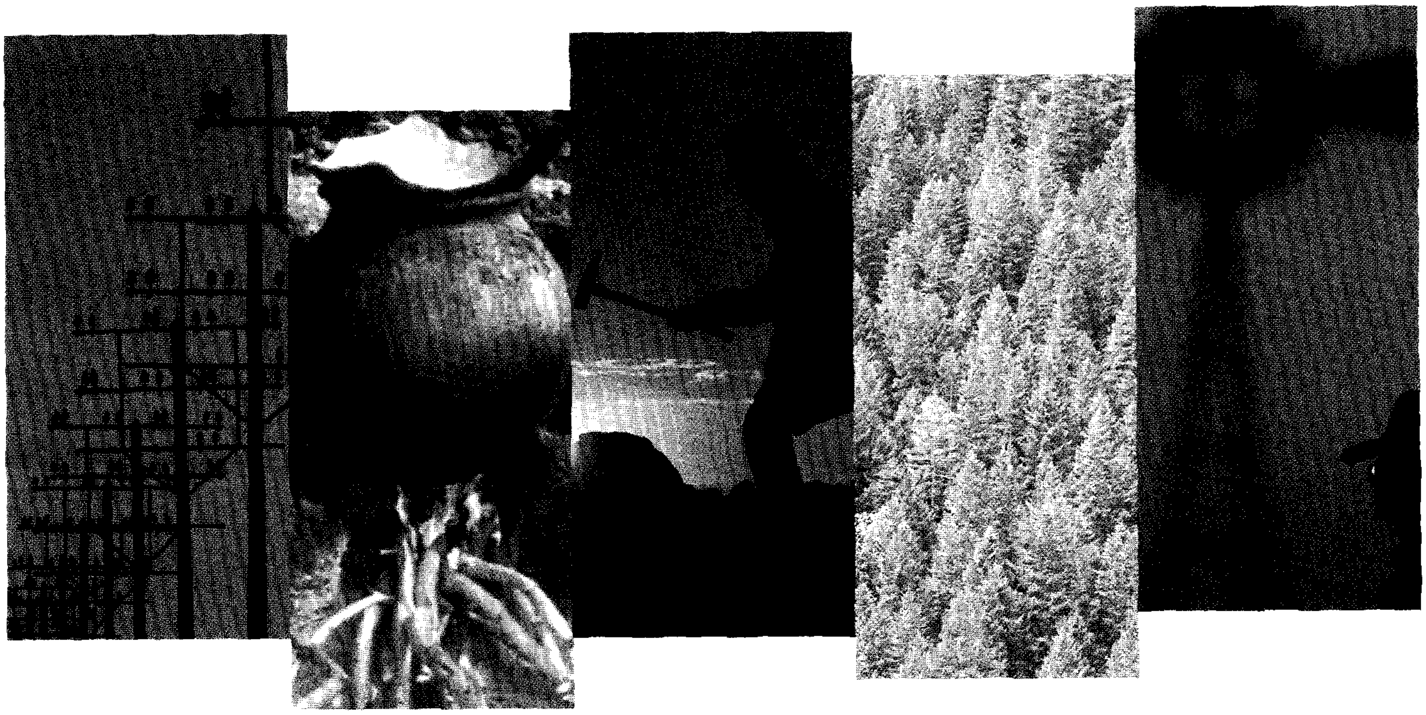
Zimbabwe

Rural Electrification Study

ESM228



Energy

Sector

Management

Assistance

Programme

ESMAP

Report 228/00

March 2000

JOINT UNDP / WORLD BANK
ENERGY SECTOR MANAGEMENT ASSISTANCE PROGRAMME (ESMAP)

PURPOSE

The Joint UNDP/World Bank Energy Sector Management Assistance Programme (ESMAP) is a special global technical assistance program run as part of the World Bank's Energy, Mining and Telecommunications Department. ESMAP provides advice to governments on sustainable energy development. Established with the support of UNDP and bilateral official donors in 1983, it focuses on the role of energy in the development process with the objective of contributing to poverty alleviation, improving living conditions and preserving the environment in developing countries and transition economies. ESMAP centers its interventions on three priority areas: sector reform and restructuring; access to modern energy for the poorest; and promotion of sustainable energy practices.

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Zimbabwe

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ESMAP Reports are published to communicate the results of the ESMAP's work to the development community with the least possible delay. The typescript of the paper therefore has not been prepared in accordance with the procedures appropriate to formal documents. Some sources cited in this paper may be informal documents that are not readily available.

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Preface

This report is based on the findings of a series of World Bank missions to Zimbabwe from September 1997 through September 1998 to assist the Department of Energy (DOE) of the Ministry of Transport and Energy in analyzing rural electrification issues. The mission team consisted of Messrs. Robert van der Plas (Task Manager) and Mike Bess (Energy Economist). The team worked directly and intensely with the following DOE staff: Johannes Chigwada (Assistant Director of Research and Development), J.M. Mashamba, Ralph Tirivanhu, Tendai Neshamba, C. Mashange, Ms. Dangeni and Ms. Tahwa.

A substantial part of this work is based on and supported by the Zimbabwe Electricity Supply Authority (ZESA) national energy use survey that paralleled this strategy development from late 1997 to mid-1998. Not only did ZESA provide access to its findings, but it also adapted its survey questionnaires, methodology and geographic coverage to permit both extensive surveying of rural areas and a thorough follow-up covering households and establishments using photovoltaic solar and diesel and petrol/gasoline generating sets captured during the overall survey.

The DOE team drew on a variety of sources, from published materials for the Department itself to primary data gathered through the ZESA surveys, and their own field surveys in 1998. The team visited all provinces and most districts in Zimbabwe from July to September 1998 to conduct extensive field interviews at farms, ranches, business establishments, government agencies and a range of rural institutions. National trade and industry associations and numerous private and public enterprises were interviewed and provided extensive information for the strategy development. All in all, more than 200 private, public and non-governmental institutions and enterprises participated in the study.

