 (1993 EC), Vol. 2, Report on Livestock Poultry and Beehives Population, Private Peasant Holdings. Addis Ababa: Central Statistical Authority.
—— 2001c. External Merchandise Trade Statistics. Statistical Bulletin, 247. Addis Ababa: Central Statistical Authority.
CESEN–ANSALDO 1986a. *Cooperation Agreement in the Energy Sector*. Main Report. Addis Ababa: Ethiopian National Energy Committee (ENEC).
—— 1986b. Technical Report 4: Wind Energy. Addis Ababa: ENEC.
EEA 1995. General Report of Small Hydropower Investigation in Ethiopia by the Small Hydropower Investigation Team from the PRC. Addis Ababa: Ethiopian Energy Authority, April.
EEPCO 2000. 'Comparison among 22 Different Countries by Installed Power per Person'. Working paper on power expansion options. Addis Ababa: Ethiopian Electric and Power Corporation, private communication, October.
EELPA/EEPCO 2000. EELPA/EEPCO Growth in Generation Capacity, 1994–2000 (derived from various brochures on general information given to the public, and private communication).
EPE 2000. Petroleum Supply and Consumption Trends in Ethiopia. Addis Ababa: Ethiopian Petroleum Enterprise (private communication).
EREDPC (Ethiopian Rural Energy Development and Promotion Centre) 2002. 'Energy Status and Trends in Ethiopia'. Paper presented at the Ethio-Forum 2002 Conference, Addis Ababa, January.
EESRC 1994. Basic Energy Survey of Ethiopia. Addis Ababa: Ethiopian Energy Studies and Research Centre.
Ethio-Forum 2002. 'Community-Driven Poverty Eradication and Restorative Development in Ethiopia'. Conference of the Ethiopian Social Rehabilitation and Development Fund (ESDRF), Addis Ababa, 16–27 January 2002.
FAO 1992. *Forests, Trees and Food*. Rome: Community Forestry Unit, Forestry Department, Food and Agriculture Organization.
Foley, G. 1995. *Photovoltaic Applications in Rural Areas of the Developing World*. Washington, DC: World Bank.
Georgescu-Roegen, N. 1971. *The Entropy Law and the Economic Process*. Cambridge, USA: Harvard University Press.
Giugale, M. *et al.* (eds) 2000. *Mexico: a Comprehensive Development Agenda*. Washington, DC: World Bank.
Haris, J. 2001. 'Experiences in Designs of Windmills in Kenya'. Nairobi: AFREPREN Library.
Hislop, D. 1992. *Energy Options: an Introduction to Small-Scale Renewable Energy Technologies*. London: Intermediate Technology Publications.
Hurst, F. *et al.* 1990. *The Energy Dimension*. London: Intermediate Technology Publications.
Johansson, T. B., Goldemberg, J., Reddy, A. M. N., Williams, R. H. 1985. *Energy for a Sustainable World*. Princeton, NJ: Centre for Energy and Environmental Studies, Princeton University.
Karekezi, S. and Ranja, T. 1992. *Renewable Technologies in Africa*. London: Zed Books, AFREPREN and the Stockholm Environment Institute (SEI).
Kebede, B. 2001a. *Coffee Processing in Ethiopia*. Addis Ababa: Ethiopian Rural Energy Development and Promotion Centre.
—— 2001b. Charcoal Production Efficiency Improvement and Supply Enhancement Options: Draft Report. Addis Ababa: Ethiopian Rural Energy Development and Promotion Centre.

—— 2003. *Country Data Validation: Ethiopia*, Nairobi: AFREPREN/FWD.
Khennas S. and Barnett, A. 2000. 'Micro-hydro Power: an Option for Socio-economic Development'. Paper prepared for the Sixth World Renewable Energy Congress.
Kristoferson, L. A. and Bokalders, V. 1991. *Renewable Energy Technologies: Their Applications in Developing Countries*. London: Intermediate Technology Publications.
Lew, D. J. 2000. 'Alternatives to Coal and Candles: Wind Power in China'. *Energy Policy*, 28, 4: 271–86.
Loiter, J. M. 1999. 'Technology Policy and Renewable Energy: Public Roles in the Development of Energy Policy'. *Energy Policy*, 27, 3: 85.
Mali/UNDP 1999. *Overcoming Rural Women's Poverty with the Multipurpose Platform*. Bamako and New York: Ministry of Industry, Trade, and Handicrafts, Republic of Mali, and United Nations Development Programme.
MME 1994. *National Energy Policy of Ethiopia*. Addis Ababa: Ministry of Mines and Energy.
MTI 1997. *Micro and Small Enterprises Development Strategy*. Addis Ababa: Ministry of Trade and Industry.
Munasinghe, M. 1990. *Energy Analysis and Policy: Selected Works*. London: Butterworths.
MWR 1995. Survey and Analysis of the Upper Baro-Akobo Basin: Final Report, May 1995, Vol. IVa. Addis Ababa: Ministry of Water Resources.
National Bank of Ethiopia 2001. *Quarterly Bulletin, Fiscal Series*, 16, 2 (First Quarter, 2000/2001).
Piscitello, E. S. and Bogach, V. S. 1998. *Financial Incentives for Renewable Energy Development*. Proceedings of an International Workshop, Amsterdam, 17–21 February 1997.
Rajagopalan, M. and Demaine, H. 1994. 'Issues in Energy Subsidies for Irrigation Pumping: a Case Study from Andra Pradesh, India'. *Energy Policy*, 22, 1: 89–97.
Rajsekhar, B. F., Van Hulle, F. and Jansen, J.C. 1999. 'Indian Wind Energy Programme: Performance and Future Directions'. *Energy Policy*, 27: 669–78.
Ranganathan, V. (ed.) 1992. *Rural Electrification in Africa*. London: Zed Books and AFREPREN.
Sharew, G. *et al.* 2001. *Appraisal of Rural Electrification Based on Renewable Energy Resources Vs Diesel Generation*. Addis Ababa: Addis Ababa University.
Sinha, C. H., Venkata, R. P. and Joshi, V. 1994. 'Rural Energy Planning in India: Designing Effective Intervention Strategies, *Energy Policy*, 22, 5: 403–14.
Skutsch, M. M. 1998. 'The Gender Issue in Energy Project Planning: Welfare, Empowerment or Efficiency?' *Energy Policy*, 26, 12: 945–55.
Smil, V. *et al.* (eds) 1980. *Energy in the Developing World: the Real Energy Crisis*. Oxford: Oxford University Press.
Tesfaye, G. 2000a. 'A Study of Efficiencies of Lamps and Other Devices in Rural Ethiopia'. Addis Ababa: Ethiopian Rural Energy Development and Promotion Centre.
—— 2000b. Rural Electrification with Rural Industries: Draft Final Report. Addis Ababa: Ministry of Mines and Energy and Sustainable Energy Institute (SEI).
—— 2001. Private communication, from an ongoing study of energy consumption and supply in rural productive activities. Addis Ababa: Ethiopian Rural Energy Development and Promotion Centre.
—— 2002. 'Justification for Tax Equity for Solar Electric Generation (Photovoltaic)'. In Rural Electrification Symposium Proceedings, 1–5 March 2002, Addis Ababa.
UNDP/Relief and Rehabilitation Commission (RRC), 1984. *The Nomadic Areas of Ethiopia*. Study Report III – The Socio-economic Aspects. Addis Ababa: United Nations Development Programme.
UNDP/World Bank, 1986. *Agricultural Residue Briquettes Pilot Project for Substituting Household and Industrial Fuels*, Vol. 1. Washington, DC: United Nations Development Programme/World Bank.
Winrock International 1998. 'Electric Power for World's Poor Now Available'. News

release. Morrilton, AR: Winrock International.

Wolde-Ghiorgis, W. 1984. 'Energy Supply Trends in Ethiopia: an End-use Oriented Study'. Paper presented at the Global Energy Workshop, Sao Paulo, Brazil, 4–15 June 1984.

—— 1988. 'Wind Energy Survey in Ethiopia'. *Solar and Wind Technology*, 5, 4: 341–51.

—— 1990. 'An Appraisal of the Performance of a 10.5 kW SAPVS at a Village in Ethiopia'. *Solar and Wind Technology*, 7, 6: 725–34.

—— 1995. 'Energy for Development in Ethiopia: Strategies and Options'. Paper presented at Energy Symposium, Mekelle, Tigrai, Ethiopia, 6–9 March 1995.

—— 2000. 'Renewables and Energy for Rural Development in Ethiopia: Terms of Reference'. Nairobi: AFREPREN Energy Research Programme 2000–2002.

—— 2001. 'Renewables and Energy for Rural Development in Ethiopia: Short-Term Study Report, June 2001'. Nairobi: AFREPREN Energy Research Programme 2000–2002.

—— 2002. 'Development of Renewable Energy Resources for Rural Electrification in Ethiopia: Lost Opportunities and Future Prospects'. In Proceedings of the Rural Electrification Symposium, 1–5 March 2002, Addis Ababa.

—— 2003. *Country Data Validation: Eritrea*, Nairobi: AFREPREN/FWD.

World Bank, 1975. *Rural Electrification*. Washington, DC: World Bank.

—— 1984. 'Ethiopia: Issues and Options in the Energy Sector'. Report of the Joint UNDP/World Bank Energy Sector Assessment Programme, Report No. 4741-ET, Washington, DC: World Bank.

—— 1996. 'Ethiopia: Energy Assessment'. Energy Sector Management Assistance Programme (ESMAP), Report No. 179/96, Washington, DC: World Bank.

—— 1998. *Implementing the Ethiopian National Policy for Women: Institutional and Regulatory Issues*. Washington, DC: Women's Affairs Office, Federal Democratic Republic of Ethiopia and the World Bank.

—— 2000. *Ethiopia: Key Socio-Economic Indicators*. Washington, DC: World Bank.

—— 2002. *African Development Indicators, 2002*. Washington, DC: World Bank.

—— 2003. *African Development Indicators, 2003*. Washington, DC: World Bank.

Part VI Appendices

VIA.1 The levels and patterns of income distribution in Ethiopia: consumption and expenditure of the rural and urban households

The critical issues in appraising levels and patterns of income distribution were discussed in the introduction to the terms for the overall study (Wolde-Ghiorgis, 2000). In assessments of energy issues in developing countries, the income statistics reported by rural households usually tend to underestimate the actual income levels of peasant farmers and rural artisans, for various reasons. As a result, a number of countries usually take household expenditure as a proxy of income. Despite this fact, income statistics conducted in the analysis of the survey results are usually utilized to estimate the levels and patterns of income, consumption and expenditures of the households. In Ethiopia, at the country level, urban households spending below 2,000 Birr (US$250) annually (or less than 170 Birr (US$20.80) monthly account for 9.7 per cent of the total households, while the top 3.4 per cent spend 12,600 Birr (US$1,542) or more per household annually, or more than 1,000 Birr (US$122) per household monthly. The remaining 86.9 per cent spend between 2,000 and 12,599 Birr per annum. However, the bulk of the population, about 62.8 per cent of the households, spends less than 5,400 Birr per year (about 450 Birr = US$ 71.20 per month) per household (as shown in summary Table VIA.1). In rural Ethiopia, households spending below 2,000 Birr per annum (or less than about 170 Birr monthly) are 10 per cent of all rural households, while the top 1.7 per cent spend 12,600 Birr or more annually (more than 1,000 Birr monthly). The remaining, 88.4 per cent spend between 2,000 and 12,599 Birr per annum. It can also be seen from this table that 65.6 per cent of rural households spend less than 5,400 Birr per year (about 450 Birr per month) per household.

Both income and expenditure levels border around US$11 per month *per capita*, which again establishes the hard fact of poverty and underdevelopment throughout the country. With total dependence on depleted biomass energy resources, and lack of infrastructure, Ethiopia will need to focus on sustainable development programmes, including the upgrading of its energy resources and systems. The size of a household varies from region to region, but according to the CSA survey result, the average household size taken for the rural population is 5.1 persons, while that for the urban population is 4.7 persons. International energy consultants and energy experts who have been jumping too quickly to the inefficiencies of stoves and the pace of urbanization, have mostly overlooked the information shown in the Table VIA.1.

What needs to be emphasized here in focusing on the energy study is that access to modern services by rural communities in general, and by rural women in particular, appears to be tackled by policy issues that further and promote transitions from traditional biomass fuels to modern energy sources for both domestic needs and productive activities, which are the domain and responsibility of rural women in Ethiopia.

Table VIA.1 Summary of percentage distribution of households by domestic expenditure and income categories at country, rural and urban levels, based on the 1995/6 survey

Reporting level	Percentage of domestic expenditure in Birr * per household per annum			Percentage of income in Birr * per household per annum		
	Less than 2,000	2,000–12,599	12,600 or more	Less than 2,000	2,000-12,599	12,600 or more
Country	9.72	86.89	3.39	16.88	78.42	4.69
Rural**	9.95	88.41	1.66	15.13	81.59	3.27
Urban**	8.48	78.54	12.97	26.53	60.98	12.50

* During the survey period (1995/6), the average exchange rate was US$1 = 6.32 Birr.
** According to a CSA survey result, the average household size for the rural population is 5.1 persons, while that for the urban population is 4.7 persons.
Source: CSA, 1998a

VIA.2 Levels of energy consumption in Ethiopia

To emphasize again the gravity of the rural energy problem as it affects development and economic growth, it is worth quoting information given previously (Wolde-Ghiorgis, 2000).

In view of the severe poverty prevailing in the country, as briefly discussed above, Ethiopia has one of the lowest levels of energy consumption in the world, both in urban and rural areas of the country. Almost 100 per cent of the rural population and up to 50 per cent of the urban population are totally dependent on biomass energy sources: fuelwood, charcoal, branches, leaves, twigs, cattle dung and agricultural waste. The penetration of modern fuels into the rural areas is limited to the use of meagre supplies of kerosene, mostly needed for lighting with wick lamps. Except for a relatively small number of flour mills utilizing diesel fuels, the presence or semblance of modern energy leaves very rare traces in traditional farming areas or pastoral regions.

Estimates of gross energy consumption *per capita* have been placed as low as 245 kg of oil equivalent (kgoe). Consumption of petroleum products (<20 kgoe) and electricity (<28 kWh) *per capita* is very low by regional standards among sub-Saharan countries. While extensive studies have been undertaken to tackle urban energy supplies, the only solution repeatedly and consistently proposed by energy experts to redress the rural energy problem has been afforestation and avoidance of rapid urbanization. Planning, budgeting and implementation of afforestation programmes have been studied, but at best very small pilot projects have materialized. The growing rural population has been left to follow its own traditions and customs, continuing to collect the remaining but fast dwindling biomass energy resources.

First, nearby supplies are exhausted (including the digging out of the roots of cut trees); then the search extends to distant hills, valleys and non-farm lands. Beyond the various uses of biomass fuels, renewable energy sources (and substitute modern fuels) are practically unknown and unaffordable to the Ethiopian rural poor. The end result is an alarming and uncontrolled deforestation on a huge scale. The ensuing negative environmental degradation is compounded by the loss of rain and ensuing drought. To date, no sources of energy have become available to 99 per cent of the rural population except the traditional ones: firewood, tree branches, twigs, shrubs, cattle dung and agricultural wastes. The utilization of modern fuels (electricity and kerosene) amounts at most to 1 per cent of the total population. The use of renewable energy sources – solar energy, wind energy and micro-hydropower using an appropriate RET – is practically unknown in rural Ethiopia. Other than the development of improved cooking and baking stoves, and the extension of rural electrification to a number of *woreda* (subdistrict) administrative towns, rural energy initiatives have been very limited. From 2002 onwards, the government and EEPCO are launching a rural electrification programme that aims to extend rather overdue but still sorely needed supports from financing institutions and friendly governments. As far as energy assessments and related studies are concerned, though, conceptual plans for national electrification and the energy infrastructure are still awaited.

VIA.3 Aspects of existing energy policy and institutional frameworks in Ethiopia

Whatever rural energy initiatives are to be launched in Ethiopia, it will be necessary to give first priority to the building of appropriate institutional frameworks. The needed energy technologies (notably renewable ones like PVs, mini/micro hydropower generators and wind generators) can be wholly or partially imported. The non-renewable ones (like diesel generator sets and kerosene stoves and lamps) can be installed easily at convenient locations for immediate uses. In principle modern energy services and options in rural areas can be promoted through a combination of financial incentives and managerial skills. Included in the mix will be the generation and distribution of electricity, a supply of oil, and possibly also locally mined or imported coal. However, without institutional frameworks at the right level of authority and jurisdiction, the rural energy problem cannot be resolved easily. It is difficult to imagine how much-needed modern energy services and options can be promoted sustainably, especially in a technologically underdeveloped country like Ethiopia. This concern was expressed in the terms of reference for the study, introducing the complexity of the challenge lying ahead (Wolde-Ghiorgis, 2000).

The federal government is responsible for enunciating overall energy policies, and the 11 regional states are responsible for managing rural and urban energy programmes and projects within their regions. At the federal level, the former Ministry of Mines and Energy (up to September 2001) had the jurisdiction to formulate and plan energy policy, and to administer central energy institutions. These were its former Department of Energy, and the Ethiopian Rural Energy Development and Promotion Centre. At each regional level, there has also been a Bureau of Mines, Water and Energy. Each regional bureau has worked closely with the federal authorities in implementing policies. But a given bureau will have direct jurisdiction over zone (district) and *woreda* (subdistrict) administrations. Within each subdistrict, there are smaller administrative units known as *kebeles* (sizable villages or cluster of smaller villages with a total population of about 2,000 and above). The rural communities live and work on their farms and have their homes in the village. Thus in Ethiopia jurisdiction over rural energy administration is in the hands of the regional Bureaus of Mines, Water and Energy. This is unlike the situation in other member countries within the AFREPREN Theme Group on Renewables and Energy for Rural Development.

The modern energy sector in Ethiopia comprises to date only the electric power and petroleum subsectors. The former is almost 95 per cent based on hydropower, with the remaining portion being diesel generation powered with imported oil fuel. It was formerly known as the Ethiopian Electric Light and Power Authority (EELPA). In 1997 it became a reorganized enterprise as the Ethiopian Electric Power Corporation

(EEPCO). The petroleum sector, formerly managed under the Ethiopian Petroleum Corporation (EPC), was again reorganized in 1993, and named the Ethiopian Petroleum Enterprise (EPE). Previously, EPE used to run a small refinery (maximum capacity 850,000 tons) at a Red Sea port that was closed in July 1997 owing to the aging of the refinery plant and costly operational inefficiencies. Since then, the petroleum subsector has been importing refined products only. Both subsectors began working as semi-independent business enterprises under the Ministry of Infrastructure in October 2001. Since then, the former Ministry of Mines and Energy has become the Ministry of Mines only. An underdeveloped alternative energy programme largely directed at the promotion of energy conservation and the improvement of stoves among urban communities is being run by the EREDPC, responsible to the Ministry of Rural Development since October 2001. The regional energy bureaus are in the process of reorganization.

The World Bank, UNDP, international consultants and other development agencies have undertaken numerous assessments of the energy sector in Ethiopia since the early 1980s. Yet, the energy subsector affecting the vast rural population of Ethiopia still remains unrecognized. No analysis of the problem has yet been undertaken with the aim of alleviating the visible and hidden negative impacts on sustainable development. The only supposedly viable solution proposed is a relatively wide but unmanageable afforestation programme involving fuel plantations to replace depleted resources. The energy assessments have not considered the contribution modern energy substitutes can make to resolving the deepening energy crisis facing the country.

In 1994 the first energy sector policy for Ethiopia was issued, laying stress on the need to harness the immense hydropower potential of the country. Starting from 2000, a five-year programme for ongoing and committed hydropower projects has been launched to increase existing generating capacity by 126 per cent. The exploitation of available geothermal energy resources and other renewable energy sources have also been included in the energy policy. The existing energy policy thus promotes the harnessing of available energy resources. But there are also noticeable gaps and barriers in its applications and implementations, and even in its interpretations.

As indicated earlier, strategies and programmes for implementing the energy policy have not been designed effectively. In particular, there are clear gaps and barriers in instituting energy reforms and developments with regard to the immediate and longer-term energy needs of the rural communities. So, while the energy policy is appropriate and sufficiently broad, the contribution and development of the rural energy subsector is at a very rudimentary stage. A vital component is smooth and effective working relations between the EREDPC (within the MRD) and the regional energy bureaus. Once again, although the energy assessment reports have addressed and emphasized this critical issue of the institutional framework in parallel with pursuit of the fuel afforestation project, there has been no tangible outcome. Precious time – perhaps 20 years or so – has been lost through failure to bring to the fore the implications and negative impacts of energy underdevelopment. In the meantime, the population rise has been increasing unabated, deepening the gravity of the rural poverty indicators. As the population is increasing, but the available energy supply is either constant or increasing only slightly, the *per capita* energy consumption can only be decreasing gradually.

Because there are no viable institutional frameworks for promoting RETs systematically and consistently, the problem is actually multidimensional. The present study has addressed the critical issues involved and the gaps created by testing hypotheses for the short-term and energy phases. The study has also aimed to gain from experiences in East, Central and Southern Africa. The more extensive experiences of other developing countries in South-East Asia and South America will also be very useful. In implementing rural energy policies and projects, the first step to be taken will be to build strong institutional frameworks at federal and regional levels.

VIA.4

Mean monthly wind speeds (m/s) measured at approximately 2 metres above ground, derived from meteorological data (1968–73)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Mean
Addis Ababa	4.1	3.6	2.9	4.8	4.1	3.1	2.9	2.3	3.5	5.4	5.2	4.5	3.9
Awash	3.8	3.1	3.3	3.3	2.8	4.6	5.4	4.1	3.8	3.9	3.8	3.7	3.8
Bahr Dar	1.5	1.9	1.9	2.2	2.0	1.6	1.3	1.2	1.3	1.4	1.5	1.3	1.6
Combolcha	1.7	1.8	2.1	1.9	2.3	2.8	2.5	2.2	1.7	1.3	1.4	1.9	2.0
Debre Markos	1.5	2.3	1.8	1.8	1.9	1.7	1.2	1.3	1.5	2.0	1.4	1.6	1.7
Debre Zeit	2.8	3.5	3.2	3.6	2.7	2.8	2.1	1.9	2.1	3.1	3.6	3.2	2.9
Dire Dawa	2.6	2.7	3.0	3.3	3.8	4.5	4.9	4.4	3.8	3.6	3.3	3.0	3.6
Goba	0.8	0.8	1.0	0.8	0.5	0.6	0.4	0.5	0.5	0.5	0.3	0.4	0.6
Gode	2.9	3.5	2.6	2.3	2.8	4.8	4.8	4.3	4.8	2.6	1.8	2.6	3.3
Gondar	3.9	4.4	5.3	4.0	5.0	4.4	3.8	4.2	4.7	3.5	3.3	3.4	4.2
Gore	3.2	3.6	4.1	4.8	3.2	1.6	1.9	2.2	5.1	2.7	1.3	0.7	2.9
Jijiga	2.6	2.1	2.1	2.4	2.6	4.6	5.1	5.6	3.0	2.8	2.7	3.0	3.2
Jimma	3.0	3.4	3.6	3.6	4.0	4.2	4.1	3.6	2.6	3.1	1.8	2.1	3.3
Kebri Daher	4.0	3.1	2.0	2.0	2.4	3.5	5.4	6.9	3.3	1.9	1.2	1.5	3.1
Mekele	3.6	3.5	4.6	3.9	2.8	2.1	1.5	1.6	4.0	5.3	4.8	3.8	3.5
Neghelle	4.3	3.1	3.3	3.1	2.6	3.5	3.6	3.9	3.5	2.4	3.6	3.9	3.4
Nekempte	1.9	1.8	1.9	1.9	1.1	0.9	1.3	1.2	1.5	1.5	1.2	1.9	1.5

Sources: Meteorological Report, Civil Aviation Authority of Ethiopia; 1968–73; Wolde-Ghiorgis, 1988

VIA.5

Extrapolated wind speeds at 20 metres above ground, power densities (W/m^2), and annual estimated energy densities ($kWh/m^2/year$) for 12 sites in Ethiopia

Site	Measured mean wind speed v_o (m/s) at 2 m above ground	Extrapolated mean wind speed v (m/s) at 20 m above ground $v = 1.79v_o$	Estimated peak mean wind power density $(0.593)(\rho v^3/2) = Kv^3$ W/m^2	Estimated annual wind energy density* $E = \eta K[T_e (2.5v)^3 T_f (0.8V)^3] \times 12 \times 10^{-3}$ $kWh/m^2/year$
Addis Ababa	3.9	7.0	96.7	1380.14
Awash	3.8	6.9	103.2	1424.52
Debre Zeit	2.9	5.2	40.3	578.18
Dire Dawa	3.6	6.5	84.7	1188.33
Gode	3.3	5.9	71.3	245.24
Gondar	4.2	7.6	124.9	1741.96
Gore	2.9	5.2	65.9	573.40
Jijiga	3.2	5.8	45.3	808.72
Jimma	3.3	5.9	60.1	868.73
Kebri Dare	3.1	5.6	61.4	860.98
Mekele	3.5	6.3	70.4	1002.81
Neghelle	3.4	6.1	68.0	962.63

Note *: η = efficiency; $K = (0.59)(\rho/2)$; ρ = air density (kg/m^3) ; T_e = average energy duration of energy winds (240 hours in a month); T_f = average duration of most frequent winds = 360 hours in a month.

Source: Wolde-Ghiorgis, 1988, with extrapolations made from data given in Table VI.A.4

VIA.6

Sample lists of electricity-supplied towns from suppliers outside EELPA, 1988

Planning zone	Administrative region	Town	No.	kVA*	No.	KW
Central	Arsi	Kersa	1	75	1	60
	Shoa	Wonji (sugar factory)	3	2250	3	1800
		Metahara **	2	8250	2	6600
		Shoa **	2	4750	2	3800
		Molala	1	75	1	60
		Gabber Guracha	1	125	1	100
Eastern	Hararge	Degahabur	1	75	1	60
Western	Wollega	Bissa	1	75	1	60
		Gidame	1	35	1	28
	Keffa	Shobe	1	100	1	80
		Tole	6	3246	6	2597
	Illubabor	Yau	1	100	1	80
		Teppi	1	75	1	60
Northern	Tigrai	Mehonnie	1	85	1	68
		Abdi Adi	1	150	1	120
		Hawsien	1	120	1	96
North-eastern	Wollo	Kemessie	1	60	1	48
		Urgessa	1	75	1	60
		Wuchale	1	68	1	54.4
North-western	Gondar	Gorgora	1	75	1	60
		Metema	1	23	1	18.4
		Serba	1	75	1	60
	Gojam	Jiga	1	156	1	124.8
		Mota	1	60	1	48
		Tilila	1	75	1	60
Southern	Sidamo	Hagere Mariam	1	70	1	56
		Arka	1	156	1	124.8
		Yabelo	1	106	1	84.8
	Bale	Ginger	1	75	1	60
		Meselo	4	2840	4	2272
	Gamu Gofa	Chencha	1	75	1	60

Notes: *1 kVA = 0.8 kW

** Generators using steam (baggasse fuel); all other generators are driven by diesel engines.

Source: EELPA, Statistical Reports

VIA.7

Plans for diesel generation in EEPCO's Five-Year Rural Electrification Programme (2001–5)

Diesel generation under the former EELPA, and currently under its inheritor EEPCO, has been the only source of electricity in the self-contained system (SCS). Generating capacities have ranged from 50 kW to 3 MW, all within the medium speed range (600–750 rpm). The total installed generating capacity within the country for the SCS stations amounts to about 50 MVA, although the energy supplied and consumed falls well below that supplied by hydropower. Mostly, the stations are located in areas that are on the average over 800 km distant from the interconnected system (ICS) grid that covers the eastern, southern, western and northern parts of the country, as well as the main load centre around Addis Ababa. Maintenance and operational problems have ranged from the supply and delivery of fuel and lubricating oils to the acquisition of replacements for damaged and worn-out parts. As the actual costs of fuel and technical personnel outweigh significantly the revenues collected from the sales of electricity at a fixed and uniform tariff, and as the technologies of the diesel generating parts have varied extensively, EELPA was not so keen to push the expansion of the SCS stations. Nonetheless, rural electrification that could not be realized by grid extension has consistently been implemented by resorting to diesel generation. In the first phase of the current five-year rural electrification programme (2001–4), up to 59 rural towns or settlements are to be electrified using diesel generation with the following distributions:

Table VIA.7 Initial phase of five-year rural electrification programme (2001–5)

Administrative region	Generating stations/units
Gambella	4
Benshangul Gumuz	11
Afar	11
Somali	20
Oromiya	9
Amhara	2
Southern Nations & Nationalities State (SNNPS)	2
Total	59

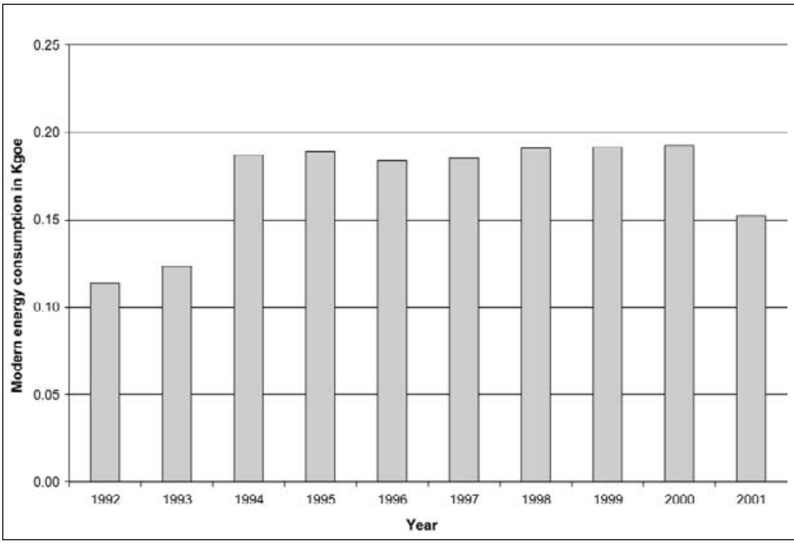
In the first phase of the implementation of the rural electrification programme, 20 diesel generators (or one third of the total number) have been tendered for as of September–October 2000. The stations/units will consist of five units in the 200–225 kW range, 12 in the 300–325 kW range, and three in the 650–680 kW range, all with a rated voltage of 400/230 volts, to be operated at a high speed of 1,500 rpm. Exact locations of the diesel stations are to be determined in consultations with regional authorities, and also in line with recommendations that will be provided by the Addis Ababa University Consultancy Group. Issues of concern will be accessibility by all-weather roads for transporting fuel, and cost of investment.