Although the original intention was to prepare a rural electrification strategy, during a peer review meeting the energy team working on Zimbabwe requested that the current study be limited to data collection and analysis. A follow-up activity will be carried out under the Africa Rural and Renewable Energy Initiative (AFRREI) to develop and finance the implementation of such strategy.

Acknowledgments

The mission team would like to thank especially Mr. P. M. Kodzwa, Permanent Secretary to the Ministry of Transport and Energy, who provided extensive guidance and support in the design and development of this study. The team would also like to acknowledge the strong support provided by the Director of Energy (DOE), Mr. Mzezewa. Additionally, the Zimbabwe Electricity Supply Authority (ZESA) provided extensive support, guidance, information and review to this work. In particular both Mr. Alex Makomva, ZESA Marketing Manager, and Mr. Ben Rafemoyo participated actively in many aspects of this study, from reviewing the rural electrification results to providing support for the follow-up rural electrification survey in mid-1998.

In addition, Mr. Regis Makomva of Quest Research, and his team of specialists, supervisors and field enumerators carried out the ZESA energy use survey and follow-ups with extraordinary thoroughness, and responded to queries and requests for clarification beyond the scope of their initial contracts. The entire Renewable Energy Team, led by Mr. Johannes Chigwada, DOE Assistant Director, also worked overtime, spending considerable time in the field to provide much of the data and information in this study.

Finally, the team wishes to acknowledge the active support and participation of hundreds of individuals from the public sector, particularly provincial and district authorities, who gave time and information openly. Dozens of managing directors and senior executives of private and public sector companies also gave time and information to assist in this survey. Various representatives of non-governmental organizations also provided considerable support and information to the development of this study. Their names appear in the list of contacts in Annex 4 and, wherever possible, are cited in the text of this study.

Acronyms and Abbreviations

AFC	Agricultural Finance Corporation
Agritex	Department of Agricultural Technical and Extension Services (under the Ministry of Lands, Agriculture and Water Development)
ARDA	Agricultural and Rural Development Authority
ARDC	Association of Rural District Councils
BAT	British American Tobacco Company
BUN	Biomass Users Network (Zimbabwean NGO)
CAMARTEC	Center for Agricultural Mechanization and Rural Technology (Arusha, Tanzania)
CDC	Commonwealth Development Corporation (UK)
CPI	Consumer Price Index
CSO	Central Statistical Office
CZI	Confederation of Zimbabwe Industries
DAO	District Agricultural Officer
dc	direct current
DFO	District Forestry Officers
DNR	Department of Natural Resources (under Ministry of Environment and Tourism)
DWR	Department of Water Resources
DO	District Officer
DOE	Department of Energy (Ministry of Transport and Energy)
EC	European Commission
ESMAP	Energy Sector Management and Assistance Programme (UNDP/World Bank)
EU	European Union
FAO	Food and Agriculture Organization
FC	Forestry Commission (under Ministry of Environment and Tourism)
FINESSE	Financing Energy Services for Small Scale Energy-Users
FRC	Forest Research Center
gdp	gross domestic product
GEF	Global Environment Facility
GTZ	Gesellschaft für Zusammenarbeit (German Co-operative Development Agency)
HVE	Hippo Valley Estates
IBRD	International Bank for Reconstruction and Development (World Bank)
IDA	International Development Agency (World Bank Group)
IEA	International Energy Agency
IPP	independent power producer

Acronyms and Abbreviations (cont'd)

ITDG	Intermediate Technology Development Group (UK)
lpg	liquefied petroleum gas (propane)
MET	Ministry of Environment and Tourism
MEWRD	Ministry of Energy and Water Resources and Development
MOE	Ministry of Education
MOM	Ministry of Mines
MTE	Ministry of Transport and Energy
NEPC	National Economic Planning Commission
NGO	non-governmental organization
NOCZIM	National Oil Company of Zimbabwe
paraffin	(illuminating paraffin) kerosene (a light distillate petroleum product)
petrol	gasoline (a light distillate petroleum product, benzene)
RDC	Rural Development Council
RREF	Rural and Renewable Energy Fund
SADC	Southern Africa Development Conference
SEIAZ	Solar Energy Industries Association of Zimbabwe
SME	small and medium enterprise
TC	Timber Council
TPF	Timber Producers Federation
TRB	Tobacco Research Board
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
USAID	United States Agency for International Development
VIDCO	Village Development Committee
ZERO	Zimbabwean Energy Research Organization (national and regional NGO)
ZESA	Zimbabwe Electricity Supply Authority
ZTA	Zimbabwe Tobacco Association
ZWB	Zimbabwe Women's Bureau

Units of Measure

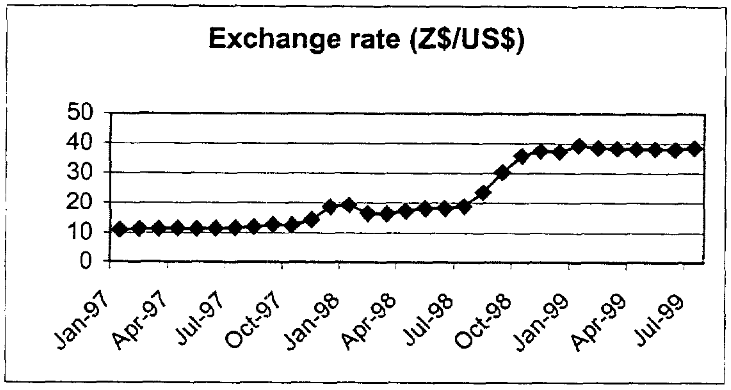
A	ampere
ac	alternating current
g (or gm)	gram
GJ	gigajoule (1,000 million joules = 10^9 joules)
GW	gigawatt (1,000 million watts = 10^9 watts)
GWh	gigawatt-hour (= 10^9 watt hours)
J	joule (amount of energy required to move 9.81 kg one meter)
kcal	kilocalorie (1,000 calories)
kg	kilogram (1,000 grams)
km	kilometer (1,000 meters)
kVA	kilovolt-amperes
kW	kilowatt (1,000 watts)
kWh	kilowatt-hour (1,000 watt-hours)
l	liter
m	meter
m^3	cubic meter
MJ	megajoule (1 million joules = 10^6 joules)
MT	metric ton (1,000 kg)
MW	megawatt (1 million watts = 10^6 watts)
MWh	megawatt-hour (= 10^6 watt-hours)
TJ	terajoule (one million megajoules)
V	volt
Vac	volt ac
1 cord of wood	= 0.35 tons (average measure in Zimbabwe)
$1m^3$ stacked	= 0.7 m^3 solid wood
$1m^3$ solid	= 600 kg (0.6 metric ton)
$1m^3$ stacked	= 420 kg (0.42 metric ton)

Specific Zimbabwe Fuelwood Measures
(based on current National Biomass Energy Strategy update,
November and December 1998)

pick-up load	= 900 kg
scotch cart	= 400 kg
wheelbarrow load	= 45 kg
head load/bicycle load	= 28 kg
cord (1x1x1m)	= 350 kg
large bundle of logs	= 10–15 kg
small bundle of logs	= 3–5 kg

Currency Equivalents

US$1 = Z$39 (Zimbabwe dollars, Feb. 2000)



Fuel Energy Values

(GJ/ton except where specified)

bagasse	7.4
charcoal	30
crop residues	15
diesel oil	40.7
dung	12
electricity	3.61 MWh
ethanol	37.7
fuelwood	16
gasoline/petrol	39.9
lpg	40.7
paraffin/kerosene	41.0
TOE (ton of oil equivalent)	41.87
ton of wood equivalent	16

Coal and Coke (GJ/ton)

Wankie HPS coal	25
Wankie WC coal	30
Sengwa coal	27
RSA bituminous coal	26
Swazi anthracite coal	31

Executive Summary

This report originates from a request from the Government of Zimbabwe to the World Bank to help define elements for a long-term strategy for rural energy and electrification. This document is a result of intensive work on the part of the Ministry of Transport and Energy's (MTE) Department of Energy (DOE) and the Zimbabwe Electricity Supply Authority (ZESA) to collect information and analyze rural electrification issues. A major source of information and data for this study was the dedicated survey on energy use contracted by ZESA for some 6,000 respondents in urban and rural Zimbabwe. In addition, more than 200 user interviews (non-household) were conducted in all provinces in Zimbabwe in a series of field visits carried out by the DOE between June and September 1998. Finally, major suppliers of energy, energy services and energy equipment were interviewed during the course of the work. All major institutions, non-governmental organizations (NGOs) and companies involved in rural energy in Zimbabwe were involved.

Although considerable information was obtained for all sources of rural energy (including biomass), the current study focuses on rural electrification. Its aim is to document the picture of rural electrification in Zimbabwe emerging from detailed information gathering surveys. In addition, based on a clear understanding of rural energy issues, elements are highlighted that could feed into the process of developing a coherent rural energy and electrification strategy.

Biomass remains rural Zimbabwe's major source of energy, accounting for over 90 percent of the final energy value from energy use in rural households and enterprises. The mission team found that, contrary to common knowledge, large numbers of households, small and medium enterprises (SMEs) and institutions have adopted their own rural electrification solutions. Over 14 percent of all households use car batteries for minimal electricity services (primarily televisions, radios and radio/cassette players), while nearly 5 percent have their own solar photovoltaic (PV) systems. Thousands of rural enterprises have bought diesel and petrol (gasoline) generators (gensets) over the past several years and rely on them to meet many of their commercial requirements. As an indication of the level of business in this field—in the absence of reliable national import statistics—two companies alone imported more than 2.3 MW worth of small diesel and petrol generator sets in 1997.

The work carried out for this study shows that rural dwellers are willing, and able, to pay high prices for "modern" electricity, prices much higher than ZESA clients pay (between US$0.02 and US$0.04 per kWh for low consumption). Costs of electricity from batteries are estimated at between US$1.4 (new) and US$2.1 (second hand), from solar home systems between US$0.7 (large system) and US$0.9 (small system), and for generators between US$0.3 (small generator) and US$0.4 (large generator). Electricity consumption from batteries and solar systems is generally low compared to consumption from the grid.

The work also suggests that all alternatives for providing rural electricity should be considered simultaneously and at an equal playing field. This would, for example, mean that elimination of tariffs and taxes should not be valid just for ZESA but for all rural electrification systems, from gensets, to PV solar systems. There are strong economic arguments to be made for ZESA to promote innovative rural electrification schemes, from electricity from bagasse, to small hydropower development, to biomass for electricity generation, to wind-driven battery charging stations. This would help accelerate the already rapid growth of rural electrification from "non-conventional" sources.

Many opportunities exist–for ZESA as well as for others—and the best institutional framework for nurturing these opportunities should be identified and developed. There is great scope for private-public partnerships at a local level (e.g., municipalities and other local authorities joining with local entrepreneurs) to rationalize and accelerate rural electrification. Such local participation is necessary to define and establish sustainable, workable, long-term strategies for rural energy. Armed with better information and data—as well as a better understanding of current energy systems and options for optimizing them—there is no doubt that local rural resources can be mobilized to provide greater access to modern, affordable, sustainable energy. There is great potential for the "other" rural Zimbabwe, the non–large-scale sector, to learn and benefit from the large-scale sector in terms of sector organization, management and technology. Zimbabwe has the people and natural resources to move a large proportion of its rural population up the energy ladder. This study sets out some of the ingredients that can make that possible.