From the maintenance point of view, while EELPA had built in the past a very successful training programme for electromechanical specialists that would be assigned to each SCS station, lack of guaranteed provision of spare parts for the diesel engines has remained a constant source of dissatisfaction and dispute between EEPCO and its relatively few customers. Besides, the timely supply of fuel to remote and inaccessible stations has allowed the utility to continue running power stations that otherwise never had any chance of profitability. Gradually, many of the SCS stations powered in the past by diesel stations have been connected to the nearest ICS grid lines, notably in the Fitche area and in the eastern, western and northern regions of the country. The issue of attaining optimum load factors is still not fully resolved, however, as connection fees to be paid by prospective consumers have been soaring beyond the expectations and financial capabilities of semi-rural communities – and all this is compounded by a shortage of readily available distribution materials and accessories. From June 2002 onwards, the rural electrification programme has been greatly expanded through the support of financing institutions.

VIA.8 Selected trend data: Ethiopia

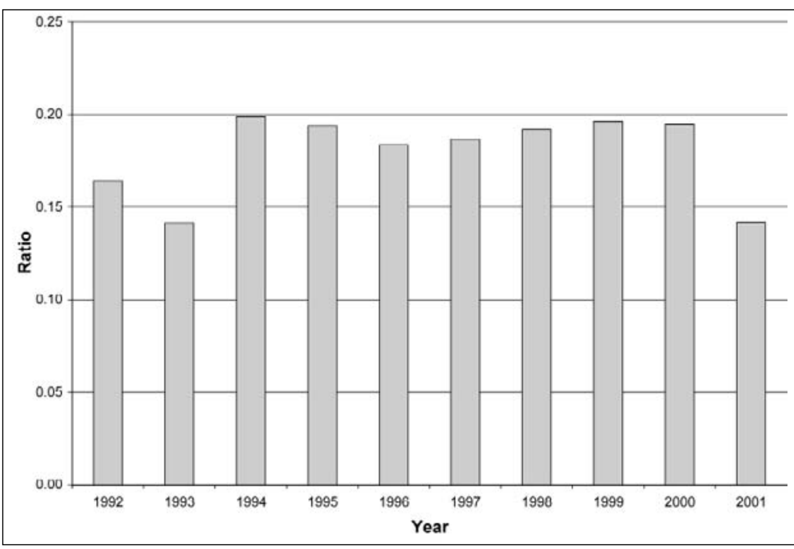
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
GDP (US$ millions)	5,197	5,920	4,545	5,026	5,543	5,875	6,028	6,003	6,230	7,933
GNP *per capita* (US$)	110	120	100	100	100	111	115	115	100	100
Total modern energy consumption ('000 toe)	590	730	850	950	1,020	1,090	1,150	1,150	1,200	1,207
Modern energy consumption *per capita* (kgoe)	10.8	13.7	15.5	16.8	17.5	18.2	18.8	18.3	19.1	18.5
Total energy production ('000 toe)	14,510	14,090	14,090	15,500	15,890	16,260	16,750	17,180	17,580	
National debt (US$ millions)	9,341	9,703	10,067	10,310	10,077	10,079	10,352	5,544	5,481	5,697
Merchandise exports, f.o.b. (US$ millions)	154	222	280	454	412	599	602	485	486	441
Installed capacity (MW)	407	407	409	417	417	417	420	420	420	493
Electricity generation (GWh)	1,147	1,278	1,389	1,470	1,554	1,604	1,610	1,650	1,670	1,812
National electrification levels (%)	10.54	10.82	11.10	11.60	11.94	12.24	12.52	12.84	13.00	13
Rural electrification levels (%)	0.13	0.14	0.16	0.19	0.18	0.16	0.16	0.17	0.17	0.2
System losses (%)	15	19	19	19	18	18	16	17	17	22
Rural population with access to safe water (%)	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5	23.0
Total electricity consumption (Gwh)	853.4	835.92	903.23	972.97	1017.6	1095.8	1157.3	1177.9	1212.2	1122.3
Electricity consumption *per capita* (KWh)	17	16.2	17	17.8	18	18.9	19.3	19.1	19.1	17.2

Sources: Wolde-Ghiorgis, 2003; Kebede, 2003; AFREPREN, 2003; World Bank, 2000; World Bank, 2003



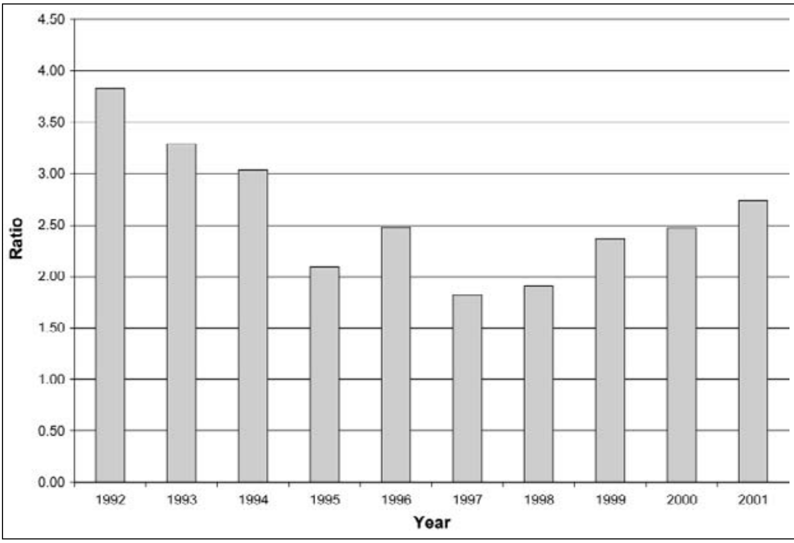
VIA.8.1 Total modern energy consumption (Kgoe) versus GDP (US$) (Modern energy consumption per US$1 of GDP)

Source: AFREPREN/FWD 2003



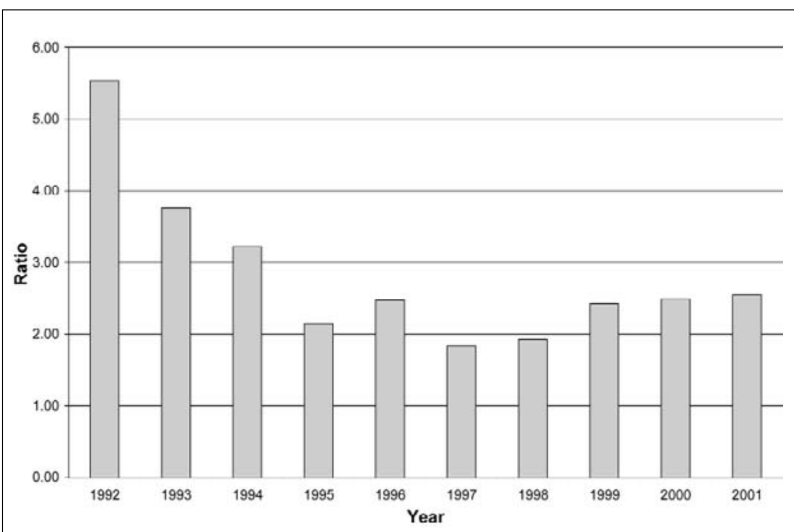
VIA.8.2 Total electricity consumption (Kgoe) versus GDP (US$) (Electricity consumption per US$ of GDP)

Source: AFREPREN/FWD 2003



VIA.8.3 Total modern energy consumption (Kgoe) versus merchandise export (US$) (Modern energy consumption per US$ of merchandise export)

Source: AFREPREN/FWD 2003



VIA.8.4 Total electricity consumption (Kgoe) versus merchandise export (US$) (Electricity consumption per US$ of merchandise export)

Source: AFREPREN/FWD 2003

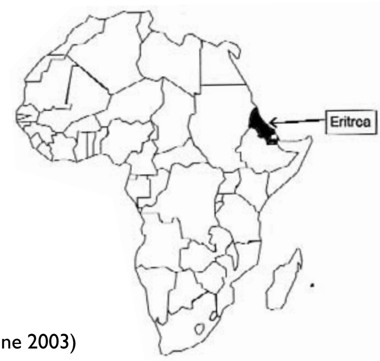
Part VII

ERITREA

Semere Habtetsion and Zemenfes Tsighe

COUNTRY PROFILE

Eritrea



SELECTED INDICATORS

Population (millions): 4.23 (2001)
Rural population as a percentage of the total: 80.9 (2001)
Land area (km^2): 124,320
Capital city: Asmara
GDP growth rate (%): 7.0 (2001)
GNP *per capita* (US$): 160 (2001)
Official exchange rate: Nakfa 14.5 = US$1 (June 2003)
Economic activities: Agriculture, manufacturing, mining, commerce
Energy sources: Biomass, imported petroleum, solar, wind
Installed capacity (MW): 98 (2000)
Electricity consumption *per capita* (kWh): 49.0 (2001)
Electricity generation (GWh): 224 (2001)
System losses (%): 17 (2001)
Electrification levels (%): (2001) National: 21
Urban: 82
Rural: 2
Biomass consumption as a percentage of total energy: 69.80 (2000)

Sources: Habtetsion, 2003; AFREPREN/FWD, 2003; EIU, 2003; World Bank, 2002 World Bank, 2003; IEA, 2002

Exchange Rate:

Year	1991–97	1998	1999	2000	2001	2002
Nakfa	7.2	8.2	9.7	10.10	13.50	13.50
US$	1	1	1	1	1	1

Source: Bank of Eritrea

Acknowledgements

The researchers express their profound appreciation of the kind support of AFREPREN/FWD and the Swedish International Development Cooperation Agency (SIDA). We also thank the AFREPREN Secretariat in Nairobi, particularly Stephen Karekezi, Director of AFREPREN/FWD, for the timely and valuable information and advice that was made available to us from the inception of the research proposal until the completion of the final report.

Here at home, several organizations and individuals, too many to mention by name, have also helped us in various ways. We express our gratitude to all, and our special thanks to the Department of Energy for supporting our research and providing relevant energy data. We also thank the Commercial Bank, the Investment and Development Bank and micro-financiers operating in the country for their inputs.

17

Introduction

In most sub-Saharan African countries, the bulk of energy consumption takes place in rural areas, most of it in the form of biomass energy, which encompasses a wide range of natural organic fuels such as wood, charcoal, agricultural residues and animal waste. A study on household energy consumption patterns in Africa by the African Development Bank (ADB, 1996) reveals the immense reliance of households on traditional fuels (77 per cent on the average). This study highlighted the fact that the subregional average biomass share of energy consumption oscillates between 85 and 93 per cent, except in the North African countries (which average 30 per cent), South Africa and Mauritius. However, there is wide variation from country to country: 43 per cent in Zimbabwe, 46 per cent in Mauritius, 66 per cent in Zambia and Eritrea, 86 per cent in Kenya, 94 per cent in Ethiopia and Mozambique, 95 per cent in Sudan and Rwanda (Hall and Mao, 1994; DoE, 1998).

Biomass is currently used in Eritrea largely in its traditional and unprocessed form. The bulk of the biomass energy is used for household cooking purposes, with energy conversion efficiencies being typically 10 per cent or less. Other important end uses of biomass energy in the rural areas include income-generating activities like small-scale charcoal production, lime and brick manufacturing, bakeries, *injera* making (*injera* is soft bread, typically 60 cm in diameter and less than a centimetre in thickness), pottery, smithery and traditional beer brewing. There are several environmental drawbacks associated with current practices of biomass energy use. The most serious environmental problem is said to be indoor air pollution from unvented biomass cookstoves. This problem is particularly acute in the rural highland areas of Eritrea where biomass is used both as a cooking (inside the home in a semi-enclosed atmosphere) and space-heating fuel. There is growing evidence linking the use of biomass energy in the rural areas with respiratory and eye diseases, which constitute two of the biggest health risks to women and young children.

Use of biomass energy has also been linked to the devegetation and deforestation that afflicts large parts of Eritrea. Although biomass energy is considered to be renewable, its renewability is conditional on adequate replanting and reforestation efforts. In Eritrea today access to fuelwood is highly constrained by the dwindling of resources, and demand is to some extent suppressed. Under pressure from this situation, the Ministry of Agriculture has enacted regulations that ban the cutting of live trees for fuel, establish closure areas – amounting to 240,000 hectares so far – and prohibit charcoal making. This intervention was dictated by the unsustainable rate of harvest, which in 1995 stood at 2.4–2.8 per cent of the stock. This rate of harvest is almost twice the critical threshold of 1.25 per cent recommended for sustainable harvest in the semi-arid regions of sub-Saharan Africa in general and Eritrea in particular (Lahmeyer/DoE, 1997). Land clearing for agriculture is also perceived to be a deforestation driver, and a more important one.

Many factors have constrained access to modern energy services in rural Eritrea. Poverty is perhaps the single most important of these, as people normally move up the energy ladder when their income increases, with people shifting from locally available traditional fuels to modern commercial energy carriers as well as to convenient and energy-efficient conversion devices. The dispersed settlement patterns of rural people is another factor, as this makes planning for integrated development even more difficult.

Lack of pro-rural energy policies and appropriate institutional frameworks are other important factors that have made rural energy programmes fail or falter, lacking the necessary momentum and vigour in the implementation process. Organizations dealing with energy lack institutional mechanisms for the identification and analysis of rural energy needs, or patterns of demand and consumption: energy statistics are rarely collected and collated. In Eritrea, as established in the short-term study, there is no representation of the Department of Energy at the provincial and local administration levels, as a result of which the energy needs and problems of rural people do not have influence in the policy- and decision-making processes. Poor linkages and coordination between the various stakeholders involved in the supply and demand chains of rural energy is also responsible for poor performances, duplication and waste of effort.

Conflict is another factor that has limited investment in the development of indigenous energy resources. In Eritrea, the 30-year war of liberation and the 1998–2000 conflict with Ethiopia seriously hindered expansion of the energy infrastructure, particularly to rural areas. Up to 20 per cent of the installed RETs and quite a number of gensets serving the small towns invaded by the Ethiopian army were either dismantled and taken or completely and deliberately destroyed. Mechanisms for generating local financial and technical resources are also far from developed.

The relationship between energy, women's work in the domestic sector and their well-being is evident in women's role as users of energy sources and collectors of traditional biomass fuels. In addition, experience in Eritrea shows that women are the most vulnerable to energy scarcity and environmental damage from energy production and use. Gender issues in energy have begun to receive a little attention in Eritrea at micro level through technological interventions such as rural electrification, dissemination of improved cookstoves, solar box/parabolic cookers, wood plantations and so on. They have yet to be addressed in macro-level policies. In principle, women's needs for energy vary depending on whether they are in urban or rural areas, their stage of economic development and whether they are economically active or not.

The development process in general, and that of income-generating activities in rural areas in particular, pivots on access to reliable and sustainable modern commercial energy. The relationship between modern energy and such factors as income and employment generation by small and medium enterprises, gender impacts, and the role of the private sector in energy production and distribution – all this is only dimly perceived and/or poorly understood in Eritrea. The study intends to address these and other related issues.

Objectives of the study

In line with the recommendation of the 1999 AFREPREN General Assembly, the objective of the Renewables and Energy for Rural Development Theme Group is to identify options for the provision of modern energy services to low-income rural areas of Eritrea as part of the eastern and southern African region, with special emphasis on commercial/service/productive uses of energy. To achieve this, the study focuses on:

- assessing the current rural household and community energy practices and technologies;
- analyzing the impact of current rural energy policies;
- reviewing rural income-generating activities and the energy technologies used;
- establishing what is hindering the removal of identified barriers in the dissemination of RETs and other efficient rural energy options (the absence, for example, of rural entrepreneurs, funding mechanisms, capacity building and policy directives).
- formulating recommendations on rural energy policies in Eritrea to (1) improve the performance and implementation of these policies; (2) improve the availability of modern and efficient energy services to rural SMEs to increase income and employment;
- identifying modern and efficient energy options for use in rural SMEs, with the same broad aims.

Major research issues

In line with recommendations of the 1999 AFREPREN General Assembly and follow-up Theme Group Meetings, AFREPREN's principal donor

SIDA/SAREC has approved the research issues discussed below for detailed study by the AFREPREN Theme Group on Renewables and Energy for Rural Development.

SHORT-TERM STUDY

1 Impact of government/utility policies and programmes on the provision of modern energy to rural areas for domestic and income-generating activities.

2 The existing government/utility institutional framework: poor linkages and coordination between stakeholders (all parties involved in rural development) are not conducive to the design and implementation of rural energy initiatives.

MEDIUM-TERM STUDY

3 Analysis of existing decentralized private sector energy production and distribution activities in rural areas.

4 Comparative analyses of demand for modern energy in rural areas (actually existing and future potential) created by income-generating activities and domestic use.

5 Analysis of components for promoting the production and deployment of RETs by private entrepreneurs in rural areas: market research; financing mechanisms; provision of infrastructure for production, repair and maintenance; training (entrepreneurial, technical, managerial) and technical back-up.

Background to the energy sector in Eritrea

Eritrea is a young country, which was liberated from Ethiopia in May 1991 after a 30-year war of independence. Two years later, a UN-supervised referendum was conducted to ascertain the wish of the Eritrean people. In that referendum, 99.8 per cent of the people voted for independence, and the State of Eritrea was officially proclaimed. Soon after, Eritrea was admitted to the UN, the OAU and many other international organizations.

Eritrea is located in the Horn of Africa, shares boundary lines with Ethiopia, Djibouti, and the Sudan, and has a coastline of 1,200 km along the Red Sea. Eritrea has a total land area of 124,320 square kilometres and a population of around 3.5 million people, 80 per cent of whom live in the rural areas.

The introduction of modern energy services in Eritrea dates back to the Italian colonial period. It is possible that electricity and fossil fuels may have been introduced to Eritrea at the beginning of the twentieth century, but the actual production and sale of electric energy commenced in 1920 under the direction of Azienda, an institution owned by the Italian government of that period. The supply of electricity was mainly restricted to Asmara and Massawa.

Sixteen years later, two private Italian companies, SEDAO and CONNIEL, took over the production and sale of electricity. SEDAO owned and managed the electricity industry in the Asmara–Massawa corridor, and thus laid the foundation of the present-day interconnected system (ICS), while CONNIEL operated in the other towns – such as Mendefera, Keren, Assab and Dekemhare – that today form the self-contained system (SCS). SEDAO also operated a small hydroelectric power station at Durfo driven by water pumped from a small water reservoir at Beleza. In 1964 and 1968, two steam turbines with a combined capacity of 15 MW were commissioned, and the reservoir was used to supply water to these turbines. The steam turbines were decommissioned in 1993 as a result of age-induced wear and tear, and because the frequent droughts of the 1970s–1980s made the reservoir unable to store enough water for their steady and reliable operation. At present the reservoir is used as a coolant for the thermal generators erected there.

In spite of the early introduction of modern fuel services to the country, the Eritrean population still depends heavily on biomass sources of energy. The energy database updated by the Department of Energy in 2000 (DoE, 2000) shows that total primary and final energy

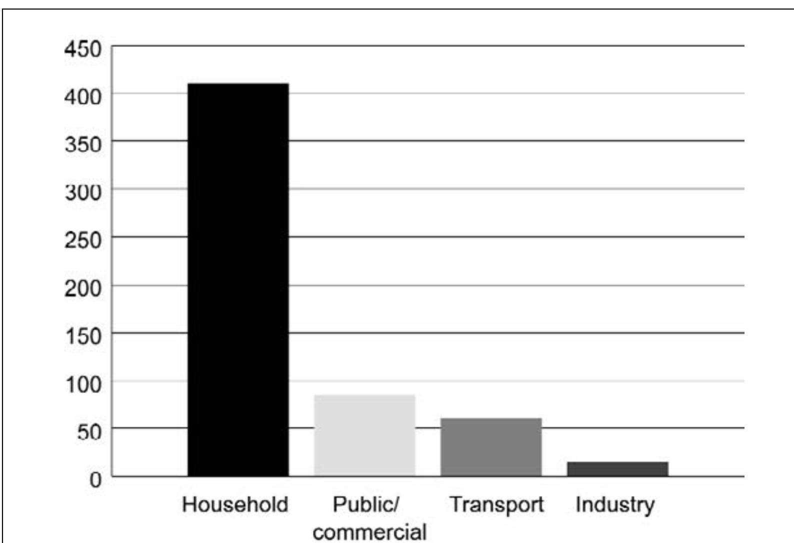


Figure 17.1 Energy consumption by sectors ('000 toe), 2000

Source DoE, 2000

supplies were 725,000 and 653,550 tons of oil equivalent (toe) respectively. Of the total final energy supply, 66.5 per cent was derived from biomass carriers of energy while oil products and electricity accounted for 31.3 and 2.2 per cent respectively. Moreover, 68.5 per cent of this was consumed by the household sector, 17.5 per cent by the public and commercial sector, 11.2 per cent by the transport and 2.8 per cent by industry (Figure 17.1). However, in the rural households, up to 95 per cent of the total energy consumed is derived from biomass sources. Many income-generating activities in rural areas like smithery, pottery or local beer brewing also depend on biomass fuel. In fact, 80 per cent of the energy consumed by rural SMEs is accounted for by biomass (Fisseha, 1996). As in most developing countries, the greater part of the energy consumed in the rural areas of Eritrea is used for subsistence (cooking, space heating, lighting); only a small proportion is used in agriculture, small-scale industries, fisheries, commerce and services.

Assuming a population of 3.29 million for 2000, the final *per capita* energy consumption stood at about 200 kg of oil equivalent (kgoe), of which 66.5 kgoe, or 33.5 per cent, was derived from modern energy (electricity and oil products). The *per capita* share of modern fuel for Eritrea is very low even by some African standards, and compares poorly with that of the Republic of South Africa (2,350 kgoe), Egypt (1,630 kgoe), Algeria (890 kgoe), Zambia (130 kgoe), Kenya (110 kgoe), Ghana (110 kgoe) and Sudan (70 kgoe) – if favourably with a few countries like Mozambique (44 kgoe), Tanzania (30 kgoe) and Ethiopia (20 kgoe) (IEA, 1999). The low share of modern energy in Eritrea is indicative of the low level of economic development of the country.

The temporal energy consumption pattern shows some interesting trends both in the relative share of biomass and modern energy as well in the mix of the biomass sources. According to the energy surveys conducted by the DoE in 1995 and 1998, the share of biomass fell from 79 per cent in 1995 to 66 per cent in 1998 (Lahmeyer/DoE, 1997; DoE, 1998) (see Table 17.1). The decrease may be attributed to the following reasons:

- The fuelwood consumption *per capita* of 440 kg, as estimated from the 1995 survey, was unrealistically high. The 1998 survey result of 250 kg /*capita*/year, or around 115 kg/household/month, is more realistic for the majority of households. This also applies to dung and charcoal.
- The introduction of regulations (see above) that ban the cutting of live trees for fuel and charcoal making, and the growing area coverage of closures, restrains access to fuelwood.
- These conditions have led to shifts to other sources of energy, mainly kerosene and agri-residues for cooking, and to energy-saving practices by users.

Note that the fuelwood consumption in Table 17.1 is actually higher than indicated, as that required for kiln-produced charcoal is not

Table17.1 Biomass energy consumption 1994–2000 (000 tons)

Type of Fuel	1994	1995	1996	1997	1998	1999	2000
Fuelwood	1,292	1,334	1,375	1,418	831	856	881
Charcoal	114	117	121	125	73	76	78
Dung	360	371	383	394	265	273	282
Agri-residue	47	49	50	52	91	94	96
Total biomass	1,813	1,871	1,929	1,989	1,260	1,299	1,337

Source: Lahmeyer/DoE, 1997; DoE, 1998, 2000

included; this is produced from wood in the ratio of 6 kg of wood : 1 kg of charcoal. The charcoal used by around 80 per cent of the households is referred to as 'recycled charcoal'. This type of charcoal is produced from burning fuelwood by sprinkling it with water to interrupt the combustion and preserve it for later usein such household tasks as making tea, coffee and sauce. The actual kiln-produced charcoal is estimated to be 20 per cent of the entry under charcoal in Table 17.1.

After biomass, oil products constitute the second important source of energy in the country. Consumption increased at an annual average of about 10 per cent in 1993–7 (Figure 17.2). In 1998 consumption was lower than in 1997, reflecting Ethiopia's boycott of the use of Eritrean ports. Higher fuel prices on the international market in 2000 might have caused forced savings in fuels, and thus the slight decrease in petrol, diesel and kerosene consumption compared with 1999. Lubricants, bitumen and bunker fuel oil are included under 'others' in Figure 17.2.