1

Introduction

Report Structure

1.1 The report presents the findings of the surveys, interviews and other data-gathering exercises. It is divided into seven chapters as follows:

- Following this section, Chapter 1 presents a general background of the Zimbabwean energy sector, along with the methodologies that were used to collect data.
- Chapter 2 considers rural energy demand, presenting information on energy end-use, the energy services delivered and their costs. In addition, it outlines the sectoral activities giving rise to energy demand.
- Chapter 3 describes the dynamics of energy supply and the trends and opportunities arising from the current situation.
- Chapter 4 discusses issues that any successful rural electrification policy will need to address, include affordability and geographic disparity.
- In order to identify the suggested policy elements within the current energy sector structure, Chapter 5 describes the prevailing institutional and regulatory situation in Zimbabwe. It also describes on-going and planned energy sector activities so that the policy elements acknowledge and build on these.
- Chapter 6 recommends policy elements from which a viable strategy for rural energy and electrification might be formulated.
- Chapter 7 draws some brief conclusions.

General Background

1.2 The Energy Sector Management Assistance Programme (ESMAP) began the current work with Zimbabwe's Ministry of Transport and Energy (MTE), Department of Energy

(DOE), in late 1997 to help develop a rural energy strategy for the country. It was felt that a number of exciting developments were taking place in Zimbabwe's rural energy economy that needed first to be examined in depth, and then to be put within the context of a strategic framework.

1.3 Zimbabwe is richly endowed with energy resources, from extensive coal deposits to large hydropower resources. It has one of the most energy-intensive economies in Africa, and, overall, its rural sector is also one of the most energy-intensive on the continent. However, Zimbabwe's rural energy economy is dualistic. The large-scale agriculture and ranching sectors, the mining sector, and the large-scale agro-processing enterprises (sugar, tea, tobacco) are heavy users of electricity and coal. Conversely, the small-scale agricultural sector, rural small and medium enterprises (SMEs), rural institutions (e.g., schools, hotels, bakeries), small-scale agriculture (e.g., tobacco), and rural households depend heavily on woody biomass. Their consumption of such "modern" conventional fuels as coal, diesel and grid electricity is only a fraction of that of the modern, internationally-linked rural large-scale agriculture, mining and industrial sectors. In energy terms, each sector is a world away from the others in terms of energy intensity and in terms of types and sources of energy consumed.

1.4 While the modern rural sector has energy problems and issues, the major issues faced in rural Zimbabwe relate to the small-scale and domestic sectors. With over 90 percent of rural households relying on woody biomass as the primary source of energy, issues of modern energy access are extremely important. Most rural households (85 percent) use kerosene, and only a fraction are connected to the national grid. Very few rural SMEs, institutions and households use coal, liquefied petroleum gas (lpg) and kerosene for heating or refrigeration. Diesel fuel is used widely to grind grain, for rural transport and agriculture and, increasingly, to generate electricity.

1.5 Careful review of the data and information gathered revealed that one of the most significant issues relevant to the development of rural energy supply was the cost-effective provision of electricity (both on- and off-grid) to rural communities. It is clear that there is a strong desire for electricity amongst the rural population. This desire is matched by a great willingness to spend time, money and effort to secure a supply of electricity.

1.6 In this report, in the context of evaluating rural electrification issues, the team identifies and profiles key programs, projects and economic activities in an effort to provide a data and information base that is as comprehensive as possible. This information, in turn, could form the basis for defining elements for Zimbabwe's first rural energy and electrification strategy. Although this report discusses many such policy elements, it does not attempt to present a comprehensive energy strategy.

1.7 It is the DOE's intention that the development of such a strategy should be a process. The elements presented herein could form the basis for that discussion, debate and, hopefully, consensus. It is hoped that this will then become an ongoing exercise in which government, donors, the private sector and NGOs—that is, all key stakeholders—reach consensus on rural energy and electrification and strategies to ameliorate the energy situation. It is further hoped that they will then continue to participate in the updating of the strategy, the revision of priorities, and the framework for guiding investment, programs and projects in the sector.

Summary of Information-Gathering Methodology

1.8 Detailed descriptions of the methodologies used to collect and assess the information on which this report is based are given in Annex 1.

1.9 Of major significance to the development of the data and information base for this study was the active participation, from the beginning, of the Zimbabwean Electricity Supply Authority (ZESA). ZESA provided considerable primary information from its own resources, and modified its national Energy Use Baseline Survey to accommodate both rural energy and specific energy use (e.g., car batteries, photovoltaics, gensets) in the urban setting. Approximately 2,000 households in "deep rural" areas of Zimbabwe were added to the ZESA survey. The format of the rural survey was made entirely compatible with ZESA's urban survey in order to compare results between urban and rural areas.

1.10 The initial results from the "deep rural" survey revealed several important factors. The extent of car battery use for powering household appliances (e.g., radios, radio-cassette players, televisions and videos) and that of penetration of photovoltaic systems was far greater than anticipated. Rural expenditures on all forms of "modern" energy, from car and dry cell batteries to photovoltaics to kerosene and lpg, far exceeded earlier estimates. This validated the rationale for studying rural energy issues, and also showed the dynamism of independent, private actions in the rural sector.

1.11 One hundred sixty households and rural enterprises were selected from the deep rural survey for certain follow-up questions related to photovoltaic (PV) and genset use. That is, all households and establishments that indicated during the course of the survey that they used PV or generators, were revisited. Over 95 percent of these were interviewed in this second round using a questionnaire that asked in-depth questions about place of purchase, price paid, date purchased, and appliances used, among other questions. The results from this follow-up survey clearly validated the initial survey results and added new depth to the analyses.

1.12 The DOE/ESMAP team also surveyed both demand- and supply-side issues in rural Zimbabwe and many key agencies, institutions and enterprises (e.g., the Forestry Commission, the Association of Rural District Councils, ministries, national commodity associations, major private sector energy equipment suppliers, NGOs) were interviewed.

1.13 Annex 2 presents all the key survey questionnaires used during the course of this work and Annex 3 presents a summary of the survey findings. Existing information and surveys on rural energy were drawn upon, although primary information was obtained wherever possible.