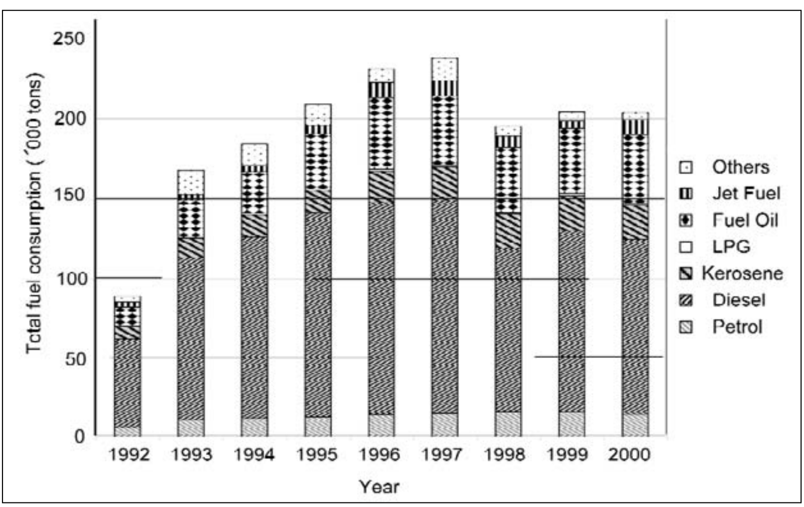
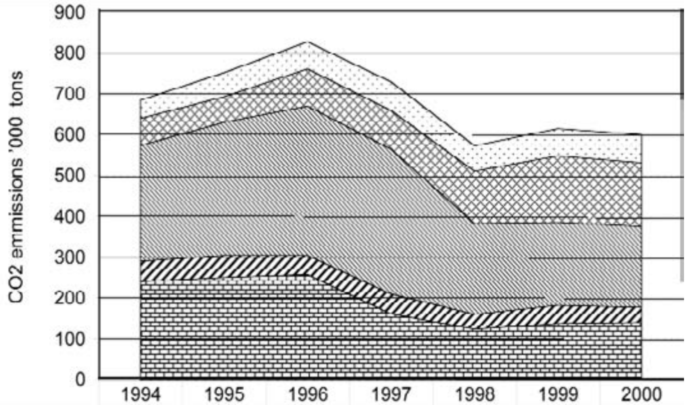


Figure 17.2 Consumption of petroleum products by fuel type and year (000 tons)

Source: DoE yearly reports



	1994	1995	1996	1997	1998	1999	2000
Residential	44.54	58.42	66.37	69.86	62.06	66.68	68.88
Public & Commercial	66.31	62.57	91.56	94.88	128.34	162.77	155.29
Transport	282.92	326.29	365.12	354.39	222.07	203.33	198.74
Manufacturing Industry	49.83	54.32	46.78	49.16	36.56	44.38	36.63
Energy Industry	240.9	250.42	258.01	160.96	124.07	138.09	140.73

Figure 17.3 Sectoral CO_2 emissions from fossil fuel combustion, 1994–2000

The inventory on greenhouse gas emissions from fossil fuel combustion is shown in Figure 17.3. As the greenhouse gas emission is proportional to the consumption of fossil fuels, the figure indirectly reveals the corresponding sectoral consumption.

Of the 1994 GHG emissions from fossil fuel combustion, the transport sector accounted for 41 per cent, the energy industry for 35 per cent, and the public/commercial sector for 10 per cent, while manufacturing industry and the residential sector each contributed 7 per cent. The closure of the Assab refinery after 31 July 1997 and the unexpected war of 1998–2000 with Ethiopia resulted in significantly lower consumption of oil products in the energy and transport sectors. Greenhouse gas emission data for the year 2000 reveal that the transport sector accounted for 33.1 per cent, the public/commercial sector for 25.9 per cent, the energy industry for 23.4 per cent, households for 11.5 per cent and manufacturing industry for 6.1 per cent.

The market share of electricity in the energy sector is only around 2 per cent (DoE, 1998), all produced by thermal means from diesel or fuel oil. Time series data of basic indicators in the electricity sector for systems operated by the Eritrea Electric Authority (EEA) are given in Table 17.2. The total installed capacity at present is about 100 MW, of which the EEA as the national utility accounts for around 70 MW, while the remaining 30 MW comes from public institutions like the Assab Petroleum Refinery or the Assab Port Administration, from small municipalities in remoter towns, or from private entrepreneurs with smaller gensets. However, the

Table 17.2 Profile of electricity from the EEA system, 1992–2000

	1992	1993	1994	1995	1996	1997	1998	1999	2000
Generation, GWh	110.3	119.9	130.2	144.7	161	180	186	205	201.4
Consumption GWh	93	93.4	105.8	123.2	124.6	143.7	145.2	158.5	159.7
Loss, %	15.7	22.1	18.7	14.9	20.7	20.2	21.1	22.7	20.7
Customers	69,584	68,902	74,439	78,000	85,250	91,096	94,380	95,695	96,186
Firm capacity, MW	30	40.8	39.1	55.7	56.8	54.4	54.2	53.8	49.8
Per capita cons. kWh	36	35	38.4	43.5	43.7	48	46.8	48	44.2
Population, 10^6	2.59	2.67	2.75	2.83	2.92	3.01	3.1	3.19	3.29

Source: DoE and EEA yearly reports.

22 MW combined capacity of the refinery and Assab Port Administration has not been operational since 1997/8 because of the war with Ethiopia. Table 17.2 shows an average increase rate of 8 per cent per annum for the generation of electricity, while consumption increased by 7 per cent annually. There was a slight decrease in the number of customers registered for 1993, probably as a result of a substantial exodus of Ethiopians immediately after independence, not matched by Eritrean returnees from abroad. However, there was an increase of about 5,500 new customers every year between 1993 and 1997. This slowed substantially in 1998–2000, indicating the low connection rates in the latter years. EEA firm capacity, which stood at around 26 MW in 1991 was more than doubled by 1996, but showed little change in the years that followed. With the commissioning of the new Hirgigo Power and Transmission Expansion Project, EEA firm capacity is expected to increase by 84 MW, bringing the total firm capacity to over 130 MW.

A look at the time series data from DoE and EEA shows that *per capita* electricity consumption grew from as low as 16 kWh in 1991 to around 50 kWh in 2000. There is about 400 kW in solar PV systems installed in the country for community-based applications such as water pumping or powering health centres and schools. This is still negligible in the national energy balance, amounting to just about 0.4 per cent of the firm capacity of the electricity generation system. Industry consumed 46.4 per cent of the EEA-supplied electricity, the household sector 34 per cent, the commercial sector 18 per cent and street lighting 1.6 per cent in 1998. Asmara alone consumed 67 per cent of the 186 GWh of electricity produced by EEA in the same year. Although 21 per cent of Eritreans have electricity, only 2 per cent of rural people do, whereas in the urban areas the average access rate is over 82 per cent.

Regional literature and relevance to Eritrea

There is now a large volume of literature on biomass energy supply and demand in Africa, from which Eritrea should learn – for biomass is currently its major primary energy source. AFREPREN has already made a major contribution to the biomass energy supply and demand debate in Africa, for example through its two major research publications on the subject (Kgathi et al., 1997; Hall and Mao, 1994). In addition, substantial research work has been undertaken on incremental technical improvements of various small-scale biomass energy technologies such as briquette production from agricultural waste, improved wood and charcoal stoves, production of biogas and other biofuels, electricity generation from agricultural and municipal waste, co-generation from agro-industries, etcetera.

There is also a growing literature on other RETs that are suitable for rural areas. Solar PV, solar thermal and wind energy applications are among the prominent ones. These technologies are environmentally benign and are attracting international attention because they meet the need to mitigate climate change. The Kenyan experience of a developed solar home private-led business is a good example from which other countries in the region could learn. Eritrea's experience in solar electricity is for welfare-focused applications such as powering health centres, schools and village water supply. As solar electricity is still very expensive compared with other conventional options, the prospects of using this RET to engender significant rural income and employment are rather slim.

One of the major limitations and constraints of the current literature on renewables in Eritrea and other countries in the region is the absence of broad national-level and regional-level techno-economic assessment of current rural energy options and the potential for renewables. The limited studies that are available are often supply-side oriented and fail to illuminate the end-user perspective. Existing studies of the potential of renewables and other improved and efficient rural energy technologies do not assess the existing potential on the basis of current energy demand patterns. Too often, a technology-dominated and supply-side orientation is emphasized in current rural energy and renewable energy research in Africa. As a result, many promising applications of renewables are missed. For example, a recent study undertaken by AFREPREN indicated that the potential electricity co-generated from the existing sugar cane processing industries of eastern and southern African countries could be equal to over 50 per cent of current installed capacity. Similar studies are needed in agro-processing sectors, particularly agro-processing industries linked to major export crops such as (in the case of Eritrea) coffee, cotton, horticulture and sisal. National-level and regional-level estimates of the potential for other renewables such as wind, solar and small hydro are either non-existent or patchy. Many of these estimates can be compiled on the basis of available agricultural and meteorological data.

While the literature on the barriers to the dissemination of rural and renewable energy technologies in Africa is fairly substantial, the options for effective and sustainable dissemination of sustainable rural energy technologies are not very evident. Additional research on this question is particularly urgent. One of the key questions that remains to be answered, is the nature, scale and duration of support required to ensure that RETs for rural areas are disseminated on a sustainable basis without requiring regular infusions of donor financial support.

18

Study Findings and Conclusions

Hypothesis 1: Decentralized private sector vs centralized public sector energy initiatives

Decentralized, private sector energy production and distribution have a better rate of success than centralized public sector initiatives in delivering modern energy to rural households and for income-generating activities.

We begin by presenting general observations concerning centralized and decentralized energy supply systems in Eritrea. In what follows, centralized energy supply refers to energy produced in a central location but transmitted to users in areas of demand. Typical examples of this are large-scale electricity generation plants with transmission and distribution networks spanning hundreds or thousands of kilometres, and gas and oil pipelines. Decentralized energy supply requires the delivery of energy technology or fuel to produce energy for a localized area; this may include a single user or multiple users. Oil products retail stations, stand-alone renewable energy systems or their hybrids, small gensets and pumpsets, even self-contained diesel generators with a small distribution network fall into this category.

Centralized energy supply systems in developing countries are mostly managed and operated by governments and public utilities, whereas decentralized energy systems are mostly owned and operated by the private sector. In the developed world and the more advanced developing countries, there is increasingly a tendency towards the complete control of energy supply systems by the private sector. The widely quoted justifications for decentralization/deregulation are consumer protection, the need for financial viability in the sector, and the provision of quality services.

In Eritrea, the EEA now operates the centralized electricity generation system, involving an installed capacity of around 150 MW (including the 84 MW new power plant at Hirgigo near Massawa), and up to 1010 km of transmission and distribution lines (up to132 kV). Around 90 per cent of this capacity (supplying Asmara, Massawa, Keren, Mendefera, Dekemhare and nine other smaller towns) is integrated, the rest a self-contained system that supplies the six towns of Assab, Adikeyieh, Senafe, Agordat, Barentu and Teseney. There are four other, remoter small towns, namely Nakfa, Afabet, Tio and Tsorona, served by small genset systems owned by municipalities or local governments.

Importation of oil products is centralized in the Petroleum Corporation of Eritrea, while the distribution infrastructure is completely decentralized and is in the hands of the private sector. However, the government sets the throughput charges at the ports; the profit margins of the oil companies (Shell, Mobil and Total) and the retail stations; and the transporters wherever energy supplies are delivered by tankers (suppliers transporting by drums/barrels to remoter areas set their own transport charges and profit margins). The business of lubricants, bitumen and other petrochemical products is totally controlled by the private sector. Oil and gas exploration activities are controlled by the government but operated by private companies.

The private sector is already playing a lead role in the dissemination of small decentralized energy systems such as gensets, pumpsets, wood and charcoal stoves, baking ovens, electric and gas cookstoves, LPG cylinders and stoves, electric or solar water boilers, and PV systems for lighting, water pumping, refrigeration, communications and other uses. Typical rural energy technologies for enterprises and households are listed below.

Assemblers and manufacturers/dealers

- There are about 50 manufacturers of the household electric or LPG stoves for *injera* baking and over 50,000 have been disseminated so far.
- Erisoc plc produces LPG stoves, LPG cylinders and institutional diesel-fired bakery stoves.
- There are two private solar water heater producers; one of them, Solar Hadad, sold over 350 systems.
- There are three PV system (including solar water pumping) dealers.
- No mechanical wind pump dealer.
- No small hydro turbine dealer.
- There are a number of dealers (at least 15 have been identified) for small and medium diesel/petrol gensets and diesel water pumps.

Overview of household energy technologies

- Charcoal stoves produced locally by artisans in Medeber (a cottage industrial area in Asmara) cost about US$2.
- Kerosene cookstoves and wicks, mostly imported, cost US$3.50.
- LPG stoves and cylinders are manufactured locally for US$50 (for both).
- Imported electric stoves (US$15–20) and water boilers (US$100).
- Traditional woodstoves, made by users (efficiency around 10 per cent): US$3.

- DoE-designed woodstoves (efficiency over 20 per cent): US$15.
- Imported solar household systems: US$150–600.
- Incandescent (US$0.50) and fluorescent lamps (US$ 7–9).
- Solar water heaters are now being produced locally (US$650–750).
- Electric or LPG *injera* stoves, locally produced at a cost of US$45–95.

An earlier report observed that the limited spatial coverage of grid electricity ensures that many privately owned, diesel-driven gensets and pumpsets are used in various parts of rural Eritrea for a variety of applications like powering churches, mosques and offices, for domestic lighting, and also for income generation. Although the exact number of gensets is not known, records of the DoE show that there were about 280 gensets in operation in 1994. However, the total number of gensets is believed to be much higher than this figure. Just recently a DoE survey of energy consumption by the military, for example, showed that there are over 400 gensets giving service throughout the country in military installations. It is known that these gensets and pumpsets have been marketed by private businesses.

The Ministry of Energy and Mines through its Energy Research and Training Centre has installed many decentralized solar PV systems for community-based welfare applications (more details are given in the findings for Hypotheses 2 and 3). These include powering health centres, rural primary schools, village water pumps and communications devices. Many other government organizations and NGOs have also installed solar PV systems, mostly with the technical assistance of the Energy Centre. Business enterprises such as the Telecommunications Services of Eritrea have installed solar-powered communications facilities in rural areas that will be operated for income-generation purposes. Altogether, over 1,000 solar systems have been installed with a capacity of around 500 kW. Note that the suppliers of these systems are local or foreign private companies and that the source of funding for the systems installed by government or NGOs is donated money, which is not sustainable. Soon wind energy projects are expected to be implemented in southern coastal areas with wind-class regimes of six and seven (speeds > 6.4 m/s), funded partly by donors and partly by the private sector.

In helping to introduce this new technology into the country, the Energy Centre must accept the responsibility of coordination and technical assistance to the private sector participants. There is no doubt that even for what at present may seem to be unsustainable approaches to disseminating alternative energy systems, the role of promoting and assisting the introduction of potentially useful rural energy options is very significant.

For deeper understanding of the relative roles of the two supply systems, the following case studies of centralized and decentralized modern energy delivery systems have been selected to test this hypothesis.

Case Study 1: Distribution of LPG and associated cylinders and stoves

The Ministry of Energy and Mines wants to encourage the market development of LPG, regarded as a preferred alternative household and commercial fuel. However, in the past its market has been limited to Asmara and the port cities of Massawa and Assab: only in recent times has the distribution of LPG and its associated accessories shown every sign of becoming a success story. To help us observe the development in its market, the time series statistics for LPG consumption are presented in Table 18.1.

Table 18.1 Time series statistics for LPG consumption and cost per kg

Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Consumption, tons	300	430	847	1255	1310	1504	824	1320	1666	3045
Price, US$/kg	0.39	0.39	0.39	0.39	0.39	0.56	0.56	0.56	0.65	0.52

Source: PCE yearly reports

Relatively high consumption in 1995–7 dropped sharply in 1998, then dramatically rose again by 60, 26, and 83 per cent respectively in the three years 1999–2001. The drop during 1998 is attributable to the closure of the Assab refinery, which used to supply LPG, in July 1997. There was no receiving LPG depot at Massawa for immediate importation to take place. None of the established companies – Shell, Mobil and Total – were willing to invest in the Eritrean LPG business, regarded by them as too small. Then a local private limited company, Erigas, was established and began the construction of its LPG depot (with a capacity of 2,000 cubic metres) in Massawa; this was commissioned and began receiving imported supplies of LPG in mid-1999. Earlier, Erisoc plc had begun to manufacture LPG cylinders and stoves. The participation of Keren Shipping Line, a local company owning a tanker, *Mereb Gas*, in the importation of LPG has contributed to lowering the cost of importation. The combination of these three factors is responsible for the sharp rise in the LPG market, now driven by the private sector. From 1992 to 1998, the public Petroleum Corporation of Eritrea (PCE) was supplying LPG to Asmara and other regions of Eritrea from the production of the Assab refinery operated and managed by itself. It was transported by road tankers from Assab, through Ethiopia. LPG was thus subsidized by other fuels in order to encourage its use as an alternative fuel. But its market growth was slower than in recent years, when private companies became the lead players.

LPG prices are perceived by many people as quite high, in spite of the fact that the cost of useful energy for cooking is cheaper from LPG than from electricity and fuelwood once efficiency is taken into consideration. The cost per kg of LPG, has gone up from US$0.39 in 1992 to US$0.52

since 2001, as shown in Table 18.1. The profit margin allowed for the dealers is just 3 Nakfa (US$0.22) per 12.5 kg cylinder, set at least 30 years ago. The LPG price build-up is given in Table 18.2 below. Besides its exposure to the international oil market, it is quite heavily influenced by capital cost recovery incurred in building the LPG depot in Massawa. Moreover, the price of the 12.5 kg cylinder is US$25, the regulator costs US$5, the smallest two-plated LPG stove costs US$20 and the cost of the gas is US$6.5. Thus, to become an LPG user, the smallest investment is around US$56, quite beyond the affordability margin of typical poor households. This points to the need for financial mechanisms that allow potential LPG users to pay in small instalments over a long period. This approach is being followed by the collaborating private companies Erigas, Erisoc and Keren Shipping Line. Through public announcements, new customers are being encouraged to become LPG users by paying for the hardware in instalments.

Encouraged by the rising demand for LPG, Erigas intends to expand service stations in other cities and towns in the future, but at present trucks to and from the Asmara filling station are serving customers. Erigas estimates that there are over 40,000 cylinders in circulation. In a recent survey conducted by the researchers, it was observed that there are LPG users even in large villages and semi-urban areas. In the town of Dibaruwa, 30 km to the south of Asmara, seven out of 16 enterprise owners were found to use LPG in their homes. Similarly in Tsada Kristian, a large village growing into a town 20 km west of Asmara, nine out of 22 households interviewed were found to use LPG.

Table 18.2 Price build-up of LPG in Asmara, 1996–2000

Description		Cost in Nakfa per kg of LPG				
		1996	1997	1998	1999	2000
CIF cost at Massawa		NA	NA	2.90	4.806	5.063
Transport to Asmara					0.12	0.12
Capital cost recovery					0.667	0.667
Commission/profit margin:	Erigas				0.3127	0.3057
	Host company	0.42	0.46	0.46	0.28	0.28
	Dealer	0.24	0.24	0.24	0.24	0.24
	Sales tax	0.074	0.074	0.074	0.074	0.074
LPG selling price		2.8	4.0	5.0	5.0-6.5	6.75

Source: Habtetsion and Tsighe, 2001

This is a clear sign that the LPG market has recently penetrated even the rural villages, but consumption is still low. Out of the 3,045 tons of LPG consumed in 2001, 96.3 per cent was consumed in the Central Zone (Asmara and its environs), 2.2 per cent in Massawa, 1.14 per cent in Debub Zone, 0.33 per cent in Anseba and 0.11 per cent in the Assab area.

However, there is one stumbling block for the LPG business. There is only one very old LPG filling station in the major market of Asmara and its capacity is not in any way sufficient to service the growing demand. Other cities, with the exceptions of Massawa and Assab, are not receiving an LPG supply. The owner of the old filling station in Asmara, Shell Malindi, refused to modernize and expand the station, as a result of which the government-owned PCE has purchased the station and preparations are under way to start the expansion work. This is a good example of the need for government intervention when the private business fails to perform as anticipated.

The above discussion makes it clear that the private sector can play the leading role in expanding modern energy services, both for household use and income generation. Indeed, within a short period of time the private sector has succeeded in popularizing and delivering LPG, an important modern fuel in Eritrea. What is even more interesting is that the above-mentioned local private enterprises are doing fairly good business in what big companies like Shell, Mobil and Total saw as an unprofitable market. The findings also show that governments can accelerate the participation of the private sector both by removing market constraints and by modernizing and expanding the energy infrastructure, particularly where either the risk factor or the required investment level is high. So long as governments do not compete with the private sector in profit making, and limit themselves to acting as facilitators, the roles of government and the private sector become complementary.

Case Study 2: Centralized and decentralized power supply

CENTRALISED PUBLIC SECTOR POWER GENERATION AND DISTRIBUTION

The public utility, EEA, has the monopoly of the centralized electricity business in Eritrea. As shown in the EEA 2001 report, its generating plants produced 224 GWh in 2001 of which 90 per cent was from the ICS. The average electricity generation was 4 kWh/litre of oil products, from all the systems. The sold electricity, including EEA's own consumption, was 186 GWh, implying a loss of 17 per cent, which is mostly technical, theft being non-existent. In 2001 there were 89,200 customers in the ICS and 10,691 in the SCS, bringing the total to 99,891. The number of employees was 710, of whom 573 are male and 137 female; this implies a customer–employee ratio of 141 : 1. According to the EEA report, revenue collected was US$24.7 million while expenditures totalled US$18 million: a pre-tax profit of US$6.7 million without including debt servicing. The maximum load in the ICS was 44 MW and the minimum was 10 MW, signifying that night activity is minimal. Income from electricity sales alone was US$21.3 million, which translates to US$0.11.5/kWh for most of the year.

The EEA performance, as a pioneer for the centralized option, has to be judged from its activity in supplying power to the urban or rural poor when testing this hypothesis. Rural electrification is perceived by the EEA as uneconomical and it thus shies away from grid expansion to villages. However, after payment of full costs up front (100 per cent of material + labour + 20 per cent overhead), it has been electrifying villages near enough to urban centres. Intervention by government, as part of its social policy, and by its development partners has led to the intensification of rural electrification. The general approach is that government covers the cost of the medium voltage distribution lines up to the centre of the village or town, while the benefiting communities share the low voltage distribution within their locality and as individuals cover the connection from the nearest line to their residences and/or enterprises. The EEA still has to provide the infrastructure, of course, as it has to conduct extension to new customers, repair and maintain services, and upgrade transformers when loads increase. To this effect a new directive has been issued by the Ministry (Directive No. EI.001/2001, 'On Procedures of Computation of Cost of Electric Line Connection and Billing in Rural Areas and Suburbia').

To elaborate on the present status of villages and towns to which electricity has been extended recently, we prepared and administered a questionnaire on the present condition and impact of electrification in two small urban centres (Dibaruwa and Hagaz) and three villages (Azien, Tsada Kristian, Maéreba).

Table 18.5 shows the recently electrified villages and towns. According to the project-driven plan, electricity infrastructure was extended to the towns first and to the villages later. However, none of the villages in the Aditekelezan and Dibaruwa areas are using electricity, in spite of the extensions. The main reason is the delay in payment by the villages for their share, as per the Ministry directive. Each village was requested to pay its share for the extension, an average sum of 640 Nakfa (US$63.4) per household, although varying in the range US$40–109 depending on village size and shape (the larger and/or the more compact the village, the less it pays). Payment rates are based on actual expenses, which is EEA policy. On top of this, each beneficiary should cover connection costs from the nearest pole to his residence/enterprise, and internal wiring – the average total connection cost is US$30. All the villages concerned have formed electricity cooperatives and/or village development committees, and fund raising is in progress through these bodies. There also appears to be some misunderstanding by the villagers because the payment was requested after the extension: the villagers believed that the government was extending electricity free of any charge. This was partly because the electrification was project-driven, initially targeting the towns of Aditekelezan and Dibaruwa, then later modified to include the villages on the way. It should also be noted that the EEA extended supply to the two urban centres of Dibaruwa and Aditekelezan and started to sell electricity there before asking them to pay their share as per the directives: this was simply because it expected a large market in the towns as opposed to uneconomic operation in the villages. Thus, the EEA seems to apply double standards in grid extension, influenced by its concern for economic viability.

Hagaz is a fast-developing town 25 km south-west of the regional capital Keren, or 116 km north-west of Asmara. The grid was extended to this town in 1998. Hagaz, with a population of 11,300 and 2,300 households, had 297 meters in December 2001. Average consumption during 2000 was 472 kWh per registered meter, rising to 496 kWh in 2001. As Hagaz is lumped with Keren for consumption accounting purposes, it was not easy to determine the exact number of electricity-using households – but 1,000 was the estimate of local administrators (note that many households could share a common meter). According to the interviewed residents, including one MP, the biggest problem the customers are facing is that they have to go to EEA's Keren office to pay their monthly bills, lining up with the Keren customers. As EEA has no representation in Hagaz, there is no one to field potential customer enquiries about electricity connection and there have been practically no new connections since 1998. The enumerator noted that there are many commercial farms in Hagaz, now using diesel water pumps, who want to shift to electric pumping for irrigation. Using the national figure of one employee for 141 customers, there should have been seven EEA employees in principle serving Hagaz; but the town at least deserves to have one accountant and one technician from EEA, as part of a new approach to the management of the electricity services in the town.

Dibaruwa is becoming an industrial town, strategically located close enough to the market centres of Asmara (30 km north) Mendefera (25 km south) and Dekemhare (25 km east). There were 2020 households in March 2002. The total number of customers one year after the availability of electricity was 744, of which 554 were households. Information collected on electricity consumption in the town for the year 2001 is given in Table 18.3, while that for Aditekelezan is provided in Table 18.4 for comparison.

The most significant noticeable impact of electrification in Dibaruwa and Aditekelezan towns is the expansion of commercial and industrial activity. Prior to electrification there were only 21 and 49 commercial and industrial activities operating their own gensets in Dibaruwa and Aditekelezan respectively. Since electrification in mid-2000 the number of commercial and industrial establishments which are EEA customers has gone up in just over a year to 190 firms in Dibaruwa and 80 in Aditekelezan. Average electricity consumption in kWh/year for 2001 for each tariff group in Dibaruwa is as follows: domestic 213; commercial 1,204; street lighting unit 2,180; small industrial low voltage 4,204; and medium voltage industrial 346,794. Interviews with customers indicated that the service provided by EEA is not commensurate with the ever-rising demand; some of them, especially the industrial establishments, expressed concern over power outages. While the latter

Table 18.3 Electricity consumption by type of customer in Dibaruwa, 2001

Tariff group	Sales, kWh	Sales, Nakfa	Service charge, Nakfa	No. of customers
Domestic	108,549	148,708	9,410	554
Commercial	187,297	265,200	8,966	163
Street lighting	20,850	29,000	330	3
Small industry, LV	85,434	113,453	7,063	22
Small industry, MV	692,800	673,302	788	2
Total	1,094,930	1,229,663	26,557	744

Source: EEA Statistics, 2001.

Table 18.4 Electricity consumption by type of customer in Aditekelezan, 2001

Tariff group	Sales, kWh	Sales, Nakfa	Service charge, Nakfa	No. of customers
Domestic	78,614	128,532	11,704	502
Commercial	34,652	51,117	4,147	70
Street lighting	2,496	3,685	83	2
Small industry, LV	36,101	47,765	2,070	2
Small industry, MV	none	none	none	none
Total	151,863	231,099	18,004	582

Source: EEA Statistics, 2001.

complaint is expected to subside when the more dependable new power plant at Hirgigo near Massawa is fully commissioned, the former concern is becoming more serious, emerging as a criticism common in all newly electrified areas. Although there is an EEA office in Dibaruwa, its capacity is too small to serve this mushrooming industrial town. As a result of this, complaints and new applications are channelled to Mendefera, the administrative centre of the region. This state of affairs demands attention.

Azien, a village electrified in 1996, is located around 20 km north of Asmara and has around 900 households. There are at present 108 installed kWh meters, each one shared by a cluster of neighbouring households. The electrification of the village was community-driven, as they paid for the costs up front – unlike in the newly electrified villages, where connection is project-driven. Many households are not yet connected – these are those that missed the opportunity for connection in 1996 for various reasons, but have been requesting connection ever since. As in Hagaz, people claim that the EEA is not responding to their requests. Of the sampled respondents, 40 per cent do not like the idea of sharing electricity meters as it is often a source of disagreement, and would like to have their own meters. The rest would like to continue sharing as they do not have the capacity to pay (US$30) for the meter. We noted that the income level of the village is still very low and that their average electricity consumption is US$1 per month (just for lighting two bulbs). New income-generating activities that use the electricity now available have not developed significantly, helping to make the case of those who contend that electrification for its own sake, unless supplemented by other development programmes, may not bring about a dramatic change in the way of life. For instance, the access road to Azien is very rough, and this is one of the obvious drawbacks.

Another example comes from the village of *Tsada Kristian*, 20 km west of Asmara. Electricity reached this village in 1998, and at present 1,000 of the 1,150 households in the village have access to electricity; 73 per cent have their own meters, while the rest share with their neighbours. The high proportion of households using their own meters tends to suggest that electricity is being used for income generation as well. Indeed, many small enterprises were observed in the village during the survey. Average consumption for households and enterprises was US$4/month and US$10/month respectively. As in the other localities, complaints on power outages and lack of response to new applicants were noted. The higher consumption rate of electricity in Tsada Kristian compared to Azien can be explained by many factors: the village has better agricultural land and access roads, and is a service centre for health, education and administration for the subzone.