1.14 Primary estimates for household rural energy demand, and extrapolation to rural and urban levels of end use, are based on the 1992 Population Census, with projections and Central Statistical Office (CSO) adjustments (see Table 1-1). The results of both the 1998 ZESA Energy Use Baseline Survey and the follow-up on this survey carried out in mid-1998 for the

DOE have been extrapolated to national levels using these population figures. This is particularly important for determining the extent of urban wood use, as well as the rural and urban use of lead acid (car) batteries for electricity and PV.

Table 1-1. Estimated Rural and Urban Population (in Households), 1992–1998

Sector	*1992*	*1993*	*1994*	*1995*	*1996*	*1997*	*1998 (est)*
Rural	1,409,106	1,446,447	1,484,778	1,524,124	1,564,514	1,606,246	1,648,812
Urban	777,622	817,825	860,106	904,574	951,340	1,000,748	1,052,486
Total	2,186,727	2,264,272	2,344,884	2,428,698	2,515,854	2,606,994	2,701,298

Source: CSO, 1992 Census, CSO adjustments and projections.

2

Energy Demand

Summary of Energy End-Use

2.1 There are an estimated 1.68 million households in rural Zimbabwe. An estimated 20,000 SMEs—primarily bottle stores, general stores, cafes, hotels, brick producers and bakeries—are also located there, as are an estimated 1,120 clinics, hospitals, schools, prisons, government offices and military centers. In addition, the rural areas are home to several thousand commercial farms and ranches, several thousand agro-processing industries (e.g., tea, sugar, tobacco), and a number of mines.

2.2 Fewer than 5 percent of all rural households are connected to the ZESA grid. This percentage includes households bulk-metered on commercial farms and ranches, mines and rural industrial estates. Fewer than 10 percent of all rural SMEs are connected to ZESA, with a slightly larger number of hospitals, clinics, schools, prisons and government offices connected to the Supply Authority's network. Almost all commercial farms and ranches, and most agro-processing plants and mines, are connected to ZESA.

2.3 This leaves a large non-biomass energy demand that is untapped and unserved in rural Zimbabwe. Many rural Zimbabweans have, without government or donor stimulation, moved quickly to meet their electricity demand.

2.4 Batteries are an important source of rural electricity. It is estimated that more than 720,000 rural households (44 percent) use dry cell batteries, mainly for powering radios and lighting purposes (flashlights). Over 40 percent of all rural Zimbabwean households own a radio. More important, from a rural electrification perspective, over 13 percent of all households (perhaps one-third of all commercial establishments) and many clinics and schools have purchased car batteries to provide electricity, primarily for radios, televisions and videos. Over 70 percent of all households who use car batteries own a television set.

2.5 Another demonstration of the growing demand for off-grid electricity is the rapid increase in rural petrol and diesel generating sets. Increasingly, petrol and diesel gensets are used by households, commercial establishments, small-scale commercial farms, and schools and hospitals. Nearly 7 percent of all rural commercial SMEs refrigerate with their own gensets. It is estimated that 6.7 percent of all rural institutions (clinics, schools and prisons) use gensets. This demand amounts to an installed capacity of nearly 5 MW.

2.6 The ZESA-DOE/ESMAP survey revealed, surprisingly, that more than 80,000 rural households own and use a PV system. Systems sizes are spread fairly evenly between 12W and 60W. While the program conducted by the United Nations Development Programme and the Global Environment Facility (UNDP/GEF) sold an estimated 10,000 PV systems,[1] the remainder have been imported independently by Zimbabweans from a number of sources. The ZESA survey showed that nearly one-third imported their own sets from South Africa and Botswana. This provides a further indication of rural Zimbabweans' strong desire to electrify their homes.

2.7 The trend towards adopting off-grid solutions to meet electricity demand is accelerating as the market develops, and as rural dwellers obtain more disposable income. Nonetheless, in spite of the innovative approach of many rural Zimbabweans, the fact remains that nearly 1.3 million homes still rely on kerosene and candles for lighting.

Services Delivered and Costs

Dry Cell Batteries

2.8 More than 80 million dry cell batteries are produced in Zimbabwe each year for domestic consumption. The ZESA Energy Use Baseline Survey found that over 44 percent of all rural households use dry cell batteries. Table 2-1 shows the range of battery types, including the retail and wholesale costs of each type.

Table 2-1. Types and Costs of Dry Cell Batteries, November 1998 (Z$)

Dry cell battery	*Type*	*Wholesale price (Z$)*	*Retail price (Z$)*
Powercell (P10) 9 V	Single	81.85	108.05
Powercell (P9) 9 V	Single	30.82	42.19
Powercell (R6) 1.5 V	Single	3.83	7. 99

Source: DOE/ESMAP market surveys.

2.9 Nickel-cadmium batteries (rechargeables) are in increasing use in rural Zimbabwe, although their relatively high price prevents all but the wealthiest rural dwellers from using them. As with dry cell batteries, they are used primarily for lighting (flashlights) and for radios and

[1] UNDP/GEF, *Final Report,* February 1998. The report states at various points that slightly more than 8,000 systems were sold under the project, while at other points indicates that nearly 10,000 units were sold. The ambiguity stems from the fact that the project sold modules rather than complete systems. Therefore, there can only be estimates of the number of households with systems installed, based on assumptions of the average number of modules per household system.

radio/cassette players. Their use is also discouraged by the need to recharge them from primarily grid-connected stations.

Lead Acid/Car Batteries

2.10 Car batteries have provided electricity for radios and lights in Zimbabwe since the 1920s. They now provide electricity for an estimated 14.5 percent of all rural households (230,000) and roughly 7 percent of all urban households, an estimated total of 310,000 households.[2]

2.11 The ZESA Energy Use Baseline Survey shows that car batteries have found their way into every corner of the country. As Table 2-2 shows, a remarkable number of people use lead acid batteries in rural areas, and a high number of urban households use car batteries. The urban figure is particularly striking in light of the fact that over 70 percent of all urban households are connected to the grid.