Maéreba tells a slightly different story. The village lies about 60 km south-east of Asmara; it was connected to the grid in 1998 after the residents paid the full cost of extension up front. Of the 500 households in the village, 375 have access to electricity sharing 99 kWh meters between them. According to the interviewees, the remaining unelectrified households have been requesting connection either by sharing or installing their own meters. In principle, sharing meters is highly advisable as it reduces initial costs to poor households, and this is being promoted in the newly electrified villages, but according to the interviews EEA's representative stationed in the town of Segheneity, 15 km away from Maéreba, has, contrary to the policy, refused new connections using shared meters. It was also noted that not many income-generating activities have sprung up after electrification, in spite of the fact that Maéreba lies along a major road. This is reflected in the low average consumption per meter per year (172 kWh and 213 kWh in 2000 and 2001 respectively).

Decentralized power generation and distribution

The decentralized power generation and distribution sector is made up of many small systems, usually in the 20–100 kW range, although there are a few with greater capacities. The combined installed capacity does not exceed 20 MW. The actors in this sector are members of the business community who supply the technologies and accessories like gensets, the port administrations, the municipalities of towns far from the national grid, NGOs, local communities, large-scale farms, military installations and establishments requiring stand-by generators (airports, hospitals, industries). Most of these installations are demand-driven and the market is responding favourably to this demand, as indicated by the growing number of suppliers and technical services. Often the market is open and competitive as tenders are announced publicly. It is important to note that the decentralized sector serves places far away from the central grid, enabling them to get better social services or promoting income-generating activities. The business community has even gone beyond supplying technologies: some of them have installed gensets in consultation with potential beneficiaries in small towns and villages. However, this sector also has its own characteristic problems, as the case study below indicates.

Areza, a town 96 km south-west of Asmara, started to get electricity in 1995 through a businessman owning a genset. It has a population of 6,500. The communities contributed to the distribution infrastructure and agreed to pay for lighting, refrigeration, and other electric appliances on fixed monthly rates for each end use. The supply duration was from 6 pm to 11 pm daily. However, for a single generator without a stand-by, wear and tear and failure in timely general services led to frequent interruptions of supply, extending for days or even months. The escalating repair and maintenance cost also prompted price revisions by the businessman, which eventually led to a serious misunderstanding with the community and ultimate closure of the facility after five years in 2000. Although the entrepreneur's initiative was commendable, his approach was not sustainable. First, the limitation to evening supply could not promote income-generating activities to sustain the demand in the face of changing market conditions influencing the cost of generation. Second, the supply was unreliable, based as it was on a single generator for income-generating activities and domestic uses. However the biggest problem was mismanagement of the power supply: the owner was living in Germany, delegating responsibility to incompetent and corrupt employees. The researchers were informed of two incidents where the employees were running the generator until 2 am local time, to power a single bar where they were drinking alcohol. The rule of thumb for cost-effective running of a genset is availability of load of at least 40 per cent of its design capacity.

As yet the market for decentralized supply options using RETs in Eritrea has not developed. Major barriers to the dissemination of such energy technologies are lack of awareness by the business community and the public, high initial costs relative to average income of the people, lack of credit supporting these technologies, lack of technical support at local level, and foreign exchange problems.

Conclusions

From the analyses and discussions presented above the following conclusions can be drawn.

- The centralized system could not satisfy the demand for modern energy services fully or effectively. This is indicated by the EEA's very slow response to new applications, even in electrified areas. For instance, the findings reveal that applications for connection with new and/or shared meter are often ignored. In addition to this, customers in certain localities have to travel to settle their monthly bills elsewhere, incurring additional costs. The absence of EEA's representatives also means that the complaints, new applications and other technical services are not promptly executed.
- The major focus of the centralized system is on the urban-industrial centres. Thus, the services of the centralized system are geographically limited. The Eritrean government, in cooperation with its development partners and with contributions from the community, has recently taken the initiative to electrify villages not very far the national grid. On the other hand, the services of the decentralized system have a more diffuse coverage. Seen in this perspective, the three actors are playing complementary rather than competitive roles.
- The LPG business has had relative success in terms of market penetration and service expansion, thanks to the participation of the private sector. Over a relatively short period of time, households and enterprises outside Asmara have started to use LPG. The government is focusing on the improvement of distribution infrastructure, while the private sector focuses on reaching end users. This clearly shows that through appropriate promotional and complementary activities, the expansion of modern energy services can be accelerated.
- Private investors whose approach is not sustainable do not succeed. Neglecting to target income-generating activities (he limited his services to evening lighting), inappropriate management and lack of close supervision led to failure in the case of the entrepreneur who for a time provided Areza with a decentralized electricity supply. The investor was living abroad, leaving the system in the hands of incompetent staff.
- The government is promoting RETs through public awareness, installations for welfare purposes, assessment of renewable energy sources, and research and training. It is also encouraging and assisting the private sector (through customs tax reductions, for example) to develop the market for RETs.

Eritrean experience – only ten years – indicates limitations in both the centralized and decentralized approaches to modern energy supply. The EEA's monopolistic status is not sensitive to poor people's power needs, as it believes that rural electrification is not cost effective. Moreover, its activities seem to have been overstretched, as a result of which its response to the growing demand is very slow, often frustrating potential customers. Thus, decentralization of part of its services is imperative for rapid and wider extension of electricity supply.

The decentralized system, though exhibiting certain shortcomings, shows very encouraging trends. This system is not only satisfying existing market demands, but also expanding the market by providing technical and promotional services. The government's initiatives in infrastructural development and other support services are further facilitating and encouraging private sector penetration of the energy business. This is in line with the general approach of the government in sustainable development led by the private sector and widely shared.

Hypothesis 2: Income-generating activities vs domestic energy use

Income-generating activities have greater impact than domestic use in promoting the delivery of modern energy to rural areas.

Relevant findings from an earlier study (Habtetsion and Tsighe, 2001).

- The fact that rural electrification creates its own new demand was observed in the recently electrified 13 villages around Asmara. The number of new customers in these villages grew by 17 per cent and consumption by 54 per cent yearly. This large growth in usage of electricity can only be explained if one assumes that new income-generating activities were mushrooming in these electrified areas. Further information will be collected from some of the villages in due course to see whether this assumption is true or not.

- The market for diesel water pumps and small gensets was reasonably vigorous over the last 30 years for applications such as horticultural activities. Though costs of energy, repair and maintenance, and labour have been quite high, enterprises are still making profits and have the potential of attracting rural electrification. In fact, 95 per cent of the respondents strongly favoured extension of the grid to their areas, as this will give rise to additional sideline income-generating activities as well as power for their residential homes. Even the remaining 5 per cent were not against electrification; they simply gave much higher priority to the development of water resources on their farms, as there was an acute shortage at the time of the survey.

- The government has given high priority attention to the energy sector in general and to power expansion and transmission in particular. An 84 MW power station and additional transmission lines (80 km of 132 kV and 150 km of 66 kV) are expected to be commissioned soon. Despite such support to the power sector, grid extension to the rural areas is a recent initiative. Government efforts to improve rural energy supply are just beginning. The emerging initiatives involve five mechanisms, namely,

1 rural electrification through grid extension;
2 improvement of biomass energy resources through various afforestation and reforestation programmes;
3 dissemination of improved stoves;
4 installation of solar PV systems (400 kW so far) for welfare-focused applications;
5 assessment of the potentials of conventional and indigenous renewable energy resources for eventual development.

With respect to rural electrification, the following two tables reflect the very laudable recent commitment by government.

Table 18.5 Rural electrification completed, 1999–2001

Project area	Number of villages/towns	Project cost (US$)
Aditekelezan	11 villages + 1 town	297,189
Dibaruwa	10 villages + 1 town	403,131
Elabered	2 villages + 1 town	142,737
Hagaz	1 village + 1 town	193,043
Teseney	3 Villages	413,900
Total	27 Villages +4 towns	1,450,000

Source: Ministry of Energy and Mines/EEA, 2001

Table 18.6 Planned electrification of rural villages and towns, 2002–4

Project area	Number of villages/towns	Project cost (US$)
Himbirti	17 Villages	319,029
Mekerka	12 Villages	484,175
Mendefera	13 Villages	399,903
Keren	14 Villages	2,256,923
Barentu	7 Villages	2,381,748
Dekemhare	40 Villages	2,668,252
Adikeyieh	26 Villages	1,398,932
Nakfa	1 Town	324,660
Afabet	1 Town	324,660
Omehajer	1 Town	242,718
Tsorona	1 Town	242,718
Tio	1 Town	324,660
Total	129 Villages + 5 towns	11,368,378

Source: Ministry of Energy and Mines/EEA, 2001

Table 18.5 shows towns and villages in which about 14,100 households have benefited from the recently completed electrification programme. Villages and rural towns programmed to be electrified during the three years 2002–4 are shown in Table 18.6. Aboutd 46,200 households are expected to benefit from this further electrification programme.

Reports from the Ministry of Agriculture indicate that about 70 million tree seedlings have been planted in the last ten years in various parts of the country. A success rate of 90 per cent in road banks and 40–60 per cent elsewhere was reported. Similarly, over 5,000 improved biomass (wood, dung, agri-residue) stoves have been disseminated by the Ministry of Energy and Mines since 1999, while the final report of the project to assess wind and solar energy resources has reached its final stages.

The government's strong commitment to expand basic infrastructures in the sectors of public construction, health, agriculture, and energy were evident, part of building a new country that depends mainly on its own resources. This is symbolized by the cumulative expenditures in the ten years since independence (Table 18.7), as stated by the ministries concerned in the *Hadas Eritrea* daily newspaper. Assistance from development partners was also instrumental in these development programmes.

Table 18.7 Ten years expenditure by some ministries (in Nakfa)

Ministry	Expenditure 1991–2000	Reporting date in *Hadas Eritrea*
Public Works	8.2 Billion	May 11, 2001
Energy and Mines	2.0 Billion	May 12, 2001
Health	4.0 Billion	May 15, 2001
Agriculture	2.3 Billion	May 18, 2001
Transport and Communications	1.5 Billion	May 19, 2001

Source: Hadas Eritrea newspaper

We have seen that one of the major obstacles to the diffusion of modern energy services to rural areas is the low level of income of rural households, estimated at no more than 4870 Nakfa nationally on average (Habtetsion and Tsighe, 2001). The present government policy is to avoid subsidies in the energy sector, and little room is left for cross-subsidies among fuels and between large- and small-scale electricity generation. These factors have contributed to the low level of modern energy distribution in rural areas. Seen against this background, income-generating activities have a better potential of attracting modern energy services to their respective localities. In fact, in many rural localities, some rural enterprises have been observed to use their own gensets to meet their energy needs for productive purposes and sell extra production to their neighbours. In some semi-urban centres some private entrepreneurs have actually installed gensets and a local distribution network exclusively for commercial purposes. Examples include the semi-urban areas of Areza Shambuko, Tekombia, Haicota and Omehajer. In some towns the local government or the municipalities have taken the lead role in electricity supply: among these are Nakfa, Afabet, Tio, Tsorona and Aditekelezan prior to its joining the central grid.

The following two case studies are presented to demonstrate the fact the income-generating activities have more potential to attract modern energy infrastructures than domestic use in rural areas.

Case study 1: Dibaruwa and Aditekelezan areas

A look at the rural localities recently electrified by the government shows that priority in rural electrification is given to places with numerous income-generating activities. A pre-electrification socio-economic and gender impact assessment on rural electrification made by Goys *et al.* (1998) showed that the two areas studied, Dibaruwa and Aditekelezan, had many income-generating activities. Dibaruwa subzone has a population of around 60,000, with the town itself having about 8,000. Aditekelezan subzone has around 19,000 people, that of the town alone being 7,400. Dibaruwa is 30 km south of Asmara, while Aditekelezan is 40 km north-west of the capital. The study circulated questionnaires to 40 respondents in each town, and to 60 respondents in the surrounding villages electrified simultaneously in each subzone (200 questionnaires altogether); 24 of the interviewees from the Dibaruwa area and 20 from the Aditekelezan area were female-headed households. The average size of a household was 5.5 in rural areas and 6.25 in urban areas. Table 18.8 provides a summary of the responses to the specific questions by these respondents.

Table 18.8 reveals a very interesting phenomenon. The expectation of all respondents that electricity will transform their lives for the better is unanimous. Many respondents are willing to pay the connection fee, assuming that it will be around US$30–50 per household, but the majority are expecting to use it for domestic purposes, mainly lighting, and to pay less than US$2 monthly for consumption. The basic infrastructure for the medium voltage distribution up to the centre of a settlement site was covered by SIDA/EEA financing. People in the Dibaruwa area seemed to have a fuller vision of the role electricity might play in expanding their production activities in the future. They also seemed to have better micro-credit facilities than their counterparts in the Aditekelezan area. This was not unexpected, as micro-financiers like Accord have been active for the last ten years around Dibaruwa.

The time spent collecting fuelwood and water was quite enormous: over 12 per cent of working hours for an adult. Time spent fetching water was even higher in the Aditekelezan area especially, where this consumed up to 34 per cent of working hours. The burden of these activities rested heavily on women and children for over 80 per cent of the cases in both areas.

Table 18.8 Summary of pre-electrification household responses

Typical questions		Responses: Dibaruwa Area	Responses: Aditekelezan Area
1	Can you afford electricity connection?	85% yes, 15% no	75% yes, 25% no
2.	How do you intend to fund connection?	Business 41% Salary/wages 25% Agriculture 24% Other sources 10%	Business 21% Salary/wages 25% Agriculture 41% Other sources 12%
3	How much can you afford to pay monthly for electricity consumption?	66% < US$2	76% < US$2
4	Do you have access to credit?	56% yes, 44% no	34% yes, 66% no
5	Would electricity change your life?	100% yes	100% yes
6	How would you use electricity?	Domestic only 74% Income generation 23% Both 3%	Domestic only 82% Income generation 16% Both 2%
7	Can electrification expand your production activity?	65% yes, 35% no	31% yes, 69% no
8	Do you have plans to introduce new production activities?	54% yes, 46% no	26% yes, 74% no
9	Do women usually participate in external activities?	100% yes	100% yes
10	Time spent collecting firewood kerosene water	21 hours monthly 6 hours monthly 25.3 hours monthly	22 hours monthly 6.3 hours monthly 60 hours monthly
11	Who does the activity in 10 above?	32% mother 47% mother & children 19% all members 2% others	24% mother 36% mother & children 36% all members 4% others
12	Who makes decisions about household expenses ?	Wife 36% Husband 35% Both 29%	Wife 27% Husband 43% Both 30%
13	Source of household income	31% agriculture 24% business 8% salary/wages 37% various mixed	40% agriculture 7% business 3% salary/wages 50% various mixed
14	Annual household income (weighted average)	$549	$372
15	Annual household expenditure (weighted average)	$790	$702
16	Educational level	Rural 42% illiterate Urban 30% illiterate	Rural 43.3% illiterate Urban 22.5% illiterate

Source: Compiled from Goys *et al.* (1998)

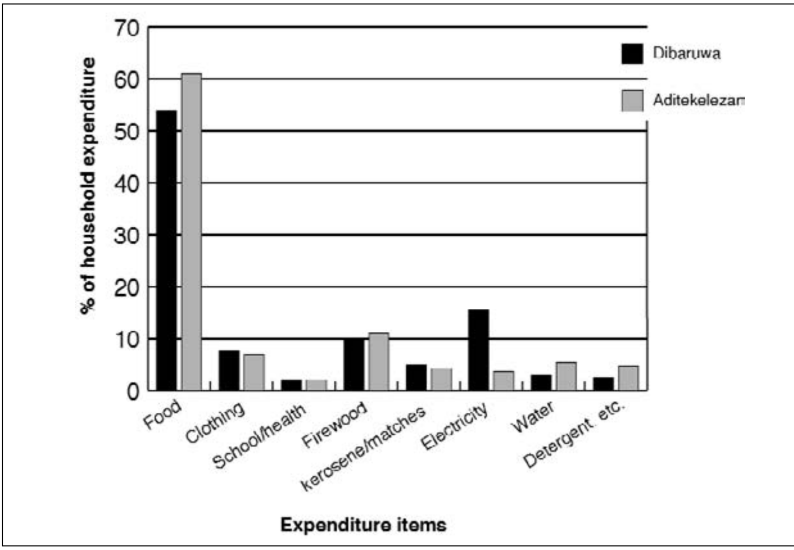


Figure 18.1 Pre-electrification household expenditures of Dibaruwa and Aditekelezan

Source: Goys *et al.* (1998)

It is quite interesting to note that wife and husband participate nearly equally in decision making concerning household expenditures. Household income depends more on agriculture in the Aditekelezan area, in spite of the fact that the Dibaruwa area is more fertile. It seems obvious that industrialization has started to have an impact on people's incomes in the Dibaruwa area. While the weighted average for household incomes is in remarkable agreement with the earlier study (Habtetsion and Tsighe, 2001), the expenditures are heavily exaggerated. This may not be unexpected, considering the fact that people are more willing to tell their true expenses than their true incomes, and that the Eritrean population still relies heavily on food aid. Figure 18.1 shows annual household expenditures for the two case study areas.

The survey noted that nearly all respondents owned land as well as housing; only 10 out of 200 respondents didn't possess land or housing. The expenses for house rent for these 5 per cent of respondents were not included in the study; they depended on salary or wages for a livelihood. Note that expenses for energy are 18 per cent for the Dibaruwa area and 19.3 per cent for the Aditekelezan area (Table 18.9). This is considerably higher than the national average of 13.4 per cent obtained in the earlier study (Habtetsion and Tsighe, 2001). Note also that the four (only) Dibaruwa respondents (served from private gensets) paid much higher prices for electricity than the Aditekelezan respondents, who were served by a cheaper community-owned genset prior to national grid extension.

Table 18.9 Annual household expenditure on various items in Dibaruwa and Aditekelezan areas

Expense items	Dibaruwa area		Aditekelezan area	
Food	54%		61%	
Clothing	7.7%		7.1%	
Schooling and health	2.0%		2.3%	
Firewood	10.1%		11.3%	
Kerosene and matches	5%		4.2%	
Electricity	15,4%	(only 4 households)	3.7%	(households in town)
Water	2.6%	(only in towns)	5.4%	(only in towns)
Detergents and others	3.1%		4.8%	
Total expenses	US$768		US$578	

The general views of the respondents on the role of electricity in the two project areas include the following themes:

- healthy society and sound atmosphere
- economic development
- job opportunity
- educational development
- social security
- work efficiency
- industrial expansion
- agricultural expansion
- urbanization
- global communication
- improved standard of living
- more business activities
- reconstruction expansion
- clean water supply
- investment expansion
- labour and time saving (labour productivity)
- production improvement
- minimizes deforestation
- facilitates technology transfer.

The responses of women interviewees tended more towards the betterment of domestic-level activities and conditions, including health, whereas those of the male respondents had more focus on electricity-driven income-generating activities through industrial and agricultural development. The survey also showed that in rural areas the work burden of household-level activities will decrease, especially for women, with access to labour-saving technologies as a result of electrification (electric grinding mills, pumps, stoves, good lighting in the home): in particular, this will reduce the time needed for processing and preparing food. The saved time may be used for other income-generating activities such as knitting and sewing, poultry keeping, etcetera. This particular survey result is direct evidence for the validity of the hypothesis that the provision of modern energy to rural areas will enhance the chances of women engaging in income-generating activities. Students will also be able to study for longer hours in the evenings.

The number of enterprises prior to electrification in these two towns is shown in Figure 18.2. The enterprises in Dibaruwa were fairly large, having over 500 employees, with some industries and hotels possessing their own gensets; by contrast, in Aditekelezan we mainly find service industries and minor workshops. There was a community-owned limited electricity supply in Aditekelezan, mainly for lighting purposes with an 80 kW genset, while some of the bigger enterprises had their own gensets.

It was noted in the study that, prior to the grid extension, many of these income-generating activities had installed their own gensets. However, the supply was insufficient and unsecured, and most of them were operating below capacity. Just before electrification, the private entrepreneurs in Dibaruwa town had a total investment of over US$10,000,000 whereas in Aditekelezan the comparable figure was about US$100,000.

The survey showed that with sufficient and secured energy supply most of the existing income-generating activities would expand their business and employment greatly. For instance, the Dibaruwa Bakery and Kokeb Plastic factories could increase their employment levels from eight

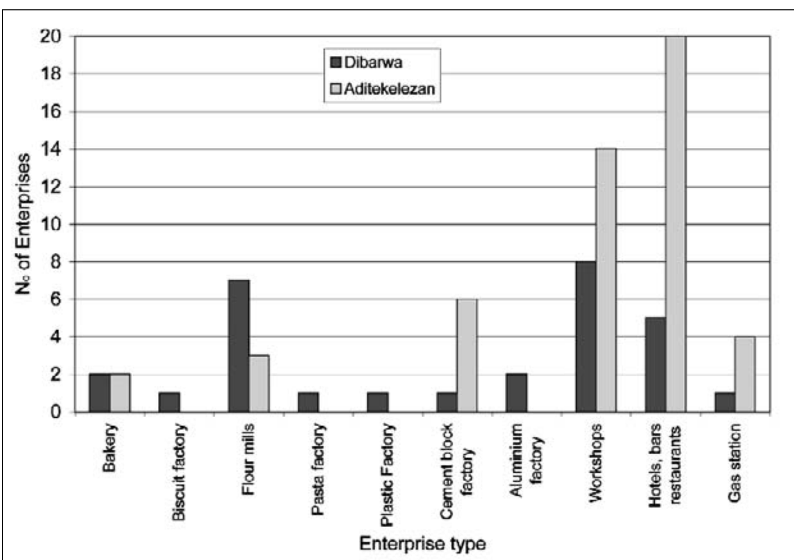


Figure 18.2 Pre-electrification income-generating activities in the two semi-urban areas

Source: Goys *et al.* (1998)

and 18 to 24 and 72 persons, respectively. Moreover, there was an increasing demand for business licences in both semi-urban areas with the prospect of the extension of grid electricity (Goys *et al.*, 1998). This reflects the cumulative causative effects of modern energy services. As the case of the two semi-urban localities indicates, the concentration of income-generating activities attracted electricity. The availability of electricity, in combination with other favourable factors, has in turn created a conducive environment for more enterprises to be established. However, it was observed that rural respondents, to a greater degree, reported that they would use the electricity for lighting only, as their income at the moment is lower than their urban counterparts.

What is more interesting is that whereas the EEA used to demand full up-front payment from semi-urban/rural localities for the medium- and low-voltage distribution and associated transformer costs, no initial payment was requested when these semi-urban areas were electrified. The major confidence booster for EEA was that there was already enough concentrated load in these places for the grid extension to be cost-effective, and that it believed the payback period for its investment to be short. To extend a grid-connected electricity supply to Dibaruwa and Aditekelezan towns and the 20 villages around them, the Ministry of Energy and Mines has produced provisional, more rural-focused policy directives in April 2001 with respect to connection fees to be paid by the beneficiaries. This policy is now being implemented. A summary of the directives is given below.

1 The main trunk medium-voltage line (grid) from the source of supply to the vicinity of the potential consumption centre is to be financed by EEA and be the property of EEA.

2 Extension to villages from the main medium-voltage trunk line to the first transformer to be financed by EEA and be its property. Costs of the transformer net-station and any further medium- or low-voltage network to be paid 100 per cent by the villages.

3 Extension to towns from the main medium-voltage trunk line to the nearest transformer is to be financed 50 per cent by EEA and 50 per cent by the customers. Costs of the transformer net-station and any further medium- and low-voltage network to be paid 100 per cent by the customers.

4 Extension to commercial, cottage or small industrial customers from the main trunk line to the transformer of the medium-voltage line is to be financed 50 per cent by EEA and 50 per cent by the customer. Costs of the transformer net-station and the low-voltage network (if any) to be paid 100 per cent by the customer.

5 For extension to a big industrial customer with a capacity of 250 kW and above or 800,000 kWh yearly consumption, the costs of medium-

voltage line, transformer net-station and low-voltage network is to be covered 100 per cent by the customer.

These guidelines establish that ownership of the electrical installation, up to the electricity kWh meter in customers' premises, shall rest with the bulk supplier, which is EEA at the moment. EEA possesses the right to extend the networks at will, and consumers cannot intervene by claiming ownership. These guidelines reflect a view that the lowest possible connection fee (compared with their urban counterparts) should be paid by village households, who are generally in the low-income category. Moreover, the villagers have been advised that they need pay only 50 per cent of the estimated costs per village for electricity connection to be effected, while the balance may be paid at a later date or even be waived in the future. These policy guidelines reflect the government's socio-economic policy and commitment to improving the living standards of rural communities. A 3 per cent levy on all electricity sales, with further contributions from the government and donors as well as from the beneficiaries themselves will be the basis for the planned Rural Electrification Fund.

Case Study 2: Rekeb-Zara in Anseba Province

The source of the case study is a direct interview with the director for economic affairs of the Anseba Provincial Administration and a staff member of the Department of Energy who was undergoing youth service with the government mining team. This has been substantiated further by an eyewitness account prepared by the research team at a later date.

Rekeb is located some 150 km north-west of Keren, administrative centre of Anseba Province, and about 240 km in the same direction from Asmara, the capital city. Virtually from nowhere, its population has gone up to around 10,000 people in the last 5–6 years; effectively, it has become the second largest town after Keren, whose population is 60,000. Historically, the Rekeb-Zara area was an important strategic place during the war of independence, as it lies in a valley with good water resources and riverine forest, but it didn't have a permanent settlement. The relatively barren surrounding area was not known for its lately discovered natural resource, gold, and was thus of use only to the local pastoralists as a grazing area.

Since 1994/5, the discovery of gold in the locality has attracted many mining artisans from all over the country, the majority of them being from Anseba Province, which gave rise to the sudden settlement of people and the creation of the town. These settled people virtually gave up farming activities in their original places in favour of gold mining. Experts from the Department of Mines and the provincial administration have estimated that the weekly production of gold in 1998 was in the range of 7–10 kg, all of it was purchased by the Department of Mines at a unit price of 60 Nakfa per gram. At its peak just before the war started with Ethiopia in

1998, the workforce reached around 2,000, implying an average weekly income per head of 210–300 Nakfa (US$27–36). This is at least three times more than what they could earn from traditional farming. The size of the workforce might have decreased since then, as the youth were required for military service in the defence of the motherland.

Not all the settlers in Rekeb-Zara are gold miners. Quite a number of them opened service enterprises like food and other materials shops, restaurants, hotels, teashops, sale of *injera* and traditional drinks and pharmacies. The establishment of the town of Rekeb-Zara induced the local administration to improve the social and economic services by building schools, health centres, radio communication facilities, and providing clean water and centrally administered electricity supplies. The availability of gold in the area has induced even the government to install its own electricity supply and a semi-mechanized gold-mining facility employing electrically driven crushers, sieves, TNT explosives, jackhammers, bulldozers, trucks, and around 1,000 employees. All the private miners are using hand tools only, and often camels for transporting gold-bearing soils or water in both directions. An undesired side effect of the gold-mining activity in the area is the pollution of the downstream water with traces of the mercury required for gold extraction.

All the stated facilities – including the modern commercial energy sources, electricity and oil products – were delivered to Rekeb-Zara as a result of the discovery and mining of gold, which is a much better income-generating activity than traditional farming. Note also that there are other rural areas in Eritrea that have developed dramatically because their agricultural potential has been exploited by modern farming methods. Thus, development of the natural resource base in an otherwise forgotten area induces the delivery of modern energy services, a requirement in the transformation of the local economy and people's way of life. The numerous other villages in rural Eritrea which had settlements for centuries were not able to attract modern energy because of their limited and often unsustainable income structure.

The above case studies involving three localities clearly reflect that income-generating activities really attract better modern energy services than domestic applications. In this sense the hypothesis is evaluated positively. Improving the general living standards of the majority of the rural population using modern energy as an instrument requires quite a strong government social policy and substantial financial commitment. Moreover, the natural resource base of the respective localities should be studied for the sustainable development of the economically feasible resources primarily for the benefit of the local communities, as the Rekeb-Zara case study has shown.

Comparison of energy intensities and expenditures

A comparison of the energy consumption of households and enterprises reveals that the latter have higher energy intensity than the former.

Whereas the average per household energy consumption in 1998 was around 3.7 GJ or 88 kgoe/month in Eritrea, the corresponding energy consumption for enterprises was 7.7 GJ, or 183 kgoe/month (DoE, 1998 and MTI, 1998).

Table 18.10 Annual average household energy consumption by fuel and settlement type

Fuel type	Urban	Semi-urban	Rural
Fuelwood (kg)	168.50	315.00	248.000
Charcoal (kg)	9.30	2.60	3.900
Dung (kg)	6.10	24.60	109.300
Agro-residues (kg)	3.70	11.10	35.800
Kerosene (lt)	18.30	11.90	10.700
Electricity (kWh)	72.10	8.40	0.500
LPG (kg)	2.30	0.00	0.001
Total, GJ	4.33	6.23	6.020

Source: Compiled by the researchers from DoE, 1998

Table 18.10 clearly shows the relative mix of household fuels in the different settlement areas. The dependence of rural settlements on traditional primary fuels – fuelwood, dung and agro-residue – is vivid. Kerosene is the exception to the otherwise very limited penetration of rural areas by modern fuel types. Kerosene is widespread, with 95 per cent of the population using it. Electrified urban areas use kerosene for cooking, but in the rural areas most of it is used for lighting. The majority of the users of electricity and LPG in rural areas are located in the vicinity of Asmara, the capital city. The total household energy consumption (Table 18.10) is higher than the national mean for all households of 3.7 GJ, as not all households use all kinds of fuels.

The higher energy intensity of enterprises reflects the higher energy demand threshold compared to households, and hence their capacity to attract modern energy services more strongly than the household sector. The high proportion of expenditure on energy by households is due to the small base of their income. It was evident that many of the farmers owned gensets or pumpsets for their horticultural farms, but no electricity for their homes, The better-off farmers use their gensets to electrify their homes in addition to pumping water for their farms. This is clearly in line with the *energy ladder* concept (see pp. 2–3). As indicated in the short-term study, the energy consumption by SMEs between 1995 and 1998 showed a growth rate of 4.2 per cent per annum. A shift towards modern energy fuels was also noted during the same period: while in 1995 these enterprises derived 76 per cent of their energy requirements from biomass sources, in 1998 biomass accounted for only 50 per cent. For instance, many brick manufacturers and bakeries have already shifted towards using oil products or electricity in their production processes. During the same period, however, rural households continued to derive 95 per cent of their energy requirement from biomass sources.

The reports of the Ministry of Trade and Industry (MTI, 1998) show that, for the 1,707 SMEs, the total gross input was 97 million Nakfa, whereas the total gross output was 130 million Nakfa. This implies an average net profit before tax per enterprise of 19,332 Nakfa, which is nearly four times higher than the average rural household income. In comparison, the national average household expenditure on energy was 13.4 per cent of their income, or 817 Nakfa/household/year (Habtetsion and Tsighe, 2001). Again, the high proportion of energy expenditure by households is due to the small base of their incomes. The Dibaruwa and Aditekelezan case studies had higher percentages for energy expenses (18 per cent and 19.3 per cent respectively), but still lie within the range throughout the country (6–25 per cent). Moreover, the figures for the enterprises show that the energy input/output ratio was 0.07, implying that for every Nakfa spent on energy the production value was 13.4 Nakfa. The average share of energy cost was 10 per cent of the production cost (assumed to be the same as the gross input). This shows that the dominant expenses for enterprises are material costs and labour. Thus, slight increases in energy prices may only narrow the profit margins of enterprises. It is also clear that enterprises are consuming a lower fraction of their production cost than the fraction of household income expended on energy. Thus they are in a much better position than households to pay for electricity connection costs, for example. The limited income of the majority of households, as well as their lack of awareness of how to use electricity for productive uses, limits electricity usage for domestic purposes, at least in the first few years. It is this fact that induces the EEA to assume around 10 kWh of electricity consumption per household/month, effectively deciding that rural electrification for domestic application is not cost-effective.

Moreover, modern energy services, developed through rural electrification, attract entrepreneurs because of greater reliability, secured supply and the facilitation of continuous productivity. A case study of the influence of electrification on Ala horticultural farmers, selected for the short-term study, revealed a number of interesting facts (Habtetsion and Tsighe, 2001). Of the interviewed farmers, 95.2 per cent per cent enthusiastically supported rural electrification by extending the grid. All of those who support electrification expressed their willingness to share expenses with the government on a loan basis (62.5 per cent) or direct cash payments (30 per cent) or both (4.5 per cent). The advantages they envisage are:

- reduced energy expenses in their respective farming operations;
- improved motor pump efficiency as submersible electric pumps can be easily used inside deep wells;

- extension of electricity to the area could trigger the establishment of repair workshops and garages in the locality, thereby improving the maintenance service and reducing expenses; and
- new opportunities for the diversification of sources of income through the development of other sideline activities.

For these reasons, rural enterprises often show willingness to invest and pay for the installation costs of modern energy technologies and appliances. This sort of motivation and drive towards investment in modern energy services is much less of a priority for rural households, as their incomes are much lower and the share of energy expenses is much higher. This is the main justification for government intervention in modern energy provision as part of social policy and the obligation to improve the way of life of the rural population. As a result of such government support, more income-generating activities will emerge as a by-product; otherwise the way of life of the people will not improve.

Major conclusions

1 Rural enterprises attract rural electrification and this in turn is immediately followed by the development of new enterprises.

2 The rural areas, which were dependent on subsistence farming for centuries, are unable to attract modern energy services cost-effectively with their current socio-economic status.

3 Initial investment from the government and donors is required to help poor rural communities to move away from subsistence farming to modern income-generating schemes.

4 Rural enterprises shift towards modern energy services faster than the rural domestic sector. As a result of this, 95 per cent of rural household energy consumption was biomass-based, whereas the share of biomass energy consumption of rural enterprises decreased from 76 per cent in 1995 to 50 per cent in 1998 as a result of their shift to modern energy, mainly electricity and oil products. This pattern was also manifested in the Ala case study (Habtetsion and Tsighe, 2001).

5 Rural people are spending a higher percentage of their incomes on energy than SMEs, and thus not benefiting, for example, from the 31 (Nakfa) cents/litre government subsidy on kerosene. Thus, there is a need to shift such subsidies to cover all or part of the up-front costs of energy technologies and appliances.

6 The household work burden of women will decrease after electrification because of easy access to labour-saving and electricity-driven technologies.

Hypothesis 3: Prioritizing components for the promotion of RETs

Of all existing and potential components for the promotion of RETs for income-generating activities in rural areas, some are far more critical than others and therefore need priority attention and action.
Associated research issue: Analysis of components for promoting the production and deployment of RETs by private entrepreneurs in rural areas – market research, financing mechanisms, provision of infrastructure for production, repair and maintenance, training (entrepreneurial, technical, managerial) and technical back-up.

Off-grid electrification using battery-based systems and solar home systems (SHS) is widely established in the developing world and Africa. Such 'complementary' rural electrification approaches are supported by the World Bank, UNDP and various donor partners in Africa. According to Mark Hankins (2001), a number of African countries have developed thriving commercial sector markets for SHS, and these systems are reaching significant portions of the off-grid rural households. In particular, as members of the Intergovernmental Authority for Development (IGAD) Kenya and Uganda have a long experience with sales of home systems to rural markets (over 150,000 rural people in these countries have SHS). Their experiences can be transferred to and adopted by the other countries in the region.

Eritrea has one of the most positive experiences with solar electricity, albeit mostly with community-based rural applications (Hankins, 2001). Over the past 15 years, off-grid solar electric power systems have been systematically and judiciously installed for clinics, vaccine refrigerators, water pumping systems, communications and meteorological stations throughout the country. With support from a number of donors, a core of technical capacity to install and train has been developed; this is primarily concentrated in the DoE Energy Research and Training Centre. Solar electricity was used during the 30-year liberation struggle to provide strategic power in off-grid locations, especially for communications as further elaborated below.

The commercial capacity of the PV sector is at a very early stage of development. During the long period of the liberation struggle the focus of attention of PV companies and donors was on the above-mentioned tactical and community-supporting systems. Rural people have little spending power and no awareness of PV for household applications. The Eritrean diaspora, which accounts for over 10 per cent of all Eritreans and remits over US$300 million per year to Eritrea, is also unaware of the potential of solar electricity to light up rural communities, 98 per cent of which are currently without electricity. Consequently, despite the vast potential of PV to meet the needs of households and small business applications, PV systems are almost entirely unavailable in shops, and

Table 18.11 Solar systems (PV and solar water heaters) marketed in Eritrea, 1992–2000

Name of institution	Starting date	Quantity sold so far	Power (in W)	Unit price (US$)	Installation cost (US$)	R&M service	End use
DM Electrical Engineering plc	1994	634	17–90	250–820	25–30	Yes	• Water heating • Lighting • Water pumping
Haddad Solar Company	1997	320	–	750–1500	Free of charge	Yes	Only solar water heating
World Lutheran Federation	1992	7	96	830	125	Yes	• Church lighting • Water pumping
Pavoni Social Centre	1994	3	NA	NA	NA	No	• Church and school lighting
Lupano	2000	4	NA	> 800	NA	No	• Lighting
Mayor International	1997	8	NA	500–800	20	Yes	• L ighting
Hydro Construction	1997	2	800–1,200	13,500-16,000	600	Yes -	• Water pumping
Asmara Electric plc	1999	600	3	160	NA	Yes	• Lighting • Refrigeration • TV and radio
AGECA	1998	1	NA	1200	NA	No	• Lighting
Total		1579					

Source: Field Survey, 2001

there is no commercial infrastructure to promote and deliver small systems to the household portion of the market that might demand them.

The first RETs introduced in Eritrea, 20–30 years ago, were wind-based and used for pumping water; none of these are operational now. During the liberation war, the Eritrean Peoples Liberation Front installed solar battery chargers for radio communication and thus was able to save over US$150,000 in foreign currency (oral communication with the supervisor of that project). The researchers are not aware now whether these solar battery chargers are still operational or not. A survey of solar systems installed in Eritrea was conducted as part of this research (see Appendix VIIA.1, p. 371 for the questionnaire circulated to the private communities and NGOs). Since 1992, the Lutheran World Federation has brought in seven solar systems, used to light rural churches and for pumping water. Since that time, many NGOs, government institutions and private dealers have been active in the dissemination of solar systems in the country. At present there are ten agencies selling solar systems in the country, mostly to order. A brief profile of the agencies is given below. By the end of 2000, there were more than 1,570 solar systems installed by the private sector and NGOs, as shown in Table 18.11. Micro/mini hydropower plants, aero generators, and other RETs such as modern biomass fuels (biogas/other biofuels), are still unknown in Eritrea. The question is what factors encourage or discourage the wider dissemination of RETs for income-generating activities in rural Eritrea?

Solar PV systems installed by the government and registered at the DoE are presented in Table 18.12. It can be seen from this table that the DoE's Energy Research and Training Centre was responsible for installing 44 per cent of these systems. As shown in the table, most of them are for welfare-focused applications like powering health centres, rural schools and village water pumping. For example, all the PV systems distributed by the Eritrean Relief and Rehabilitation Commission (ERREC) are used for pumping water in settlement areas for repatriated refugees.

Table 18.12 Solar PV systems installed in Eritrea, 1992–2000

Authority	Health services	Schools	Water pumping	Communi-cations	Met. stations	PV lighting	Animal vaccines	Total
ERTC	27(41.4)	75(10.1)	63(75.7)	8(65.7)	35(.39)	232(1.9)	440	(195.2)
MoA				22(11.8)			34(6.4)	56 (18.2)
DoWR					11(.11)			11(.11)
MoH	165(62.4)							165(62.4)
ERREC			35(46.2)					35(46.2)
Zoba			2(3.4)	84(15.5)				86(18.9)
TSE				31(25.5)				31(25.5)
Others	6(12.2)		3(3.8)			166(4.0)		175(20.0)
Total	198(116)	75(10.1)	103(129)	145(119)	46(0.5)	398(5.9)	34(6.4)	999(387)

Note: The quantity expressed in brackets is the aggregate capacity in kW (387 kW in total).
Source: MoA – Ministry of Agriculture, MoH – Ministry of Health, DoWR – Department of Water Resources, ERREC – Eritrean Relief and Rehabilitation Commission, TSE – Telecommunications Services of Eritrea, Zoba – Ministry of Local Government.

In general, strategic long-term objectives – such as the reduction of the importation of oil products through the development of indigenous resources like fossil fuels, biomass products and the promotion of RETs – do stand out prominently in the policy documents. There is however, much to be desired in terms of the commitment of resources, and it may take a long time to realize them. It is true that there is a Energy Research and Training Centre (ERTC) within the DoE, entrusted with R & D in RETs, but it is still in its infancy, and depends heavily on external funds for its activities, although government inputs are also substantial. It provides technical and advisory services to other government agencies, which has led to complaints by some private entrepreneurs that it is dominating the PV business. The repair and maintenance services conducted by staff of the ERTC in the last five years is compiled in Table 18.13.

Note that such services are more frequent in the villages having water pumps as they don't have trained technicians who could do the routine repair and maintenance services. It is interesting to note that there was no request from Telecommunications Services for Eritrea (TSE) for ERTC help, as it has established its own repair and maintenance team. This implies that TSE is encouraged by the importance of PV systems in its income generation programmes in remoter areas without electricity supply. The government, some Ministry of Local Government administration offices and the Ministry of Agriculture have installed solar-powered communication systems, while still depending on ERTC for repair and maintenance.

Table 18.13 Repair and maintenance services conducted by the ERTC, 1996–2000

Year	Solar PV systems and equipment repair and maintenance services					
	Schools	Health centres	Water pumps	Lighting	Communication	Total
1996	10	5	7	4		26
1997	2	5	9	1		17
1998	1	4	8	2		15
1999	1	1	6	22	2	32
2000			5	6		11
Total	14	15	35	35	2	101

Source: ERTC Reports

Existing barriers to and opportunities for RET dissemination

The literature from Africa suggests that some factors are more critical than others for the dissemination of RETs for various applications. Factors selected for this study in the Eritrean situation are:

- lack of knowledge of renewable energy resources and technologies;
- lack of market research;
- high initial cost of RETs systems;
- undeveloped financing mechanisms;
- installation, maintenance and repair problems;
- lack of training and capacity building, especially at local level;
- gender considerations; and
- quality control.

To discuss these issues with various stakeholders in the country, a national seminar was conducted in October 2001 in Asmara, the capital, as part of this research work (Habtetsion *et al.*, 2002). Considerations that motivated the planning and conducting of the national seminar on *sustainable energy development in Eritrea* included:

- the heavy dependence on unmanaged biomass energy which is largely regarded as unsustainable;
- the practically non-existent access to modern energy by rural households and rural manufacturing and service-providing small enterprises;
- the need to conduct sensitization and promotional efforts to maximize private sector involvement and popular participation, and coordinate the efforts of many stakeholders;
- recommendations of the AFREPREN/SIDA regional studies on Renewables and Energy for Rural Development;
- important global environmental initiatives to promote renewables and rational use of energies.

Two papers, focusing on the basic principles of sustainable energy and on barriers to and opportunities for promoting renewable energies in Eritrea, were presented by the researchers. In one of these ('Opportunities and Constraints for Sustainable Energy in Eritrea'), Zemenfes Tsighe presented the following main findings:

- Current practices in energy use are unsustainable and have created numerous problems such as the emission of greenhouse gases and CFCs, leading to global warming and ozone layer depletion, deforestation and loss of biodiversity, desertification, soil erosion and balance of payments crises.
- There is a need to shift from unsustainable to structured and diversified energy sources by making available alternative new and renewable sources of energy, as well as improving energy efficiency.
- At the heart of sustainable energy is *energy security* for the majority of the population, which implies access to an *affordable*, *suitable*, and *reliable* supply of energy at any time.
- There exist ample opportunities for sustainable energy, both in the old practices and in introducing new practices.
- Sustainable energy will contribute to the betterment of life and help to arrest environmental degradation.

The suggestions made included:

- Gear more efforts towards designing sustainable energy policies, strategies and programmes that take into account environment, gender and socio-economic development.
- Link sustainable energy initiatives with broader national objectives to which the government of Eritrea is currently giving great attention.
- Find and promote ways of conserving energy in the domestic, commercial, transport and industrial sectors.
- Develop awareness among the population on the efficient use of energy.

Semere Habtetsion's paper ('Challenges and Opportunities for Renewable Energy Use In Eritrea') offered the following main findings:

- Studies made so far show that there are good potential renewable energy resources (biomass-based, wind, solar, geothermal, mini-hydro) in Eritrea.
- Renewable energy sources and technologies have directly beneficial effects on the environment and living conditions of people.
- Strategies to develop renewable technologies in Eritrea will have to be developed and refined.
- The challenges faced in developing renewable energy sources and technologies include all those selected by the researchers, as stated above.

The suggestions made included:

- Eritrea can gain from national and international experiences in such matters as innovative financing and management mechanisms, policy formulation, training, market research and promotion to remove all or many of these barriers.

This seminar brought together 73 participants from the various stakeholders, including government ministries, utilities, the university, national and international NGOs, financial institutions, the private sector, donor communities and the UN systems in Eritrea.

The IGAD study on potential business for solar home systems (SHS) in Eritrea conducted by Hankins (2001) identified the following barriers:

- poverty and low spending power in rural areas;
- low awareness of SHS market potential;
- import restrictions and government policy;
- poor availability of PV products;
- lack of capacity and linkages between PV Suppliers.

Hankins further stated that if PV solar home systems are considered to be a viable alternative to grid electrification, there are a number of steps that can be taken to overcome the present market failure. Most importantly, a country-scale information campaign on PV needs to be carried out among all stakeholders. Government should seek to include SHS as part of the overall rural electrification process, and should specifically develop policy to encourage such 'complementary' electrification. Government policy should be developed to encourage use of PV SHS in areas where the grid is unlikely to be extended in the near future.

A stakeholders' seminar was arranged by the DoE in collaboration with IGAD on 29 November 2001 in Asmara, to discuss the Hankins findings and the presentations by the principal researcher on the existing barriers and potential opportunities for the development of RETs in Eritrea – widely reflected in this report and in Habtetsion *et al.*, 2002. Table 18.14 lists the barriers identified by this study as well as those added by the stakeholders during the seminar. Issues such as who is likely to be affected by a specific barrier, and whether a barrier is critical or not, have also been discussed, with findings that are reflected in Table 18.14.

Table 18.14 Barriers to the growth of the commercial PV industry in Eritrea

Barriers mentioned in paper (Habtetsion, 2001)	Barrier affects:	Critical?
Lack of knowledge of the renewable resource itself	Consumer Business	NO
Lack of awareness about the renewable energy technology	Consumer Business	YES
High initial capital cost of PV technology	Consumer Business	YES
Installation maintenance and repair problems	Consumer	YES
Lack of financing mechanisms for systems	Consumer Business	YES
Lack of market research	Business	NO
Lack of training and capacity building, especially at the local level	Consumer	YES
Gender issues (who makes the purchasing decision?)	Consumer	NO
Quality control issues	Consumer Business	NO
Barriers mentioned by stakeholders		
Cultural aspects. Most people are nomadic/mobile and this needs to be considered in promotion programmes	Consumer	NO
Shorter lifetime of installations in hot areas	Consumer	NO
Importer access to hard currency/letters of credit	Business	YES
Installation/sales network	Business Consumer	YES
Lack of coordinated approach to PV dissemination	Business Consumer	NO

After extensive discussions, the stakeholders agreed on the following rankings of the top five barriers to the development of the PV market arranged in order of their importance:

1. initial cost and lack of financing mechanisms;
2. lack of awareness among all stakeholders of PV and its capabilities;
3. lack of maintenance, servicing, installation and training network;
4. shortage of hard currency (lack of importer access to hard currency);
5. culture and gender issues.

More emphasis will be given to these barriers in the analysis.

Moreover, Lahmeyer International (1999) had identified the following barriers with respect to the introduction of wind energy applications in the southern coastal areas of Eritrea:

- The ERTC is the sole governmental institution in which wind energy expertise is available, but it is presently understaffed to play a significant role in promoting the widespread adoption of wind energy in Eritrea.
- The ERTC also lacks adequate computer facilities, testing and measurement equipment.
- The public is not fully aware of the advantages that wind energy technology offers.
- There is insufficient knowledge and expertise in the private sector regarding wind energy project development, wind energy equipment procurement, tendering, installation and maintenance.
- The EEA has no experience with installation and/or operation of grid-connected wind turbines.
- Lack of financial sustainability and an already existing commercial market: there is a general lack of financing, in particular with regard to implementing wind energy technology in off-grid applications. There is not only a lack of grants or subsidies in order to remove barriers and implement items such as pilot and demonstration projects, but the non-existence of a revolving-type fund has been an even greater obstacle.
- The low level of income, particularly in rural areas remains a barrier. Only a small number of rural inhabitants can actually afford to pay for electricity.
- Regarding implementation of wind energy projects, there is a lack of adequate wind project development and implementation procedures and guidelines. Such procedures must be developed in order to define how to identify projects, make preliminary assessments, obtain approval, and finance the necessary budget for actually implementing those projects.
- There is no adequate project implementation model for renewable energy technology – only the simple turnkey based only on grant financing.
- With no projects in operation similar to that proposed for Eritrea, the people's belief that the technology would work well in their environment is hindered.
- Regarding integration of wind turbines into existing grids (wind diesel systems), the existing grids present technical barriers.
- Although knowledge about wind energy resources in the southern parts of Eritrea has been significantly improved by the project, there is still insufficient knowledge regarding the wind resources in the central and northern part of Eritrea. This is important information, since the vast majority of the replication potential of grid-connected wind parks and decentralized wind hybrid systems would be conducted in this part of Eritrea because the population is more concentrated there. This problem is, however, being addressed by the SIDA-financed project.

- Wind technology implementation also faces obstacles because future economic development and the overall economic situation is uncertain – particularly economic development in and around the city of Assab and the rural regions in the southern parts of Eritrea.

With regard to overcoming the possible barriers to the implementation of wind energy resources, Lahmeyer conducted extensive discussions with all parties involved (including future customers of this energy supply). It stated that in principle none of its findings from these discussions seriously threatens the implementation of this renewable energy source. Instead all interviewed representatives and potential customers emphatically supported the idea as an excellent contribution to the solution of the problem of supplying electricity to the Eritrean rural population, in wind-favourable regions.

Further analyses of the selected barriers by the researchers incorporating those barriers identified by Mark Hankins (for solar home systems) and Lahmeyer International (for wind energy), the impacts of these factors on the dissemination of RETs in Eritrea (not necessarily limited to income generation) are given below.

Lack of knowledge of renewable energy resources and technologies

Availability and access to information on renewable energy resources and technologies is a critical prerequisite for the promotion and diffusion of RETs. The choice and promotion of RETs primarily depends on local resources and energy needs/requirements of households and different income-generating activities. In the absence of such information, any RET intervention by public and particularly by private investors will remain highly constrained.

In Eritrea, a systematic assessment of the renewable energy resources of the country has started only recently. The ERTC is now responsible for the collection of data on renewable energy resources. The assessment of renewable energy resources must be based on detailed local surveys, as their availability, variability and intensity greatly varies from place to place. Other place specificities like nearness to power distribution networks, road networks and urban settlements also influence their development (UNDP, 2000).

The assessment of wind and solar energy started in 1999, and a complete one-year report has already been made available for wind and solar energy. The map of the meteorological stations installed for this purpose by the Ministry of Energy and Mines with SIDA grants is given below. Summary for wind energy potential is also presented in Table 18.15 for five of the 25 stations that have sensors at 10- and 30-metre heights, and the respective wind classes for all stations are given in Table 18.16.

Based on the USA wind power class denominations of one to seven, where a wind class of seven indicates the highest potential, all the 25

Table 18.15 Average wind speeds from five stations with sensors at 10-metre and 30-metre heights, 2000

Stations	Asmara Airport (WS1)		Tio (WS2)		Assab Airport (WS3)		Nakfa (WS4)		Aligeder (WS5)	
Month	10 m	30 m	10 m	30 m	10 m	30 m	10 m	30 m	10 m	30 m
January	3.41	4.97	5.07	5.71	8.26	9.14	2.96	2.86	3.26	4.28
February	3.29	4.72	5.16	5.65	4.53	8.4	2.87	2.8	4.45	4.36
March	3.27	4.73	5.47	6.2	8.82	9.7	3.0	2.9	3.64	4.5
April	3.29	4.68	4.45	5.16	6.62	4.38	3.79	3.69	4.02	4.9
May	3.54	5.34	4.14	4.7	5.91	6.78	4.35	4.25	4.06	4.9
June	3.6	5.45	3.42	3.95	5.28	6.09	6.61	6.81	4.45	5.42
July	3.9	5.48	3.7	4.15	5.15	5.89	10.1	10.38	4.64	5.62
August	3.88	5.39	3.64	4.18	5.05	5.76	9.26	9.6	4.45	5.41
September	2.75	4.39	3.73	4.15	5.27	5.82	4.77	4.68	3.24	4.07
October	3.26	4.92	4.15	4.59	5.16	5.73	3.38	3.17	2.81	3.62
November	2.84	4.27	5.9	6.65	9.28	10.17	3.19	3.15	3.01	3.96
December	2.74	4.25	4.78	5.53	8.38	9.26	2.85	2.75	2.99	3.98
Annual average	**3.31**	**4.88**	**4.47**	**5.05**	**6.73**	**4.51**	**4.76**	**4.75**	**3.75**	**4.59**

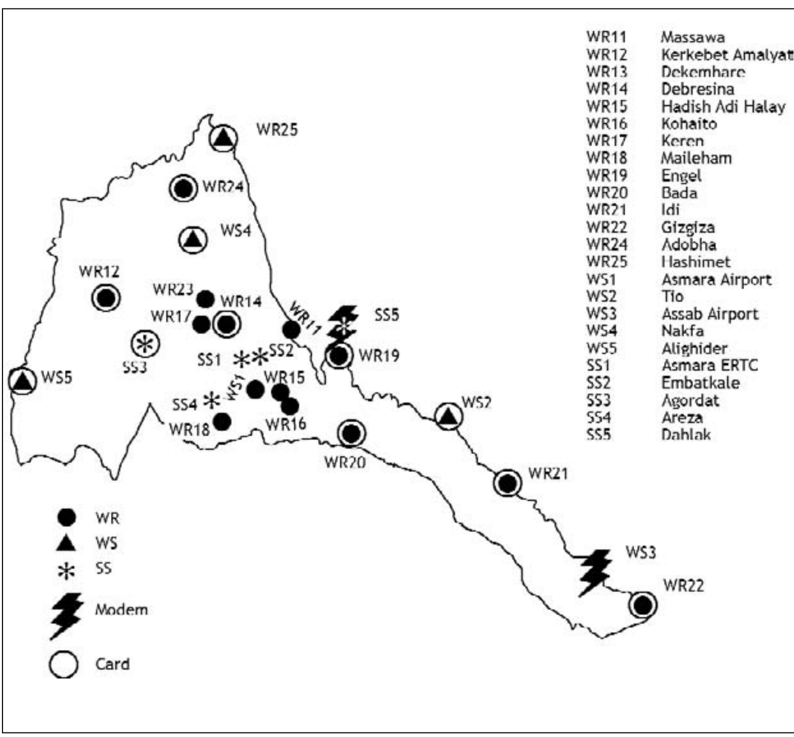


Figure 18.3 Meteorological stations in Eritrea

stations are classified as shown in Table 18.15. At 30-metre height, Assab changes class from six to seven, Asmara and Alighider from one to two, Tio from two to three; Nakfa stays where it is at two. Moreover the wind measurements have identified two promising sites in the highland areas for wind electricity conversion, namely Gizgiza (class five) and Dekemhare (class four). These places are along the windy passes that exist to and from the eastern and western escarpments. Areas classified in class one, with an average wind speed range of 2.5–4.4 m/s, are expected to be suitable only for wind water pumping and not for electricity generation.