Table 2-2. Car Battery Ownership and National Estimated Distribution

Category	No. interviewed owning car battery for household electricity	% of sample owning car battery for household electricity	Est. national households owning car batteries for electrification
Rural	192	13.7	226,608
Urban	211	6.9	73,003
Total	403	9.1	299,611

Source: ZESA/DOE Main Rural Energy Survey and 1998 Follow-Up.

2.12 Car batteries are expensive in Zimbabwe (Table 2-3). There are a number of producers, and a wide range of sizes. More than one-half of all rural households that use car batteries for household electricity purchase them second-hand (usually from automobile owners). Interviews and the ZESA survey show that these batteries can be expected to last an average of 12 months. New batteries, on the other hand, can be expected to last a rural household an average of 2.5 years, depending on make, size, and, of course, the way the household discharges and charges the battery.

2.13 The average lifetime of car batteries used in rural and urban households is long considering that over 70 percent of these batteries are used to power televisions, and that households tend to deep-discharge these batteries. Given that car batteries are charged primarily from the grid at a number of trading and other centers at an average distance of 7–10 kilometers, the incentives to deep-discharge the battery is high.

2.14 Moreover, the manner in which batteries are charged goes against conventional wisdom. For example, they are almost always charged in series, with too many batteries being charged at once; and many of the charging stations lack a meter to measure the state of charge. A number of batteries are also charged at rural diesel electricity sites in the country. Monthly expenditures for car batteries in rural areas average between US$5 and US$15 (excluding the cost of

[2] The ZESA/DOE Rural Energy Survey of 6,001 respondents in urban and rural Zimbabwe (Annex 3) provides the most thorough database on car battery use in Zimbabwe. This is the primary source for these statistics.

replacement), which is more than the average grid-connected household in rural or urban areas pays per month to meet all their electrical needs. That people should go to such expense and trouble to obtain electricity through this mode speaks far more than any other factor in defining their willingness to pay for electricity.

Table 2-3. Types and Prices for New and Used Lead-Acid Batteries, November 1998 (Z$)

Type	*Voltage*	*Retail Price (Z$)*
Car battery, new		
Light vehicle	12 V ordinary, 36 Ahr	1,048.13
Medium light	12 V ordinary, 90 Ahr	2,054.81
Lorry	12 V ordinary, 118 Ahr	2.425.35
Heavy vehicle	12 V ordinary, 158 Ahr	4,053.56
Car battery, used		
Light vehicle	12 V ordinary, 36 Ahr	450.00
Medium light	12 V ordinary, 90 Ahr	500 to 1,000
Lorry	12 V ordinary, 118 Ahr	600 to 1,200
Heavy vehicle	12 V ordinary, 158 Ahr	1,600.00
Deep-cycle batteries, new	12 volts, 40 Ahr	1,250.00
Leisure battery, new	12 volts, 100 Ahr	2,329.66

Note: November 1998 exchange rate was approximately Z$35 to US$1.
Source: ESMAP/DOE team.

Solar

2.15 Zimbabwe has a considerable solar energy resource (see Annex 4). This has been utilized traditionally for crop and meat drying. During the past two decades, solar energy has been harnessed for solar water heating, primarily with locally-manufactured solar water heaters. Most of these units have been utilized in the tourism industry. After several years of decline, solar water heating is now increasing, with two companies producing complete systems and another eight importing systems and components. Photovoltaics (PV) are a major, and rapidly growing, source of rural electrification in Zimbabwe. The ZESA 1998 National Energy Survey showed that more than 80,000 rural households, and perhaps as many as 10,000 rural commercial, industrial and institutional users, utilize PV electricity. This figure was much higher than anticipated. (Annex 5 contains information on companies engaged in the solar energy industry.)

Photovoltaics

2.16 Solar refrigeration is used extensively in isolated rural hospitals and clinics in Zimbabwe. Various private, church, NGO and donor programs have extended photovoltaic refrigeration to the most isolated areas of Zimbabwe as part of the national extended program for immunization (EPI), following international World Health Organization (WHO) guidelines.

2.17 Solar pumping has been undertaken since the mid-1980s. Gesellschaft für Zusammenarbeit (GTZ, the German Co-operative Development Agency) has for a number of years operated a solar pumping project comprising 16 systems. Another 165 systems are in use throughout the rest of the country. In general, however, solar water pumping has not caught on to any appreciable extent in Zimbabwe. This is mainly because, in most cases, it is not cost-effective relative to alternatives, such as hand pumping or petrol or diesel pumps.

2.18 Photovoltaics have been in domestic and commercial use in Zimbabwe since the late 1970s. Zimbabwe has a robust and mature PV market. Production of PV systems began in 1988 and continues to this day. Cells are purchased on the international market and assembled into panels. Their capacity is 320 kW per year. There are four local companies producing lights. Two companies undertake various stages of solar refrigerator production (150 and 300 liters). There are four local battery companies that service the solar market. The industry has experienced considerable growth since 1991. By late 1998 some 73 companies were involved in various aspects of the solar photovoltaics market, although the sector has seen a major contraction of suppliers in the past year as the UNDP/GEF project has drawn to a close and the country's economic problems have escalated.

2.19 It was estimated in 1992 that several thousand PV units were in operation, and nearly a dozen Zimbabwean firms were engaged in the photovoltaic business. The UNDP/GEF began its large-scale program to stimulate the solar photovoltaic industry in 1992, under the assumption that this was necessary to help the industry to "take off", increase employment in the sector, increase exports, and bring down the price of PV units to be more affordable for rural Zimbabweans.[3]

2.20 In five years (from 1992 to 1997) perhaps 10,000 household systems were sold in Zimbabwe at subsidized prices through the UNDP/GEF project. As at September 1998 a total of 50 companies were active in PV and approved by the UNDP/GEF project. The project imported photovoltaic panels directly, duty-free (although duty was levied on non-project PV imports). These were then sold to a number of dealers at a 15 percent reduction on the import price. Although the project was intended to stimulate the marketplace, it actively intervened in a number of areas, from purchasing PV equipment offshore with its own lines of credit, to importing them duty-free, to selling them to "approved" dealers.