Table 18.16 Wind speed, power density, and power class of the 25 Eritrean wind stations

Mean annual wind speed, at 10 m ht.	Wind power density at 10 m ht in W/m^2	Wind power class	Stations in each class
0–4.4 m/s	0–100	1	Massawa, Bada Debresina, Hadish Adi, Engel, Adobha, Embatkala, Asmara, Alighider, Agordat, and Dahlak
4.4–5.1 m/s	100–150	2	Idi, Hashimet, Tio Nakfa, and Keren
5.1–5.6 m/s	150–200	3	Kerkebet, Areza Kohaito, Maileham
5.6-6.0 m/s	200–250	4	Dekemhare
6.0–6.4 m/s	250–300	5	Gizgiza
6.4–7.0 m/s	300–400	6	Assab
7.0–9.4 m/s	400–1000	7	Gahro

The preliminary reports show that the southern coastal areas and certain localities in the highlands and eastern escarpments have good potential for wind–electricity conversion technologies. Indeed in the southern coastal areas, as exemplified by Assab (class six) and Gahro (class seven), the best wind velocities in the country of over 7 m/s have been recorded. This is well above the minimum requirement of 2.5 metres per second for producing stationary shaft power that can be used for activities like water pumping, while places with 4 m/s or more can generate electricity using aero generators, although the output would be better for higher velocities. The prospects for solar energy are also quite promising, particularly in the highlands. Eritrea receives solar radiation of 4–7 kWh/m^2/day. For simple solar home systems or water heaters, detailed knowledge of daily, monthly and yearly solar insolation may not be necessary for a tropical country like Eritrea where there is very good sunshine for at least nine months of the year. In the southern highlands of Eritrea where solar insolation is the highest it is not uncommon to get around 2,000 kWh/m^2/year. Even during the rainy season, enough radiation could be available each day for topping-up a storage battery. Thus, for simple systems this barrier is not critical – thought it certainly is for larger systems.

Although the energy potential of Eritrea from small and mini hydropower plants is not yet fully assessed, it might be possible to generate electricity from mini-hydro plants erected on the streams that flow eastward from the highlands. In fact, the Italians started such a plant at Durfo in the past. Studies done so far also show that about 30 MW of electricity can be produced from Tsebab near the town of Keren on the river Anseba, while at Abala 27.5 MW can be generated. The Danakil, an area of active volcanic activity in the south-eastern part of the country, is also believed to be a potential area for geothermal energy.

However, the level of exploitation of such energy resources is still low. Up to the end of 2001, there were nearly 2,000 solar system units with a combined installed capacity of over 500 kW in various parts of the country. The exploitation of biogas, wind, hydropower and geothermal energy has yet to begin in Eritrea. A 4,000-ton cotton stalk briquetting factory that was erected at Alighider Agricultural Estate was completely destroyed by the Ethiopian army when it invaded the area in May 2000.

A major project for introducing wind energy applications in the southern coastal areas of Eritrea is expected to start during 2002. These will involve three major components, namely:

- a 2.4 MW wind park to feed the Assab electric grid;
- pilot decentralized wind stand-alone or hybrid systems to power small towns and villages;
- demonstration projects on decentralized wind stand-alone or hybrid systems to power various income-generating activities.

Measures to remove existing barriers in all three components, as identified by Lahmeyer (1999), will be funded under the Global Environmental Facility (GEF). The pilot project components will also be covered fully by GEF. The EEA and a private company will have a joint venture on a BOO (Build, Operate and Own) basis for the wind park. Local private entrepreneurs will be encouraged to participate in the demonstration projects. Altogether the project cost is around US$8.5 million. As wind energy resources in the rest of the country are also now known, replication of this type of project will be relatively easy.

In addition to lack of knowledge until recently of existing resources, little information is released to the public in Eritrea today about the advantages of using RETs for various income-generating applications or for lighting and entertainment purposes. This could easily qualify as a big barrier to both consumers and the business community. Thus, public sensitization and promotional activities are highly desirable. A sound energy information system must be developed and made available to the public through the mass media, newsletters, websites and demonstrations.

Installation, maintenance and repair problems

A proper installation and maintenance service is an important factor for the sustainable and continued use of RETs, as the service that users get ultimately depends on technical back-up. The field survey summarized in Table 18.11 above indicates that those companies who only import and sell to customers without offering installation, repair and maintenance services, even at cost, are the ones who have the least market. Haddad Solar manufactures the solar water heaters locally and installs the sold systems without any charge to customers. This means that they have included installation costs in the sale price of the systems. Many of the companies reported that buyers are responsible for the installation of RETs. Similarly, although most of them reported that they provide maintenance and repair services, only four had their own trained technicians to provide the service. These are DM Electrical Engineering, Haddad Solar Company, Mayor International and the Pavoni Social Centre (the recent death of the trained technician responsible for this service at the last-named institution means that it is no longer provided). DM Electrical Engineering provides a free maintenance and repair service within the guarantee period, which is one year. Mayor International guarantees equipment for ten years, while Haddad Solar Company trains owners on how to maintain their solar heater but also provides free service if the repair required is beyond the ability of the owner. Moreover, Haddad claims to provide a 20-year guarantee. The other agencies that claimed to provide maintenance and repair services do not have their own technicians: they make arrangements with ERTC personnel for repair work. This tends to frustrate clients, as making such arrangements delays the repair work.

Thus, lack of services from suppliers and dealers linked to installation, maintenance and repair, especially at the local level, could easily become a killer barrier to the promotion of RETs. Indeed this barrier ranked third in importance in the Solar Home System Business Opportunity Workshop conducted in Asmara last November. The ERTC should be viewed as an asset by the private community rather than as a competitor in their business. In principle they can sponsor training on RETs for their staff members at the Centre, an opportunity already taken up by the major government agencies with RETs installations.

As to the performance of the PV systems installed, the beneficiaries are extremely pleased with those powering health centres and village water pumps, and often consider them as symbolic fruits of independence. All of these systems continue in operation. Temporarily, component malfunctioning might arise but is reported immediately to the ERTC, where technical staff are now experienced in identifying defective components and usually succeed in remedial measures at first visit. On the other hand, village hand-pumping systems or diesel-powered water pumping often encounter system breakage.

The ERTC is not happy with the performance of the PV systems installed for rural school lighting and/or power supply for audiovisuals. The systems have failed mainly because (1) students, especially those living on school premises during a summer vacation tree-planting campaign, abused and mishandled them; and (2) the school directors, normally responsible for protecting the facilities, left them unattended when they were transferred elsewhere or during their vacations, especially when the lighting was not extended to their residential rooms. Moreover, the Ministry of Education itself delayed the start of illiteracy eradication services for the elderly using the lighted schools. Thus the PV systems were not fully utilized for what was one of the main intended applications. This lack of technical capacity among local users and installers is easily avoidable if strong cooperation with the ERTC is maintained and a sense of ownership of the installed systems is enhanced among the users. All solar systems installed to power the data-logging systems of meteorological stations are working perfectly: they normally have salaried attendants.

High initial RET cost and undeveloped financing mechanisms

One of the major reasons hindering the wider dissemination of RETs in Eritrea is the high initial cost of such technologies. In the stakeholder seminar on solar home systems mentioned above, this was regarded as the number one barrier. It is a well-known fact that poor people use high discount rates. This implies that they attach greater importance to initial cost than to the life-cycle cost of energy technologies and fuels. Thus, although RETs may be cost-effective in the long run, high initial cost tends to discourage rural people from adopting them. Indeed, for Eritrean rural households whose annual income is US$400–600, the current price of RETs is exorbitant, and hence easily regarded as unaffordable.

The financing problems might be overcome in a number of ways. First, access to credit by poor people must be improved. With increased access to credit facilities, affordability is improved and poor people will be encouraged to use RETs, particularly if the payment schedule is amortized over the life cycle of RETs. At present there are no appropriate financing schemes for RETs in Eritrea. Although there are micro-financing institutions with good reputations like ACCORD, ECDF, and REIP, almost all of them extend credit to directly productive activities only. The energy dimensions of the projects they finance are seldom considered. With little adaptation, the lending mechanisms of these micro-financing institutions can accommodate RETs. The creation of RET rotating funds could augment the efforts of such institutions.

Second, the dissemination of RETs must be linked to the poverty alleviation programmes of the country. This can be achieved by gearing

RETs to the generation of income rather than focusing on social or welfare aspects of rural people. As indicated above in Tables 18.11 and 18.12, most solar systems disseminated in the country so far are for welfare purposes. Such welfare-focused energy initiatives are unlikely to be sustainable. On the other hand, RETs geared to income generation have the potential to finance themselves. Coupled with the benefits derived from energy savings in the long run, the gearing of RETs to improve productivity of income-generating rural enterprises could be an important strategy for the promotion of RETs in rural Eritrea.

Third, the initial cost of RETs can be reduced by assembling and/or manufacturing RETs in the country. At present, only Haddad Solar Company manufactures the solar water heaters it sells in Eritrea. Although the customs tax is only 2 per cent for RETs in Eritrea at present, prices of imported equipment remain high. The government could design appropriate incentive structures to attract private investment in this area.

Lack of market research

The market for solar home systems in Eritrea is still narrow, constrained not only by the perceived high initial cost of the technology, but also by the failure of local agencies, particularly the dealers, to engage actively in promotional activities. Before assessing their markets and/or conducting commercialization efforts, they import the technologies and display them to window shoppers. In fact, Asmara Electric plc, one of the leading sellers of PVs in Eritrea, openly admitted that the market for PVs is shrinking because of lack of proper advertisement. Mayor International expressed a similar opinion, but stated in addition that the shrinking market for PVs reflects the increasing expansion of grid electricity to many villages. This tends to give other villages the signal that grid electricity will be extended to their localities as well, which discourages investment in PV systems. However, this claim may be valid only for villages that are in the neighbourhood of major urban centres, from which grid electricity is slowly expanding. It appears that RETs dealers have been trying to sell their products from a single point of sale somewhere in Asmara and without commercialization efforts, rather than selling them to localities whose prospect for connection to grid electricity in the near future is remote. This clearly reflects lack of proper demand assessment and targeting of potential users.

The market for RETs can be expanded through strategies that have been mentioned earlier, like access to micro-credit, amortization of payments over long periods, and the integration of renewable energy services with income-generating rural enterprises. Such strategies are demand-enhancing, and they will not only expand the market for RETs but, as the UNDP (2000) has aptly observed, they also 'make explicit the connections between renewables and human development'.

There is a need to establish and develop a partnership process with the business community to support the continuing emergence of appropriate policies and procedures governing the conduct of RETs business in Eritrea. The minimal levels of corruption, low level of import duty (only 2 per cent for developmental imports including energy) and the willingness of the government not to be involved in business are very helpful in improving the business environment. Although Eritrea has opened its economy to foreign direct investment, flows of inward investment to date are small. Thus it is appropriate for the government to appraise its strategy. Key policy issues may include:

- further honing of the competitiveness of the business environment;
- adopting an incentives framework which would keep Eritrea competitive with regional countries;
- developing a professional support service for incoming investors.

Eritrea has to learn from the excellent PV market experience in Kenya, which has cumulative sales in excess of 150,000 units and current sales of over 20,000 systems per year compared to 62,000 rural customers connected to the grid to date (Ossawa, 1999). The innovative financing mechanisms employed in the Kenyan case are presented in Appendix VIIA.2 (p. 372). Each of the models was discussed and debated in terms of its relevance and applicability to Eritrea at the November 2001 stakeholders' workshop in Asmara. There was a view among many stakeholders that some type of subsidy would be required to start the market. A range of views emerged on the various financing models.

- To be successful, the charging of fees for service systems needs a large number of systems in order to be financially viable. It should be introduced in response to the market, not vice versa.
- Micro-credit schemes must enable companies to access finance for their operations. The successful operation of micro-credit schemes often requires the support of donor organizations or international financial institutions like the World Bank and the awareness of financial organizations in the country.
- Rural enterprises in Eritrea give loans for those projects that can demonstrate an ability to generate income. If the installation of solar home systems can create income-generating activities the enterprise will approve the loan. The loan will be given to PV businesses under normal terms, however, with 12 per cent interest rate.
- The concept of hire purchase is that you pay monthly (or grant a stoporder) to a hire purchase company. Such schemes are not familiar as they don't exist in Eritrea.
- The Ministry of Agriculture credit scheme gives loans to women for poultry, sheep, goats, etcetera. It was suggested that the government should introduce the concept of subsidy in covering part of the high initial costs, and facilitate the introduction of fees for service to promote RETs.

Even though shortage of hard currency (lack of importer access to hard currency) emerged as one of the serious barriers stated by stakeholders, it is now widely believed among government officials that this is a temporary problem. The unexpected war with Ethiopia has definitely induced restricted access to hard currency.

PV MARKET STAKEHOLDERS

As Hankins (2001) explains in detail in his report, PV was introduced into Eritrea during the mid-1980s and the country rapidly experienced a positive effect. To date, however, the industry largely exists to respond to requests by donors and government to supply equipment. There is little over-the-counter activity or commercial trade in the sector, and there are few inter-industry linkages between equipment suppliers. Solar modules were only found as stock items in three companies, and only one or two companies visited were selling to the consumer market.

In a less-developed country, an ideal PV market is made up of a number of stakeholders including the government, donor/financiers and consumers. In Eritrea, all of the above groups are theoretically present but with limited or no coordination. However, the limited consumer and supplier knowledge of solar home systems, for example, virtually rules out sales activity. Companies that supply this market respond mainly to tenders made by NGOs and international agencies. Some companies complained that it was hard for them to compete in the market of international tenders for equipment in Eritrea because only established players could compete for these major contracts.

There is no development of a PV marketing chain. All PV products are found in the capital city, and installations are done mostly on a project-by-project basis. In general, most of those interviewed felt that the market for PV SHS would be extremely small because of widespread rural poverty.

PV companies. Only a handful of companies sell PV products, including representatives of Siemens and NAPS. Other major international players (BP Solar, Kyocera, a-Si manufacturers) are not in the market. All of the companies involved in PV are engaged in a number of businesses, and consider PV as a minor component of their turnover. None of the companies has made inroads into the supply of solar home systems, for example, although at least two are planning to get into the business. There is some marginal informal PV trade, in addition to recognized importers as the survey found at least one shop that sells PV over the counter.

Battery and electrical appliances/parts suppliers. There are at least three automotive battery manufacturers/assemblers in Eritrea. A number of other companies import batteries for the automotive market. Thus far, there is little interaction between the local battery manufacturers and the PV industry. Other PV components, such as DC lamps and regulators, are not available on the market. However, it should be noted that there is an active market for consumer appliances such as TVs (240 VAC), cassette players and stereo equipment. This implies *some* demand for amenities, though the split between rural and urban demand is difficult to judge.

Government/utility. At present, the government, through the ERTC, is the most important player in PV in Eritrea. Through its rural-focused and welfare-oriented policy and donor coordination, the government has established a strong foundation for PV. There is a good knowledge of the technology, a standards base, a training capacity, and a very positive history. The various ministries are also important stakeholders in the PV industry, including the Ministry of Health (PV-powered clinics), the Ministry of Local Government (which uses PV village water pumps and communication facilities) and the Ministry of Information (which would like to introduce village-level PV-powered televisions for communication and education purposes). Finally, the government's Macro Policy Office is an important stakeholder as it allocates development assistance from partners to the various economic sectors. There is now strong backing from this office for the introduction of wind energy applications in the southern coastal areas.

Donors/promoters. Donors have played a key role in dissemination of PV technology for community development applications. Important donors include the German Lower Saxony Government, Oxfam, Swiss Support Committee, World University Service-German branch, and others. Given their other priorities, however, donor partners have not recognized the role that PV can play among households for rural electrification.

Consumers. Final consumers are still unaware of the technology, and need to be involved. For example, business people, teachers, health workers and other professionals in rural areas might be interested in getting PV sets if finance was available. At present, primary consumers are local governments, NGOs and government. Rural households themselves are uninvolved. Innovative financing methods need to be developed by finance groups to engage the attention of final consumers. Customers' access to information on the advantages of RETs is equally vital for their dissemination. Users do not know that they are better off after three years with a solar PV system than if they use 6-volt batteries for their cassette player. They have to be informed that 1 kWh of electricity lighting is equivalent to the light you get from 12 litres of kerosene with lamps. Policy reforms, particularly the involvement of private investment in the power sector, are also important for sustainable and decentralized renewable energy services.

Gender and cultural issues

In rural Eritrea, women shoulder the responsibility of energy provision and cooking for their households. Moreover, about 30 per cent of the households in Eritrea are headed by women. As women are also the users of energy, it is they and the children they carry on their backs who suffer from indoor pollution most. Yet, the decision to buy RETs, widely perceived as expensive, is often made by men. Since the increasing scarcity of fuelwood in Eritrea increases the burden on women mostly, providing access for women to sustainable and affordable energy technologies like RETs is critical for the dissemination of RETs in rural Eritrea. However, gender-sensitive energy policies and appropriate RETs can be identified only if the energy needs and problems of women are properly understood. Thus, to promote RETs in rural areas, a needs-based approach would be a better strategy than a simple supply-based approach. Unfortunately, such an approach does not seem to be employed in Eritrea today.

In Eritrea, the average distance travelled to fetch wood is 10 km and this is 80–90 per cent the responsibility of women and children. This barely meets their energy needs for 5–7 days. Although the ILO prohibits manual carrying of loads of more than 20 kg by women, they have been observed to carry more than 35 kg of firewood over a distance of 10 km (Dankelman and Davidson, 1989). Carriage of heavy loads leads many women to suffer from health problems like damage to the spine and chest complaints. These problems have further effects during child bearing, while pressure on the health of women is compounded by poor nutrition.

Other health hazards arise from the fact that women do most of the cooking. They and their cooking fires are generally inefficient (often <10 per cent) and produce a number of pollutants associated with incomplete combustion. Pollutants found in smoke from these fires include particulates, carbon monoxide, benezoprene and formaldehyde. Exposure to these pollutants commonly leads to acute respiratory infections, chronic obstructive lung diseases, low birth weights, lung cancer and eye problems.

In Eritrea, girls are involved in traditional women's chores from an early age. Like their mothers, they spend long hours in collecting fuelwood and water and in other household level activities, leaving little time or opportunity for education. While primary school enrolment of girls is nearly the same as boys, only 10 per cent of those who pass university entrance examinations in Eritrea are girls. Besides the responsibilities in household cooking and fuelwood collection, other cultural biases like early marriages may have played an important role in the poor performances of girls in the educational establishments.

Lack of safe and reliable lighting in the evening or early morning makes it difficult for women to pursue educational and entrepreneurial opportunities, or to perform essential childcare and community responsibilities. In many cases, women's informal income-generating activities are energy-intensive and could be made more profitable if better-diversified energy choices were available. Eritrea, at the moment, has started quite an extensive rural electrification programme with the involvement of the rural communities and its partners in development. The supply of the household fuels, kerosene and LPG has also been improved. This will definitely improve the productivity and well-being of women with access to these modern energies.

Acceptance of new technologies or improved ones can be enhanced if users, including women, participate in the design of energy projects and adaptation of technologies to fit local needs, preferences and priorities. For instance, solar box cooker projects have been initiated in a number of developing countries including Eritrea, but their success is limited and in many cases women have abandoned them for quite valid reasons, despite the fact that their use can reduce fuelwood consumption and harmful emissions. In the case of Eritrea, the main reasons for their unpopularity stems from the fact that solar box cookers are too slow and cannot be used in the early morning hours or evenings when the household meals are normally served. Recently, however, the Ministry of Energy and Mines introduced 400 parabolic cookers, which have attained huge popularity among women and military camps. The concentrated radiation has been observed to cook much faster than even LPG or electricity.

As the Eritrean experience in introducing more efficient biomass-fired stoves shows, the most successful efforts have been those in which women users themselves were involved. A good example is the improved *mogogo* stove that the Ministry of Energy and Mines has developed. In the design, testing and pilot phases of its dissemination programme, artisanal women have taken the lead role. Compared with the efficiency of the traditional stove of less than 10 per cent, the improved stoves have efficiencies of more than 20 per cent. The environmental and socio-economic advantages of this improved biomass stove have been presented in an earlier study: a summary is provided below.

SUMMARY OF BENEFITS OF THE IMPROVED *MOGOGO* STOVE

1 Improved stove use will decrease deforestation pressures.
2 The standard of living will increase at the household level.
3 Wood or dung collection labour will be reduced by at least 50 per cent.
4 With less onerous wood collection duties, students will be able to spend more time studying.
5 Cooking time is reduced, and so is cooking labour.
6 Household cash expenditures for wood and kerosene purchases are reduced.
7 The health of people in the household will improve as smoke inhalation during cooking is almost eliminated.
8 There is also a social benefit, as cooks will no longer have clothes that smell of smoke.

9 Each improved stove has the potential to reduce 600 kg of CO_2 emissions.

Quite a significant fraction of the Eritrean population is pastoralist and nomadic. If their way of life is to change for the better, they need modern energy services. For lighting and entertainment, solar home systems are ideal as they can be carried easily on their camels when they move from place to place. The scattered watering points of their livestock, the mainstay of their livelihood, can be supplied with wind pumps. If they are to settle around modern agricultural farms, as is happening in many remote areas in the country, modular RETs can meet their energy needs and this has to be incorporated in the development plan. The wind energy project in the southern, desert-like coastal areas is expected to improve the quality of life of the local people by providing energy to produce ice for fishermen, pump seawater to salt farms, irrigate agriculture and power their homes.

Quality control

The quality of energy technologies – their ability to deliver the promised energy services – is equally imperative for their wider dissemination and continued use. In Eritrea, the Eritrean Standards Institute is supposed to be responsible for quality control and certification of any product imported or locally produced. Unfortunately, the Institute is very weak and understaffed. The Institute has so far no guidelines or certification procedures to ensure the quality of RETs. Recently, the Institute has given the DoE the mandate to set standards for RETs, and the DoE has developed a set of guidelines that will be implemented soon. When dealers that are involved in the marketing of RETs were asked to rate the quality of the products they sell, all of them claimed to be of high quality and they often mentioned the country of origin as an indication of high standard. Two dealers, DM Electrical Engineering and Haddad Solar Company, stated that they get their products and/or materials from European manufacturers whose quality is certified by the country of origin. On the other hand, ERREC and Hydro Construction rated the reliability of products they are selling or distributing at 65 per cent. The Kenyan experience shows that, among the market impediments, low quality of available local Balance of System (BOS) components as well as low installation standards are quite serious.

Conclusions

- The majority of rural communities in Eritrea have no access to modern energy, and RETs offer good opportunities to them.
- Excepting a few RETs, mostly donor supplied, that have been introduced for welfare purposes like powering schools, health centres and

village water supplies, the use of RETs either for domestic or small rural enterprises is still negligible.

- Renewable energy sources in Eritrea have good potential; if properly utilized, the new technologies will facilitate shifts to diversified sources of energy, thereby improving the security, reliability and sustainability of energy supply in the country.
- Certain barriers have been identified as being critical and they will have to be addressed if RETs are to diffuse widely among rural communities. The major barriers are:

  - *Lack of knowledge of renewable energy sources.* The systematic assessment of renewable energy sources was initiated in 1999, and there now exists a one-year record for solar and wind energy. However, as yet this knowledge or information has not been released to the public.
  - The *low income level of rural people, on the one hand, and the high initial cost of RE*Ts on the other, have made RETs unattractive to rural dwellers. By intensifying credits and amortization mechanisms, this barrier can be removed easily.
  - *Installation, maintenance and repair constraints.* Most RET dealers do not provide such services.
  - *Lack of market research and professional activities.* All the existing RETs dealers are located in Asmara, the capital, and they have not designed any mechanism to popularise their technologies. In the absence of promotional mechanisms, it is difficult to imagine or expect potential users to drop in the shops and purchase RETs. Moreover, no attempt has been made so far to target potential customers.
  - *Lack of RETs awareness among the population.* This is a critical barrier, and needs to be resolved by involving the media, CBO, NGOs, Government agencies working in rural areas.
  - *Lack of access to foreign currency by dealers.* This is widely regarded as temporary.
  - *Gender and cultural issues.* Women have to be empowered in decision making in the home as well as the economy if they are to influence the RET market positively. The energy needs of pastoralists, island communities and other special groups should be assessed and incorporated in development planning.
  - *Quality control.* Customers have to be protected from poor-quality RET systems as well as installation standards.

19

Final Policy Recommendations

The major findings and conclusions of this study give rise to the following draft policy recommendations. The filtering process with respect to institutional and management arrangements, legal framework, economic and financial mechanisms, as well as human resource needs and technical capability has been conducted and are taken into account below. The researchers are quite optimistic that these recommendations are realizable in Eritrea. Indeed there are many emerging signs that the recommendations are being favourably considered by the institutions concerned.

Hypothesis 1: Decentralized private sector vs centralized public sector energy initiatives

Policy recommendations

- Part of EEA's services have to be decentralized.
- The government should continue to expand modern energy infrastructure, particularly in those areas in which the private part of EEA's services have to be decentralized.
- A more conducive investment climate in energy for the private sector is required to complement the government's energy initiatives.

Part of EEA's services have to be decentralized

INSTITUTIONAL AND MANAGEMENT

The options are decentralization either by giving more management roles to the relevant local administrations, or engaging private service agents to manage the distribution of bills, revenue collection, compiling demand applications and complaints, and even managing new connections for simple systems. A move made by the National Insurance Corporation of Eritrea in this direction shows good success. There are at least ten service agents who obtain commissions proportional to customers served or turnovers managed. The EEA can also involve local administrative organs, as is the case in the water supply utility, where they are largely responsible for the overall operation, management and expansion activities. The central Department of Water Resources is responsible mainly for conducting feasibility studies, water quality monitoring and other research. The electricity service agents that may be established in such a manner can get their commissions from every kWh sold in the territories they serve.

The EEA and/or the government can also subcontract the laying of the rural electricity infrastructure to certified electrical contractors. Furthermore, once such infrastructure becomes operational, its management may be left to electricity cooperatives, local government organs, energy service companies or other interested bodies. Through this decentralized approach, (1) the quality of the existing service could be greatly improved; (2) new applicants will be connected faster; and (3) the service agents could promote new connections to increase their commission, and hence more people could be served.

Legal framework

A conducive and enabling legal framework is being created by the Draft Electricity Proclamation, which encourages the establishment of Independent Power Producers (IPPs) and Distributors (IPDs), the formation of electricity cooperatives, and participation of private energy service companies. The Proclamation is expected to be approved shortly.

Economic and financial

Private companies or agencies who want to initiate electricity business can have access to various capital sources such as the Investment and Development Bank, the Commercial Bank of Eritrea, the Housing and Commerce Bank, and many micro-financing organizations. Private sector penetration of the energy market, the existence of electricity cooperatives or local government IPDs all depend on the economic and financial soundness of the businesses. However, this should not be a problem, as the present EEA overhead cost charge to manage rural electricity distribution will be their major source of income. As rural electrification intensifies, their income and margin of profitability are also expected to expand. Energy service companies can also be engaged in other energy delivery business like LPG, kerosene and RETs to the rural communities.

Human resource needs and technical capability

The country's educational institutions are the major sources of human power for the public and the private sectors. In addition there are institutions like the ERTC which give specialized training to candidates sponsored by government or private companies. The demobilization programme of young conscripts will also create a large labour pool with various skill levels. Moreover, the Ministry of Energy and Mines has plans to recruit and train electricians for each electrified village. As of the academic year of 2003/4, the government is introducing a new curriculum designed to transform the whole educational system in the schools to sensitize students in production and information technology. The motive behind it is to make school drop-outs and those who could not pursue higher-level academic studies employable when the leave school.

The government should continue to expand modern energy infrastructure, particularly in those areas in which the private sector is not prepared to invest.

Institutional and management

The expansion of modern energy infrastructure is indeed capital-intensive. High investment requirements and limited knowledge and capital in the local business community may delay the development of this infrastructure, thereby depressing the expansion of modern energy services in the country. Moreover, the big oil companies operating in the country are not interested in investing in the LPG infrastructure, as they believe that its market in Eritrea is too small. A similar problem exists in rural electrification. This makes it necessary for the government to intervene and expand the respective infrastructures.

Legal framework

The major constraint limiting private sector penetration in the energy market has been the absence of the necessary legal framework to liberalize the energy market and to allow flexibility of tariffs. The forthcoming draft proclamation is expected to ease the situation, even though energy tariffs will continue to be regulated and controlled for the foreseeable future.

Economic and financial

The government is committed to allotting finances (from its own resources and development partners) for the energy sector. Indeed, the highest single investment in the country has been for the expansion of the power generation and transmission system (US$200 million) since independence. As a continuation of this effort, two projects of direct relevance to rural energy are being initiated, US$4 million worth of wind energy and US$9 million worth of rural electrification projects.

Human resource needs and technical capability

Institutional and human development issues should be part of the strategy in integrated economic and rural development initiatives. Emphasis should be placed on awareness raising for the rural poor, on job training for the unskilled and semi-skilled labour force, and on specialized technical training. The country has had useful experience in incorporating the training of local people in projects involving technology transfers.

A more conducive investment climate in energy for the private sector is required to complement the government's energy initiatives.

Institutional and management

The Ministry of Energy and Mines has decided to form a powerful Project Management Unit that will manage and coordinate the rural energy programmes through wind and grid extension sited above. This Unit will study the conducive investment climate required for private sector participation in the delivery of modern energy to rural areas. The ERTC has been established to promote and give technical support services to the private sector in this area. In addition to this it is necessary for the Ministry to conduct various pilot and demonstration projects to introduce new technologies both to users and investors.

Legal framework

Although the government has recently taken certain measures like customs tax reduction (only 2 per cent for RETs), there are still certain constraints. No foreign direct investment in the energy sector has so far been registered in the country. Indeed, until recently, there has been no regulation concerning private investment in the energy sector. Realizing this problem, the Ministry has prepared draft energy laws and regulations (soon to be promulgated) to attract private investment.

Economic and financial

Additional policy instruments (tax relief, guaranteed margin of profits, reasonable pay-back periods, access to foreign currency, level of profit remittances for foreign investors), not covered in the legislation cited above, have to be developed and effected. There is also a general understanding between the various stakeholders that the market in small energy technologies – like household appliances, solar home systems, solar or electric water heaters, wind pumps – is to be left to the private sector.

Human resource needs and technical capability

The private sector has the ability to attract the best minds from the market. Nevertheless, to upgrade the existing staff to the rigours of modern technology, they should be allowed to sponsor them in the various government-initiated, short-term, on-the-job training programmes attached to new projects.

Hypothesis 2: Income-generating activities vs domestic energy use

Policy recommendations

- Promote the development of rural enterprises using any natural resources available, with modern energy as an integral part.
- Rural areas dependent on subsistence farming have to be supported to change their way of life, using modern energy as a tool.
- Shift any subsidies for energy prices or any cross-subsidies amongst energy fuels towards the capital costs required by first-time users of modern energy in rural areas.
- Reduce the drudgery of women in rural areas through modern energy delivery and income generation programmes.

Promote the development of rural enterprises using any natural resources available, with modern energy as an integral part.

INSTITUTIONAL AND MANAGEMENT

It was shown in the short-term study that there are many institutionalized rural development agencies, NGOs and micro-financing institutions operating in the country. Rural enterprises normally get directives, guidelines and advisory services from the relevant ministries: Agriculture, Trade and Industry, Energy and Mines, Fisheries and Tourism. Many of these ministries are engaged in natural resources studies in their respective areas throughout the country. When any given situation is ripe – when the peace initiative between Eritrea and Ethiopia reaches an irreversible stage, for example – it should be possible to exploit the economically feasible resources for the benefit of the inhabitants. The Chamber of Commerce as well as the Federation of Employers play facilitation roles for their members (mostly urban and rural enterprises) in international and national trading, information and awareness raising, protecting the interests of their members with respect to foreign exchange requirements, financial borrowing, etcetera. It should not be difficult to coordinate all of the above for the benefit of new rural enterprises while expanding established ones. The use of modern energy, conventional or renewable, should be an integral part of promotional efforts.

LEGAL FRAMEWORK

The macro policy of the government clearly states the need to develop the private sector in its role as the key player in the economic development of the country. In early June 2001, the Economic Adviser to the President stated that private entrepreneurs should play the lead role in running the economy of the country; the government does not want to be engaged in production and operational activities, but wishes to relinquish this responsibility to the private sector.

Even if land is declared as public, rural communities have usufruct rights in areas where they live and licensed rural enterprises may obtain lease rights to a designated area giving priority of employment to the local people.

ECONOMIC AND FINANCIAL

Promoting rural enterprises requires considerable finance. Promotional efforts need require little expenditure for the stakeholders, whose mandate is to give support services, but the bulk of the investment has to be covered by the entrepreneurs themselves. It is possible for the relevant government institution to solicit national and international financiers to make money available for borrowing, possibly at low interest rates, provided there is willingness on the part of the private entrepreneurs. For example, the government has recently secured soft loans from the World Bank for use by the private sector. Micro-financiers operating in the country could supply loans to small-scale enterprises up to the level of 100,000 Nakfa.

HUMAN RESOURCE NEEDS AND TECHNICAL CAPABILITY

One of the serious problems in Eritrea at present is the absence of indigenous technical, financial and human resource capacity in the private sector to invest in the energy infrastructure. With the current policy of privatizing existing public institutions – opening up energy, fishing, tourism, mining, commercial agriculture and other sectors to international and regional companies – joint venture schemes between local and foreign entrepreneurs may help to transfer knowledge and skills through on-the-job training. The major training institutions in the country – the university and the technical schools – are increasingly consulting with the relevant government ministries and other institutions, anticipating their intervention in identifying future manpower requirements.

One important potential source of trained manpower is the Eritrean community in the diaspora, estimated to be around a million. Some of those who have lived abroad for many years and have good professional skills are interested in investing in their country, while the majority of the others are a source of financing for their relatives and friends at home. The amount of foreign currency that flows into the country in remittances, averaging over US$300 million per year, is a good measure of this potential and more can be diverted into enterprise creation in both urban and rural areas.

Rural areas dependent on subsistence farming have to be supported to change their way of life, using modern energy as a tool.

INSTITUTIONAL AND MANAGEMENT

A good example of helping the rural poor who continue to live by traditional subsistence farming to change their way of life is through integrated farming programmes initiated by the Ministry of Agriculture in 1998, using mechanization and chemical fertilizers. During that year, 42,504 hectares owned by rural farmers were cultivated using 228 government-owned and 121 privately owned tractors, with the farmers themselves giving additional manual labour up to harvest time. Modern energy, specifically diesel, was used extensively, replacing the traditional human and animal labour for tilling the land and threshing. The yield improved by a factor of 2.5 times for sorghum and teff, 1.5 times for barley and 2.15 times for wheat and maize. Total expenditure was 28 million Nakfa, while the value of overall production was over 105 million Nakfa. The Ministry, after deducting its expenditures, distributed the rest of the income to the farmers. Almost all farmers obtained record incomes from their farms. Encouraged by these results, the Ministry doubled the hectarage covered under integrated farming in 1999 (Habtetsion and Tsighe, 2001).

The effort by the Ministry of Public Works to link areas of major economic potential with a road network is commendable. As shown in Table 18.7 (p. 324), the expenditure of the Ministry is the highest among the service-providing ministries over the ten years since independence. Most of the other rural development agencies have financed feeder roads and it can be said that most of the rural villages in the highland areas now have access roads up to their respective villages. In addition, the rural electrification initiated, the rural water development programmes, and the health and school facilities being established are components of an integrated approach to the development of rural areas. Thus, this hypothesis is implementable in Eritrea considering the positive experiences achieved so far. The Ministry of Local Government is largely responsible for co-ordinating rural development programmes. It has representation even at the village administration levels and each village has a *baito* (assembly), making coordination of community participation very easy.

Legal framework

The central motto in the country's macro-economic policy is the creation of a modern technologically advanced and internationally competitive economy within the coming decades. Strenuous effort is in progress to transform the war-ravaged economy into a modern one characterized by self-sustaining growth. The government gives much priority to the development of the rural areas, where modern energy provision is expected to play a key role. Thus, there is no barrier with respect to legality issues in these drives. A new tax system that aims to encourage private investment has also been instituted as of September 2001, not only reducing the taxation rate but also simplifying the tax structure.

Economic and financial

Exploiting the potential of diversified energy sources in stirring rural development requires high investment in the various economic sectors and in modern energy, necessitating strong government commitment. Preferably, government should seek the involvement of development partners, international, regional and national financial institutions, NGOs, the private sector and, above all, community participation. The study showed that availability of electricity in rural areas creates its own demand. At least in the Eritrean village settlement system (villagized rather than scattered) rural electrification has to be viewed as potentially economic. At present, the government and the resident UN offices in Eritrea are preparing an UNDAF (UN Development Assistance Framework) with three strategic areas: (1) democratic governance; (2) access to basic quality social services; and (3) sustainable livelihoods for the poor while fostering economic growth. (Note: the principal investigator in the present study is a member of the team preparing UNDAF.)

Human resource needs and technical capability

Institutional and human development issues should be part of the strategy in integrated economic and rural development initiatives. Emphasis should be placed on awareness raising for the rural poor, on-the-job training for the unskilled and semi-skilled labour force and specialized technical training. We have seen that the country has useful experience in incorporating the training of local people in projects involving technology transfers.

Shift any subsidies for energy prices or any cross-subsidies amongst energy fuels towards the capital costs required by first-time users of modern energy in rural areas.

Institutional and management

It was shown in the short-term study that the cost of kerosene in remote areas, the capital cost of becoming an LPG user, and electricity connection fees are all becoming unaffordable for low-income groups. A system has to be developed to circumvent these problems. To boost agricultural production, low tariffs for energy fuels have to be considered. The government has abolished direct subsidies in the energy sector. There are a few cross-subsidies among fuels – gasoline to kerosene, for example, or large-scale electricity generation to small-scale electricity generation. In spite of these cross-subsidies, the rural poor are not benefiting, as user prices are more influenced by transport costs, especially to remoter places.

It should not be difficult to implement this proposal of shifting fuel subsidies to new energy technologies and appliances in rural areas. The institutional and management structures recommended in the short-term study could also be responsible for implementing this proposal.

Economic and financial

There are already government initiatives in modern energy delivery for rural development. Many other stakeholders, like the micro-financiers, could easily incorporate energy into their financing programmes, as observed in the National Energy Policy Seminar in November 2000. The shifting of fuel subsidies to new energy technologies and appliances will boost the finance available to help the poor get modern energy.

Legal framework

The shifting of subsidies requires policy support from the Ministry of Energy and Mines in the form of a declaration, as in the case of the 3 per cent levy proposed on electricity sales to support rural electrification.

Human resource needs and technical capability

This recommendation does not require human resources or technical capability beyond the institutional/management needs mentioned above.

Reduce the drudgery of women in rural areas through modern energy delivery and income generation programmes.

INSTITUTIONAL AND MANAGEMENT

The response of the women interviewed in the socio-economic survey in the newly electrified semi-urban and rural areas around Dibaruwa and Aditekelezan areas is the basis for this proposal. This recommendation can easily garner policy support from relevant government institutions, bilateral and multilateral donors, international financial institutions and NGOs as support for disadvantaged women is already on their agendas and programmes. The addition of modern energy provision to existing priorities requires horizontal and vertical communication among government agencies, NGOs, the private sector and all institutions and stakeholders concerned. The DoE is expected to act as a lead agency in facilitating dialogue among the various stakeholders and coordinating their activities towards the improved access of local communities, and disadvantaged women in particular, to modern energy services. This proposal does not require additional institutional and management staff.

ECONOMIC AND FINANCIAL

Institutions and management need to generate and justify additional financial resources to implement this proposal.

LEGAL FRAMEWORK

Eritrea has a powerful National Women's Association established by law with a mandate to fight for the interests of women. A simple example of the government's commitment to involving women in decision making at all levels is its declaration that at least 30 per cent of the number of parliamentarians at all levels (national and local) should be women. No additional legal framework is required to implement this recommendation.

HUMAN RESOURCE NEEDS AND TECHNICAL CAPABILITY

Most of the Eritrean women in the rural areas are illiterate and lead a subsistence life based on traditional agriculture. They have to be educated in the opportunities of new income-generating activities using modern energy services. The existing structure of the National Women's Association as well as government and donor institutions in the country can manage the implementation of this project.

Hypothesis 3: Prioritizing components for the promotion of RETs

Policy recommendations

- Strengthen the ERTC so that the tasks of resource assessment and training of RET technicians can be handled smoothly.

- Conduct sensitization and promotional efforts to popularize RETs among the public and the business community.
- Considering the present low income level of rural people and perceived high initial cost of RETs, focus on their use for income generation to stimulate strong intervention by financial institutions.

Strengthen the ERTC so that the tasks of renewable energy resource assessment and training of RET technicians can be handled smoothly.

Institutional and management

Quite an interesting exercise in restructuring the Ministry of Energy and Mines and its affiliated parastatal utilities, the EEA and the Eritrea Petroleum Corporation, took place in December 2001. The central mission, main tasks, goals and project implementation programmes to achieve them, and the restructuring of the Ministry Headquarters with its Departments, Divisions and Units – all this was discussed and formulated. The priority tasks of the Centre were to be assessment and development of renewable energy resources, including training RET technicians, and sensitization and promotion of RETs. Its serious problem is shortage of skilled manpower and the Ministry has been taking measures to solve this bottleneck; a new Director has been appointed and at least three engineers will be employed shortly. The prospects are that the institutional and management needs of the Centre will be well met.

Legal frameworks

Regulations and guidelines for the promotion of RETs are in place: no additional legal framework is required to execute this recommendation.

Financial and economic

The Energy Centre has been established at a high cost with the assistance of the government of Lower Saxony in Germany. It continues to depend on donated money for the time being but the long-term plan is that it will become financially self-sufficient through charging money for its services.

Human resource needs and technical capacity

We have seen that this is among the main current constraints in the Centre. Nearly half of its present workforce is either University in-service students or young people undergoing national service. It should not be difficult to retain some of the service students after they graduate. Nevertheless, there is already high competition with the private sector to employ young graduates from the University. The only way out is to make salaries competitive. The research and training facility is quite reasonable. Already two of its members are being trained at MSc level abroad: upon their return, ERTC's ability to provide services will be boosted.

Conduct sensitization and promotional efforts to popularize RETs among the public and the business community.

Institutional and management

During the December 2001 Ministry restructuring exercise as well as discussions at the stakeholder seminars conducted on 30/31 October and 29 November 2001, this proposal was among the priority recommendations put forward. The Divisions of Energy Management and Development Planning (directed by the principal investigator of this study) and the Energy Centre will take lead responsibility in conducting the sensitization and promotional efforts for RETs.

Legal Frameworks

No special legal issues envisaged here.

Financial and economic

Demands for financing are very limited and could easily be accommodated by government sources.

Human resource needs and technical capacity

Core staffs exist in the Department capable of coordinating these activities. Nevertheless, it is a multi-stakeholder activity including government agencies, private businesses and funding agencies – and many workshops, information releases and commercialization efforts have to be conducted to achieve the desired goals. The exercise, which is already gaining momentum, is quite feasible and mutually beneficial to policy makers, entrepreneurs and customers.

Considering the present low income level of rural people and perceived high initial cost of RETs, focus on their use for income generation to stimulate strong intervention by financial institutions.

Institutional and management

The current approach of the Ministry is that low-capacity RETs for domestic-level applications should be introduced and supported by the private sector, whereas larger systems, combinations of applications and installation contexts where no modern energy services currently exist should be supported by covering part of the initial capital costs through various means. In both cases bigger financing institutions and micro-financiers have a key role to play for the majority of rural communities, as their capacity to pay up-front costs is limited. The financiers want their money back with some interest and they require guarantees involving either collateral or group responsibility. It becomes much easier and convincing for the financiers if the beneficiaries use the RET systems for income generation. The credit departments of the banks and the micro-financing institutions are quite experienced and may not need additional institutional structure.

LEGAL FRAMEWORKS

No special legal issues are envisaged here.

FINANCIAL AND ECONOMIC

Income-generating activities have the capacity to pay for their investment needs, including energy.

HUMAN RESOURCE NEEDS AND TECHNICAL CAPACITY

The rural areas generally lack technical personnel to give installation, repair and maintenance service at the local level. As RET systems require relatively high-level skills and on-the-job training, private entrepreneurs, local governments and NGOs should work together with the Energy Centre to remove this avoidable barrier. Through recent workshops awareness to this effect is spreading and the importance of the Energy Centre is being appreciated.

Part VII Select Bibliography

ADB 1996. *Household Energy Consumption Pattern in Africa,* Abidjan: African Development Bank.

Dankelman, I. and Davidson, J. 1989. *Women and Environment in the Third World*. London: Earthscan Publications Ltd, in association with the International Union for the Conservation of Nature (IUCN).

DoE 1998. *Updating the Energy Database of 1995 for the Year 1998*. Asmara: Department of Energy.

—— 2000. *Energy Balance for 2000*, Asmara: Department of Energy.

Fisseha, Yacob 1996. *Micro, Small and Medium Enterprises (MSMEs). Research Conducted Under the Auspices of the Office of Macro Policy*, Eritrean Studies Association, USA.

Goys M., Weldegebriel Tareke and Luul Yehdego 1998. 'Eritrea – Socio-economic Study and Gender Impact Assessment on a Rural Electrification Project in the Dibaruwa and Aditekelezan Areas'. Final report in a study commissioned by SIDA.

Habtetsion, S. (ed.) 2001. 'Occasional Paper No 9, Energy for Rural Development in Eritrea. Proceedings of a National Policy Seminar'. Nairobi: AFREPREN/FWD.

Habtetsion, S. 2003. *Country Data Validation: Eritrea*. Nairobi: AFREPREN/ FWD.

Habtetsion, Semere and Tsighe, Zemenfes 2001. 'Renewables and Energy for Rural Development: Second Draft Report of Short-Term Study'. Asmara: African Energy Policy Research Network (AFREPREN).

Habtetsion, Semere, Tsighe, Zemenfes and Andebrehan, Amanuel 2002. *Proceedings of the Seminar on Sustainable Energy Development in Eritrea*. Asmara.

Hall, D.O. and Mao, Y.S. (eds), 1994. *Biomass Energy and Coal in Africa*, London: Zed Books in association with AFREPREN.

IEA 1999. *Energy Balances of Non-OECD Countries, 1997–98*. Paris: Organization for Economic Cooperation and Development/International Energy Agency.

IEA 2002. *Energy Balances of Non-OECD Countries, 1999–2000*. Paris: Organization for Economic Cooperation and Development/International Energy Agency.

Hankins M. 2001. *PV Solar Home System Market Study for Eritrea*. Nairobi: International Governmental Authority for Development (IGAD) Regional Household Energy Project, Energy Alternatives Africa.

Kgathi, D. L., Hall, D. O., Hategeka, A., Mlotshwa, C. V. and Sekhwela, M. B. M. (eds) 1997. *Biomass Energy Policy in Africa: Selected Case Studies,* London: Zed Books in association with AFREPREN and Stockholm Environment Institute.

Lahmeyer International and DoE 1997. *Strengthening the Department of Energy Project: Final Report*. Asmara: Department of Energy.

—— 1999. *Feasibility Study for Wind Energy Applications in Southern Coastal areas of Eritrea: Final Report,* Asmara: Department of Energy.

Ministry of Energy and Mines/EEA 2001. *Proposed Capital Budget Year 2002, and Planned 2003–2004*. Asmara: Ministry of Energy and Mines/ Eritrea Electric Authority.

MTI 1998. *Report on Manufacturing Enterprises*. Asmara: Ministry of Trade and Industry.

Ossawa, B. 1999. *PV Commercialisation: the Kenyan Experience*. Nairobi: Energy Alternatives Africa.

UNDP 2000. *Sustainable Energy Strategies: Material for Decision Makers*. New York: United Nations Development Programme.

Part VII Appendices

VIIA.1 Information on solar systems

Open-ended Questionnaire to Private Dealers:

Full Name ______________________________

Address ______________________________

PO Box ______________________________

Street ______________________________

Tel. ______________________________

1. How long is it since you started importing and selling solar systems?
______________________________ years

2. Up to now, how many solar systems have you sold?
   i) PV systems ______________________________
   ii) Solar heaters ______________________________
   iii) Solar cookers ______________________________

3. What is the average cost of:
   i) PV systems/Wp ______________________________
   ii) Solar heaters ______________________________
   iii) Solar cookers ______________________________

4. What is the power of the PV systems you sell? ____________________

5. Who are your main customers? ____________________

6. For what purposes were the PV systems mainly sold/bought?____________________
____

7. Who installs the solar systems that you sell?

8. How much does it cost to install i) PV systems ____________________
ii) Solar heaters ____________________

9. Do you give maintenance services? ____________________

10. If you do not give any maintenance services, who provides maintenance and repair services to the solar systems you sell? ____________________

11. If you provide maintenance and repair services, how much do you charge?
____

12. If you provide maintenance and repair services, where did your workers get the training, and for how long? ______________________________

13. What is the rate of taxation for solar systems? ____________________

14. How do you evaluate the quality of the solar systems you import? Do you consult the Eritrean Standards Institute? ____________________

Questionnaire to Ministries and NGOs

1. Are there any solar systems installed by your institution? ____________________

2. If there are, how many of them were donated and how many were purchased?
   i) Donated ____________________ ii) Purchased ____________________

3. What are the solar systems used for? ____________________

4. Who installed the solar systems? ____________________

5. Who does the maintenance and repair work for the solar systems installed?
____

6. At this time, how many of the solar systems installed are still operational and how many of them are out of order? ____________________

7. How much does it cost to run one solar system? ____________________

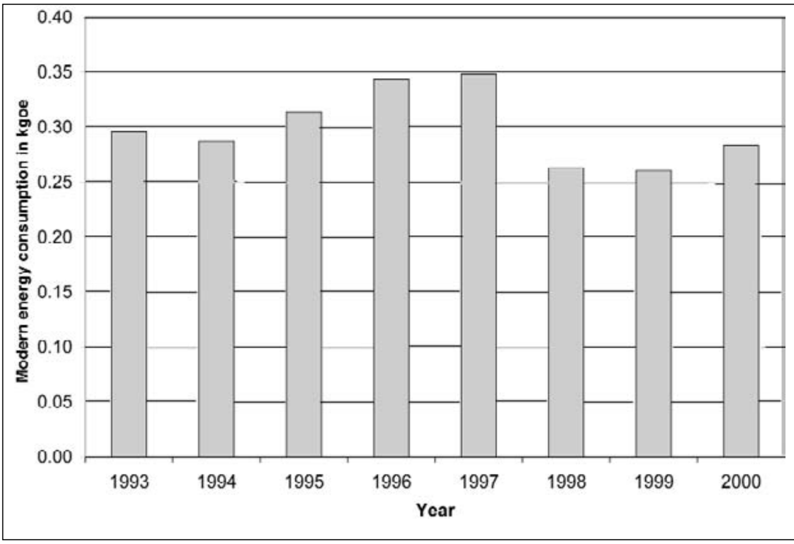
VIIA.2 Kenyan experience in financing PV

Type	Examples of agencies	Description	Channel for funds	Advantages	Disadvantages
Subsidized	Donors	•Direct financing •Subsidies	• NGOs •Community-based organizations • Government	•Access to international funds, •Flexible lending •Quality systems installed	•Reliance on external funds •Donor dependence even for spare parts
Pre-payment	•Private companies •Savings and credit coopera-tives	•Down-payment required before installation •Payments in agreed number of instalments	Direct	System is paid for once and for all	High initial capital cost
Fee for service	Energy service company (ESCO) like Shell Renewables (South Africa)	• ESCO installs and services • End users pay for the energy used on a regular basis	Direct	•ESCO provides complete service •Customers do not bear initial costs of system •Pays for electricity as used	•ESCO owns the system •Can have high running cost •Wide services from a single organization
Commercial credit	Commercial banks	Direct finance	Direct	•Have developed lending and savings functions •Can have a wide geographical spread •Have access to international finance	•Favour large-scale borrowers •High transaction costs and bureaucracy •Requires collateral •High interest rates
Wholesale lending	Cooperative banks	Loans to organized groups	Savings and credit coopera-tive societies, SACCOS	•Low management costs •No collateral •Enables easy access	Users pay interest charges
Micro-finance	Rural enterprises	Lending to groups who guarantee each other	Direct to new groups	Members able to pay in instalments, no collateral	Users pay interest charges
Hire purchase	Hire purchase companies	Repayments are on a 'check-off' basis	•Direct •Through employers	•Companies able to resource own financing •2 year repayment period	•Very high interest rates (40%) •Questionable quality

VIIA.3 Selected trend data: Eritrea

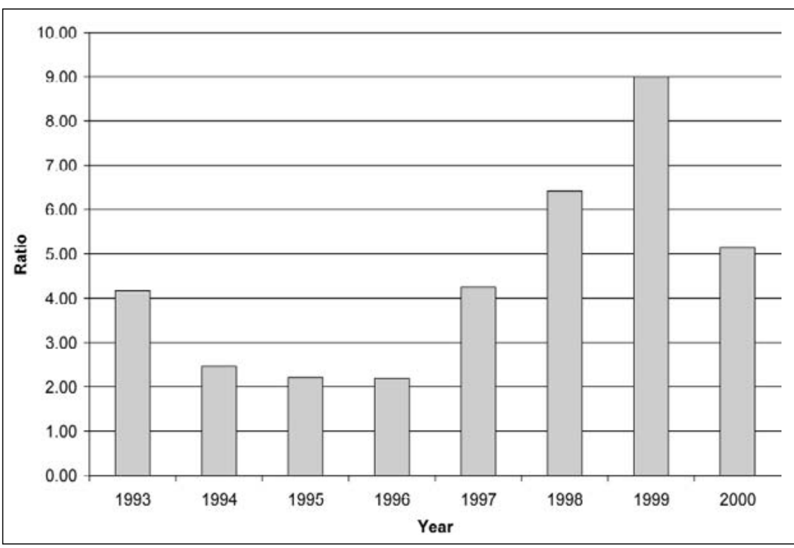
Year	1993	1994	1995	1996	1997	1998	1999	2000	2001
Population (million)	3.40	3.50	3.60	3.70	3.80	3.90	3.99	4.11	4.23
Population growth rate (%)	3.0	2.9	2.9	2.8	2.7	2.6	2.3	2.5	2.5
Rural population (millions)	2.8	2.9	3.0	3.1	3.1	3.1	3.1	3.0	3.3
GDP (US$ millions)	508	558	574	612	661	686	692	635	612
GNP *per capita* (US$)	130	180	180	200	230	200	200	170	160
Total modern energy consumption ('000 toe)	150	160	180	210	230	180	180	180	
Modern energy consumption *per capita* (kgoe)	44.1	45.7	50.0	56.8	60.5	46.2	46.2	43.8	
Total energy production ('000 toe)	710	710	730	540	560	450	470	510	475
National debt (US$ millions)	31	39	46	76	149	273	312	410	
Merchandise exports, f.o.b (US$ millions)	36	65	81	95	54	28	20	35	20
Installed capacity (MW)	88	100	103	92	92	92	98		
Electricity generation (GWh)	151	161	172	193	213	194	204	210	224
System losses (%)	21 1	6	16	15	16	17	19	19	17
Rural population with access to safe water (%)	7.0	7.0	8.0	9.6	9.6	9.6	9.7	9.7	9.8
Total electricity consumption (GWh)	–	–	–	–	160.0	158.4	167.7	173.3	207.1
Electricity consumption *per capita* (kWh)	–	–	–	–	42.1	40.6	42.0	42.2	49.0

Sources: Habtetsion, 2003; AFREPREN, 2003; EIU, 2003; World Bank, 2002 World Bank, 2003; IEA, 2002.