2.21 The project placed the proceeds from its local PV sales into a revolving fund. This has been used to import more PV panels to sell on to local dealers. However, the massive depreciation of the Zimbabwe dollar has nearly wiped out this revolving fund, which was established in Zimbabwe dollars. The value of the fund has dropped five-fold in the 18 months since June 1998, and has seriously undermined the project's ability to continue in its past mode of operations.

2.22 One of the spin-offs of the UNDP/GEF project was the formation of the Solar Energy Industries Association of Zimbabwe (SEIAZ). It was established primarily as a way of protecting the industry's reputation from unqualified suppliers trying to cash in on the project.

2.23 Results from the 1998 ZESA-DOE/ESMAP Rural Energy Survey and PV follow-up survey show that, at least in the recent past, the number of PV systems countrywide has been seriously underestimated. The survey of 6,000 interviewees, which included nearly 2,000 rural and

[3] UNDP/GEF, "Photovoltaics for Household and Community Use in Zimbabwe" (Project Paper, 1991).

just over 3,000 urban households, found that just on 2 percent of Zimbabwe's households (4.6 percent of all rural and slightly under 1 percent of all urban households) own and operate photovoltaic systems.

2.24 The results from the survey were verified and validated in mid-1998 with repeat visits to, and surveys of, virtually all households who claimed to own PV during the first, broad-based survey. A specially-designed questionnaire was used (see Annex 2). More than 100 respondents were interviewed in this second round, resulting in the collection of much of the in-depth information on use, cost, source of supply, and other key issues presented and analyzed in the present work. The large-scale survey sample was randomly stratified by sector (rural-urban, household, commercial, agricultural, mining and industrial). Randomness in the household and commercial sector was obtained following standard, internationally accepted, statistical methods. The results of the survey are representative and statistically significant. Therefore, the results from the follow-on PV survey (and the follow-on genset survey) can be used and extrapolated with confidence.

2.25 This ZESA-DOE/ESMAP Rural Energy Survey provides the best estimate for photovoltaic systems in use today in Zimbabwe. As Table 2-4 shows, the survey found significant use of PV in the rural commercial sector from 1991 to 1998, with little usage in the agricultural, rural industrial and mining sectors. In the absence of a good national census of establishments in the commercial sector, it is impossible to extrapolate the survey results to a national level. Nevertheless, with over 5 percent of all rural commercial establishments surveyed (278), it is probably safe to say that another 1,000, or more, PV systems are in use in Zimbabwe today.

Table 2-4. Historical and Contemporary Estimates of PV Systems in Zimbabwe, 1991–1998

Year	*kWp*	*No. systems (min)*	*No. systems (max)*	*Source*
1991	150	3,750	7,500	DOE
1994	300	7,500	15,000	DOE
1997	700	17,500	35,000	DOE
1998	1,689	25,000	84,468	ZESA/DOE

Source: Various, and ZESA Energy Use Baseline Survey.

2.26 A number of interesting facts emerge from the ZESA-DOE/ESMAP surveys. First, a high proportion (over 32 percent) of all systems were imported from South Africa and Botswana. An overwhelming majority of all systems were either self-installed (33 percent) or installed by "local technicians" (44 percent). Furthermore, the average age of system was reported as more than 2 years, with over 20 percent more than 7 years old. This would indicate that there were more than 15,000 PV systems in operation in 1991, the year before the UNDP/GEF project began. This would indicate that the DOE estimates of systems in use from 1991 to 1997 were low.

2.27 The average system size clusters around 28W, although about 18 percent are 20W or less and 26 percent are 50W or greater. Approximately 10 percent of the respondents said they used their systems for "lighting only" (which corresponds roughly to the distribution of small power systems in the survey). Thirty-five percent said they used their systems only for "powering" (i.e., radio/cassette players, televisions, videos). Over 90 percent of the PV respondents owned televisions, and this is borne out by the fact that 85 percent said they used their systems for powering and/or powering and lighting. The survey offers some interesting insights into the dynamics of the PV business. Over 10 percent of PV respondents were urban[4] dwellers. Given the fact that PV retailers are located in towns, rural Zimbabweans have shown a strong desire to electrify their homes using PV by importing a large number from abroad or going to urban areas to purchase the systems, and then either installing the systems themselves or hiring local technicians to install them.

Solar Water Heaters

2.28 The solar water heating industry in Zimbabwe has a long history. Solar water heaters were first produced in-country in the late 1970s. The industry catered primarily to urban high-income groups and to the tourism industry. It is not known how many solar water heaters have been produced in Zimbabwe over the past 20 years, but estimates put it as high as 10,000, including all industrial, tourism and service sector units. The industry ran into difficulties in the late 1980s as consumers lost confidence in the quality of most units, and even good producers and assemblers received a bad reputation as a result.

2.29 The industry has been slowly turning around over the past five years. This seems likely to accelerate as the price of electricity goes up and its reliability goes down. Ten companies import and/or produce solar water heaters today. Two companies produce them. There is currently one big company in Bulawayo and another, smaller company in Harare. The Bulawayo producer has been in business for seven years.

2.30 There have been positive spin-off effects from the growing photovoltaic industry to the solar water heating industry over the past several years. Now, at least ten firms import solar water heaters and components. Most are small firms, with not more than five employees. All are engaged in solar photovoltaics, and order and install solar heaters on request.

Small Hydropower

2.31 Zimbabwe has built a number of dams to supply water for drinking, irrigation and livestock. As Table 2-5 shows, however, even with several hundred of such dams in the country, only eight small hydropower sites have been developed for electricity and motive power (see Annex 6).

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[4] *Urban* was defined using Central Statistics Office census definitions.