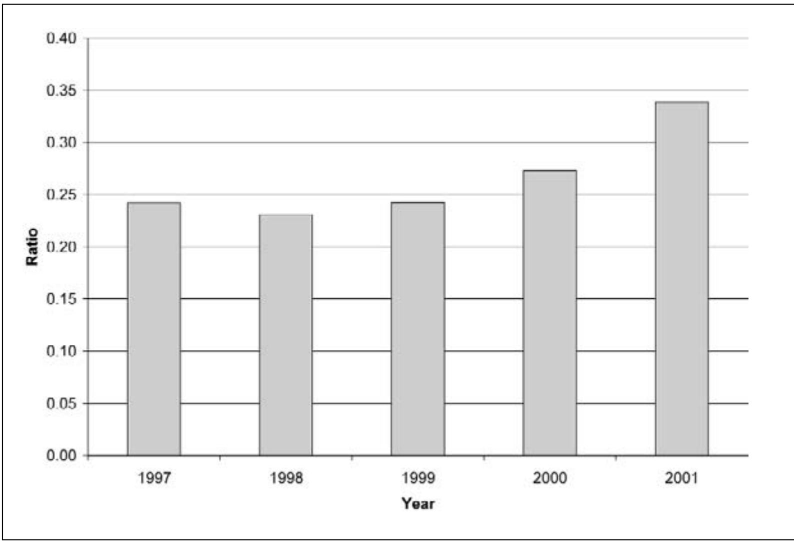
VIIA.3.1 Total modern energy consumption (Kgoe) vs GDP (US$)
(Modern energy consumed to produce US$1 of GDP)

Source: AFREPREN, 2003



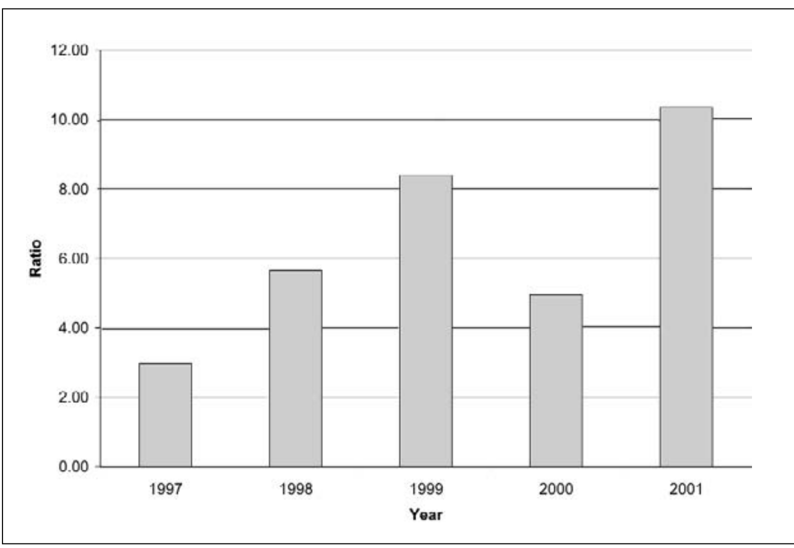
VIIA.3.2 Total modern energy consumption (Kgoe) vs merchandise export (US$)
(Modern energy consumption to produce per US$1 of merchandise export)

Source: AFREPREN, 2003



VIIA.3.3 Total electricity consumption (kWh) vs GDP (US$)
(Electricity consumption to generate US$1 of GDP)

Source: AFREPREN, 2003



VIIA.3.4 Total electricity consumption (kWh) vs merchandise export (US$)
(Electricity consumption to produce US$1 of merchandise export)

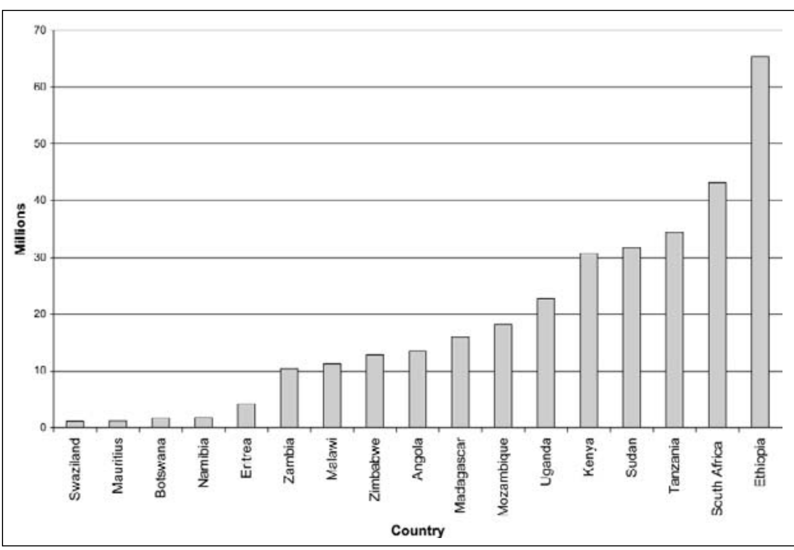
Source: AFREPREN, 2003

Part VIII

DATA AND STATISTICS

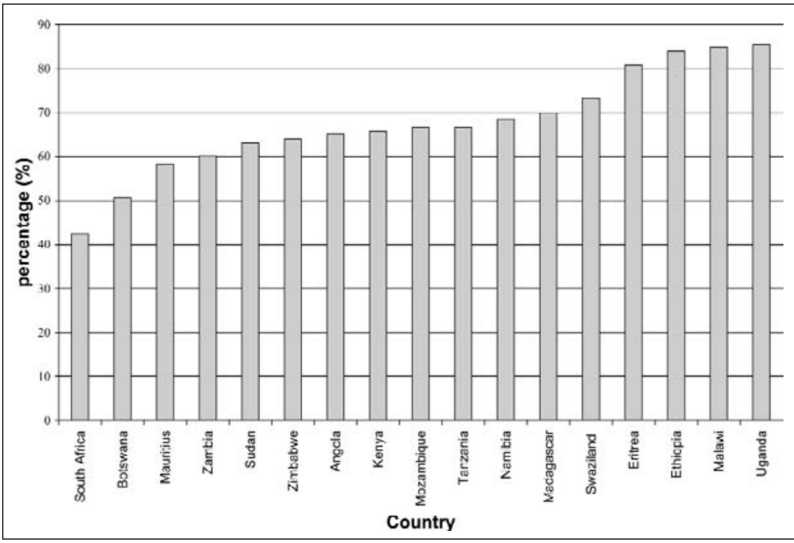
Compiled by
Stephen Karekezi, Waeni Kithyoma,
Ezekiel Manyara and Geoffrey Muthee
AFREPREN/FWD Secretariat

VIII.1 Basic socio-economic indicators



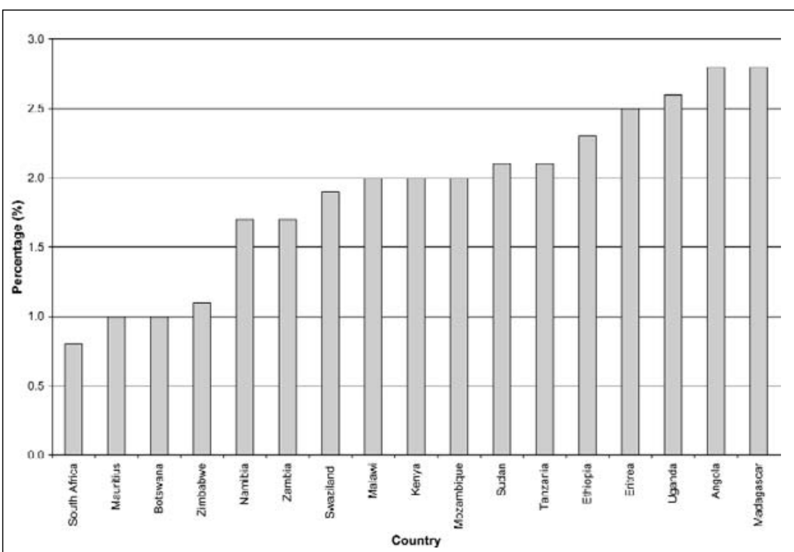
VIII.1.1 Population (million), 2001

Sources: World Bank, 2003a, AFREPREN, 2003



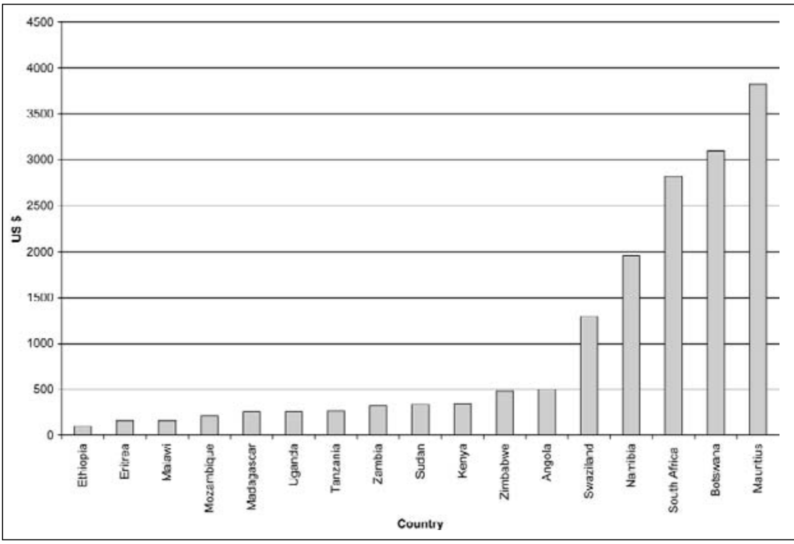
VIII.1.2 Rural population (%), 2001

Sources: World Bank, 2003a



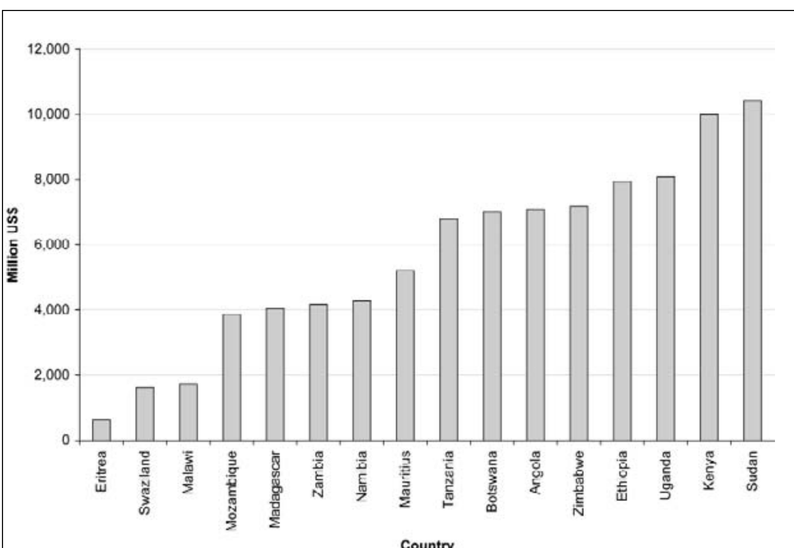
VIII.1.3 National population growth rate (%), 2001

Source: World Bank, 2003a



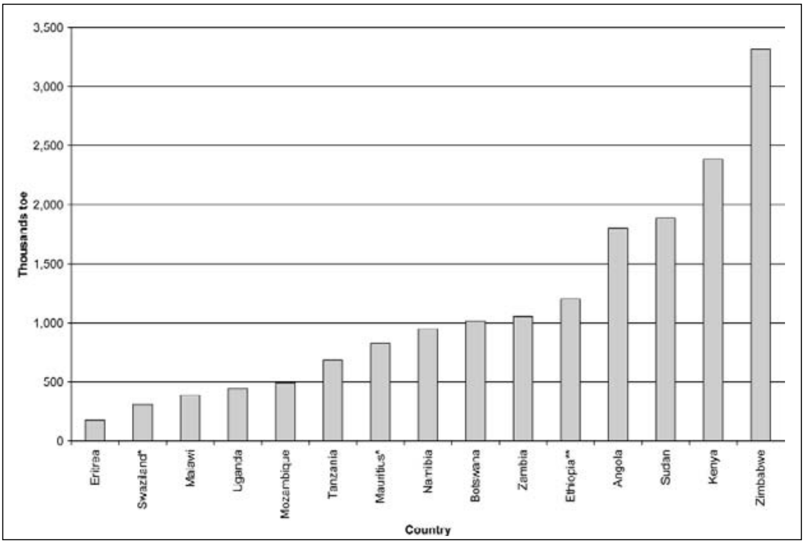
VIII.1.4 GNP *per capita* (US$), 2001

Source: World Bank, 2003a



VIII.1.5 GDP (million US$) 2001

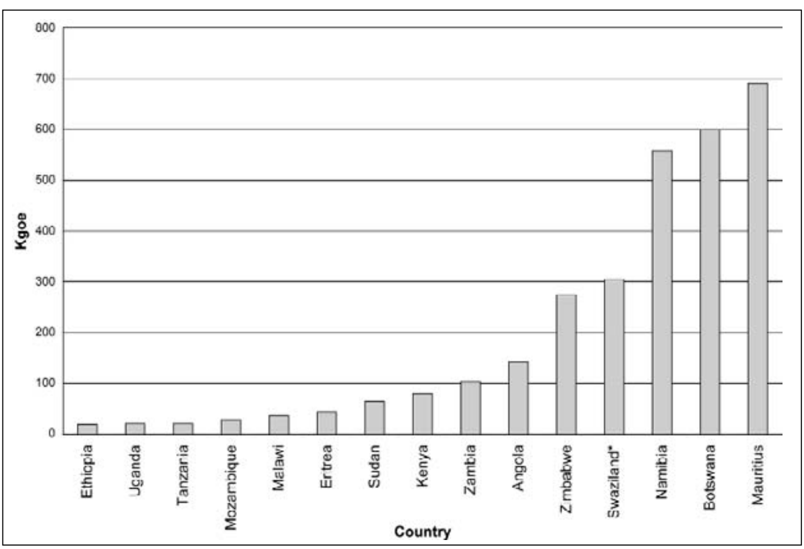
Source: World Bank, 2003a



VIII.1.6 Modern energy consumption ('000 toe), 2000

* 1999 data; ** 2001 data.

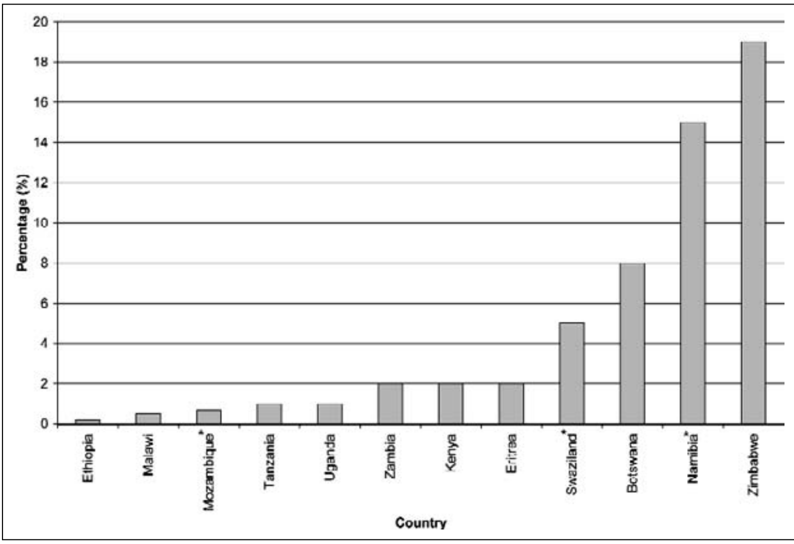
Sources: EIU, 2000; Mogotsi, 2000; Teferra, 2002; Nyoike, 2001; World Bank, 2001



VIII.1.7 Modern energy consumption *per capita* (kgoe), 2000

* 1999 data; ** 2001 data.

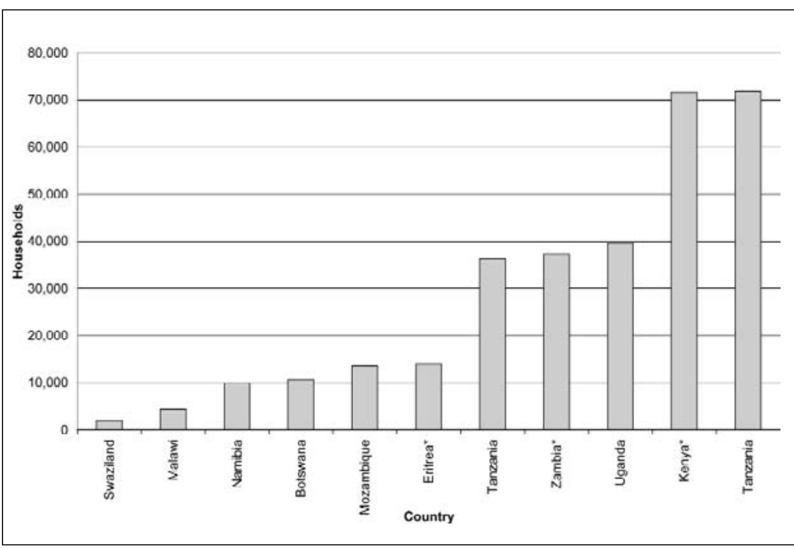
Sources: EIU, 2001; Mogotsi, 2000; Teferra, 2002; Nyike, 2001; World Bank, 2001; AFREPREN, 2003



VIII.1.8 Rural electrification levels (%), 2001

*2000 data.

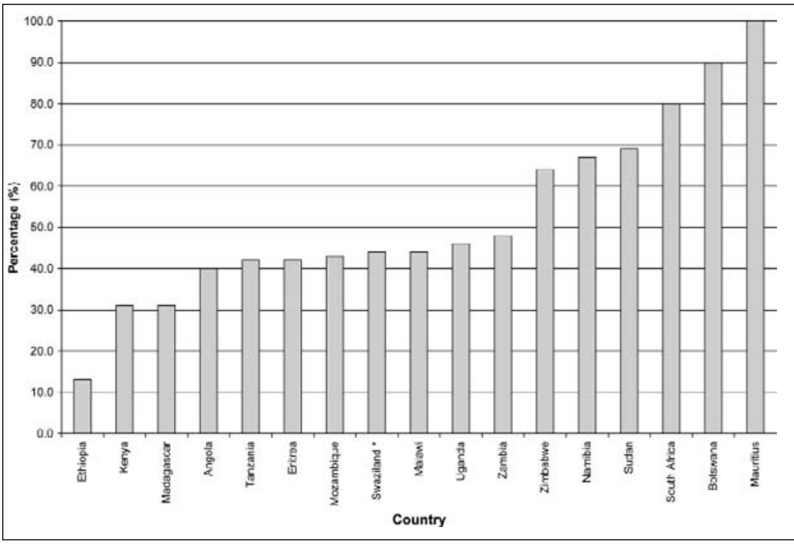
Sources: AFREPREN, 2002; Habtetsion, 2002; Katyega, 2003; Marandu, 2002; Matinga, 2003; Kyokutamba, 2002; Mbaiwa, 2003; Ditlhale, 2003; Mapako, 2003; Dube, 2003; Kayo, 2002; AFREPREN, 2003



VIII.1.9 Number of rural households connected to electricity, 1996

* 2000 data.

Sources: AFREPREN, 2002; Habtetsion, 2002; Katyega, 2003; Marandu, 2002; Matinga, 2003; Kyokutamba, 2002; Mbaiwa, 2003; Ditlhale, 2003; Mapako, 2003; Dube, 2003; Kayo, 2002; AFREPREN, 2003



VIII.1.10 Rural population with access to safe water (%), 2000

Source: World Bank, 2003b

VIII.2 Renewable energy technology resource potential

	Average wind speeds (m/s)	Average solar insolation (kWh/m^2)	Vegetation cover ('000 hectares), 2000	Deforestation rate ('000ha/year) 1990–2000	Afforestation rate ('000 ha/year)
Angola			69,800	124.2	3
Botswana	3.0	6.1	12,400	118.4	
Eritrea	5.5	5.5	1,600	5.4	
Ethiopia	2.9	5.3	4,600	40.3	10
Kenya	3.0	6.0	17,100	93.1	10
Madagascar			11,700	117.4	12
Malawi			2,600	70.7	1
Mauritius	8.0		16,000	0.1	
Mozambique	2.6	5.0	30,600	63.7	4
Namibia	8.0		8,000	73.4	
South Africa	8.5	5.5	8,900	8.0	63
Sudan	3.0	6.1	61,600	958.9	13
Swaziland		5.0	500		6
Tanzania	3.0	8.0	38,800	91.3	9
Uganda	4.0	4.7	4,200	91.3	2
Zambia	2.5	4.0	31,200	850.9	2
Zimbabwe	3.5	5.7	19,000	319.9	4

Sources: Chandi, 2000; Habtetsion, 2003; Mogotsi, 2000; World Bank, 2003b; Karekezi, *et al*., 2002

VIII.3 Renewable energy technology dissemination data

	Improved household stoves disseminated	Biogas units disseminated	Estimated PV units disseminated	Estimated PV installed capacity (kwp)	Wind pumps disseminated
Angola				10	
Botswana	1,500	215	5,724	1,500	200
Eritrea	50,000	5	2,000	400	10
Ethiopia	45,000	1,000	5,000	1,200	200
Kenya	1,450,000	1,100	120,000	3,600	360
Madagascar					
Malawi	3,700		900	40	
Mauritius				8	
Mozambique				100	50
Namibia		10		446	30,000
South Africa	1,250,000		150,000	11,000	300,000
Sudan	28,000				12
Swaziland			1,000	50	
Tanzania	54,000	1,000		300	58
Uganda	52,000	10	3,000	152	13
Zambia	4,082	18	5,000	400	100
Zimbabwe	20,880	200	84,468	1,689	650

Sources: Karekezi and Ranja, 1997; Habtetsion, 2003; Karekezi *et al*., 2002; World Bank, 2001; Habtetsion, 2001; Wolde-Ghiorgis, 2003; Mbuthia, 2003; Mwihava, 2003; Karekezi, 2002; Chandi, 2002; Chandi, 2001; Karekezi, 1995; Wolde-Ghiorgis, 2002

VIII.4 Renewable energy production and consumption

	Bagasse production ('000 tonnes) (1997–2000)	Estimated cogeneration potential (GWh)	Biomass as a % of total energy consumption
Angola	65		67.1
Botswana	250		31.2
Eritrea			94.9
Ethiopia	410	150.33	94.0
Kenya	1,800	530.33	68.0
Madagascar	313	114.77	91.0
Malawi	575	250.80	93.0
Mauritius	1,800	586.67	
Mozambique	165		62.2
Namibia			61.1
South Africa	13,953	2,720.00	60.0
Sudan	1,755	643.50	84.0
Swaziland	1,092		
Tanzania	429	100.83	90.0
Uganda	615	173.43	92.8
Zambia	489		78.6
Zimbabwe	1,476	686.40	66.1

Sources: Karekezi, *et al*., 2002; World Bank, 2003; Karekezi and Ranja, 1997; UN, 1994; UNDP, 2000

Part VIII References

AFREPREN/FWD 2003. *Africa Energy Data Handbook*. Nairobi: AFREPREN/FWD.
Banda, G. 2003. *Country Data Validation: South Africa*. Nairobi: AFREPREN/FWD.
Chandi, L. 2000. *Country Data Validation: Zambia*. Nairobi: AFREPREN/FWD.
—— 2001.*Country Data Validation: Zambia*. Nairobi: AFREPREN/FWD.
—— 2002. *Country Data Validation: Zimbabwe*. Nairobi: AFREPREN/FWD.
Ditlhale, N. 2003. *Country Data Validation: Botswana*. Nairobi: AFREPREN/FWD.
Dube, I. 2002. *Country Data Validation: Zimbabwe*. Nairobi: AFREPREN/FWD.
—— 2003. *Country Data Validation: Zimbabwe*. Nairobi: AFREPREN/FWD.
EIU 2001a. *Country Report: Zimbabwe*. London: Economist Intelligence Unit.
—— 2001b. *Country Profile: Namibia, Swaziland*. London: Economist Intelligence Unit.
—— 2002. *Country Profile: Mozambique*. London: Economist Intelligence Unit.
—— 2003a. *Country Report: Zimbabwe*. London: Economist Intelligence Unit.
—— 2003b. *Country Report: Zambia*. London: Economist Intelligence Unit.
—— 2003c. *Country Reports: Botswana, Lesotho*. London: Economist Intelligence Unit.
—— 2003d. *Country Reports: Ethiopia Eritrea, Djibouti, Somalia*. London: Economist Intelligence Unit.
Habtetsion, Semere 2000. *Country Data Validation: Eritrea*. Nairobi: AFREPREN/ FWD.
—— 2002. *Country Data Validation: Eritrea*. Nairobi: AFREPREN/ FWD.
—— 2003. *Country Data Validation: Eritrea*. Nairobi: AFREPREN/FWD.
IEA 2002. *Energy Statistics and Balances of Non-OECD Countries, 1990–2000*. Paris: International Energy Agency.
Kalumiana, O. 2002. *Country Data Validation: Zambia*. Nairobi: AFREPREN/ FWD.
—— 2003. *Country Data Validation: Zambia*. Nairobi: AFREPREN/FWD.
Karekezi, S. 1995. *Solar Energy Development in Sub-Saharan Africa: Status and Prospects*.
Karekezi, S. and Ranja, T. 1997. *Renewable Energy Technologies in Africa*. London: Zed Books.
Karekezi, S., Mapako, M. and Teferra, M. (eds) 2002. *Energy Policy – Africa: Improving Modern Energy Services for the Poor*. Oxford: Elsevier Science Limited.
Katyega, M. 2003. *Country Data Validation: Tanzania*. Nairobi: AFREPREN/FWD.
Kayo, D. 2002. *Country Data Validation: Zimbabwe*. Nairobi: AFREPREN/FWD.
Kebede, B. 2003. *Country Data Validation: Ethiopia*. Nairobi: AFREPREN/FWD.
Kyokutamba, J. 2003. *Country Data Validation: Uganda*. Nairobi: AFREPREN/FWD.
Mapako, M. 2002. *Country Data Validation: Zimbabwe*. Nairobi: AFREPREN/ FWD.
—— 2003. *Country Data Validation: Zimbabwe*. Nairobi: AFREPREN/ FWD.
Marandu, E. 2002. *Country Data Validation: Tanzania*. Nairobi: AFREPREN/FWD.
Matinga, M. 2003. *Country Data Validation: Malawi*. Nairobi: AFREPREN/FWD.
Mbaiwa, J. 2001. *Country Data Validation: Botswana*. Nairobi: AFREPREN/FWD.
—— 2002. *Country Data Validation: Botswana*. Nairobi: AFREPREN/FWD.
—— 2003. *Country Data Validation: Botswana*. Nairobi: AFREPREN/FWD.
Mbewe, A. 2003. *Country Data Validation. Zambia*. Nairobi: AFREPREN/FWD.
Mbuthi, P. 2003. 'Renewable Energy in Kenya'. Presentation at the HBF/AFREPREN RETs Brainstorming Workshop, Nairobi, 23–24 May.
Mogotsi, B. 2000. *Country Data Validation:* Botswana. Nairobi: AFREPREN/FWD.
Mwihava, N. 2003. 'Renewable Energy Technologies: the Case of Tanzania'. Presentation at the HBF/AFREPREN RETs Brainstorming Workshop, Nairobi, 23–24 May.
Nyoike, P. 2001. *Country Data Validation:* Kenya. Nairobi: AFREPREN/FWD.
Teferra, M. 2002. *Country Data Validation:* Ethiopia. Nairobi: AFREPREN/FWD.
—— 2003. *Country Data Validation: Ethiopia*. AFREPREN/FWD,
Teferra, M. and Karekezi, S. (eds) 2002. *Capacity Building for a Reforming African Power Sector*. London: Zed Books.
UN 1994. *Energy Statistic Yearbook – 1994*. New York: United Nations.
UNDP 2000. *Human Development Report 2000*. New York: United Nations Development Programme.
Wolde-Ghiorgis, W. 2002. *Country Data Validation: Ethiopia*. Nairobi: AFREPREN/ FWD.
—— 2003. *Country Data Validation: Ethiopia*. Nairobi: AFREPREN/ FWD.
World Bank 2000. *World Development Report 1999/2000*. Washington, DC: World Bank.
—— 2001. *World Development Report 2000/2001*. Washington, DC: World Bank.
—— 2002a. *World Development Indicators 2002*. Washington, DC: World Bank.
—— 2002b. *African Development Indicators 2002*. Washington, DC: World Bank.
—— 2003a. *African Development Indicators 2003*. Washington, DC: World Bank.
—— 2003b. *World Development Indicators* 2003. Washington, DC: World Bank.
—— 2003c. *African Statistics Database*. www.worldbank.org.

This page intentionally left blank

Index