Table 2-5. Small Hydropower Sites in Zimbabwe, 1998

Location	*Capacity (kW)*	*Installed*	*Electricity*
Claremont	250	1963	yes
Aberfoyle	25	1966	yes
Nyafaru	30	1995	yes
Rusitu	700	1997	yes
Mutsikira (pump scheme)	3	1995 (rehab)	no
Svinurai (hydro-mill)	10	1995 (rehab)	no
Sithole-Chikane (hydro-mill)	25	1965	no
Kuenda	75		not operational

rehab: rehabilitated.
Source: Department of Energy, various.

Wind

2.32 Zimbabwe has relatively good wind resources. Wind has provided rural energy for water pumping for a century (see Annex 7). Wind use reached its peak in the 1930s. The use of wind for water pumping fell steadily with the availability of cheap petroleum products and electricity grid extension to ranches and commercial farms during the 1950s. Today, wind is making something of a comeback, with increasing interest on the part of government, schools, hospitals, NGOs and others in windpumping, and increasingly in electricity generation for isolated, non–grid-connected areas. There is considerable potential for wind energy to be harnessed for applications in isolated areas. The economics for this are improving steadily.

2.33 During the 1980s, various donors and government installed a number of wind pumps for rural water supplies. Perhaps as many as 300 such sites were developed between 1981 and 1992. Initially, the costs of maintenance, and the requirements for locally-based organization to maintain, operate and recover costs for these wind pumps led to a general disillusionment with them. However, there has been a marked increase in demand for these pumps over the past six years.

2.34 Currently, two companies manufacture wind pumps. Studies carried out by the larger of these companies and the Institute of Agricultural Engineering indicate that there are up to 650 wind pumps currently in use countrywide. There are good manufacturing capabilities in the country, and as much as 85 percent of the value of the wind pumps can be manufactured locally. The total number of windmills installed by the largest of the companies over the past 5 years (1992 to 1997) is around 138.

2.35 Zero, a local NGO carried out a three-year wind monitoring program that has established that there is potential for wind electricity generation in a number of areas of Zimbabwe. In 1997, a local company manufactured several wind turbine prototypes for electricity production, rated at 1 kW and 4 kW. The prototypes tested well. With ESMAP support, the company recently installed five wind-powered electric turbines in Rusape in a village electrification scheme (see Annex 8 for more details). It is also exporting these systems to South Africa.

Petroleum Electricity Generation

2.36 Diesel and petrol generators have provided electricity for commercial, domestic, industrial and institutional use in isolated rural areas of Zimbabwe for more than 70 years. More recently, low-cost petrol (gasoline) and paraffin/kerosene electric generators have become increasingly available. They provide small business establishments, clinics and some households with simple electricity to meet numerous requirements.

2.37 Diesel generators can be found in every district in Zimbabwe. Many gensets serve as essential back-up systems for health, industrial and tourism applications, providing electricity in the event of disruptions from the grid. These have become increasingly necessary as the grid has become over-extended in rural areas, and as electricity supplies have become more erratic. However, a growing number of industries and commercial establishments have purchased diesel generators as their primary source of electricity, serving as base load for a variety of applications. A number of diesel generators charge batteries for households and commercial establishments in rural Zimbabwe.

2.38 As can be seen from Table 2-6, farming accounts for the largest proportion of generator sets, as indicated by ZESA. Some 695, representing nearly 50 percent of all gensets recorded by ZESA, are in the farming sector.

Table 2-6. ZESA Area Manager Estimates of Diesel Gensets, by Area and Demand Sector (1998)

ZESA Area	*No. gensets*	*% Total nationally*	*% Farming*	*% Industrial/ commercial*	*% Institutional*	*% Domestic*	*% Total by Area*
Northern Area	1,123	80.2%	56.8%	38.3%	4.3%	0.6%	100.0%
Western Area	57	4.1%	14.0%	61.4%	21.1%	3.5%	100.0%
Eastern Area	97	6.9%	20.6%	44.3%	35.1%	0.0%	100.0%
Southern Area	123	8.8%	23.6%	70.7%	0.0%	5.7%	100.0%
Country-Wide		100.0%	49.6%	42.5%	6.7%	1.1%	100.0%
Total number of gensets:	1,400	1,400	695	595	94	16	

Source: ZESA.

2.39 These estimates (Table 2-6) show that over 90 percent of all gensets are used for agricultural, industrial and commercial purposes, whereas only 6.7 percent are for used for institutional purposes (e.g., hospitals, clinics, schools, airports, prisons). Given the large number of gensets recorded by the Ministry of Local Government and the ZESA Energy Use Baseline Survey results (see below), it is possible that the ZESA area managers underestimated the number of institutional generating sets. Consequently, it is probable that the ZESA area managers also underestimated the number of generating sets in the rest of the country, particularly in areas outside the Northern Area.

2.40 The Ministry of Local Government and Housing (now Ministry of Construction) was asked to provide information (Table 2-7) for this national rural study on all generating sets listed with them in each of Zimbabwe's eight provinces. Four of the eight provinces replied to the DOE's request. The data show considerable capacity in rural areas, primarily for hospitals, airports and schools, but also for border posts and other government institutions. They also show that over 90 percent of the installed capacity is for standby, although the frequency of use is not indicated. In some provinces, and in some circumstances, gensets intended for standby have become base load in order to meet essential requirements, particularly in hospitals.

Table 2-7. Summary of Institutional Generating Set Capacity in Four Provinces, 1998 (kVA)

Province	*kVA*
Matabeleland North Province	1,964.2
Mashonaland East Province	1,192.0
Midlands Province	1,351.5
Manicaland Province	445.6
Total	4,953.3

Source: Ministry of Local Government and Housing (now Ministry of Construction).

2.41 Department of Energy surveys DOEof genset suppliers show that two companies imported more than 2.3 MW in small gensets in 1997. These were only two of eight important genset importers. They accounted for more than 350 generating sets imported solely for private purposes in 1997.

2.42 However, the ZESA-DOE/ESMAP Energy Use Baseline Survey of 1998, which also covered gensets, found a large number, particularly in the mining, large-scale farming/ranching, and commercial sectors. As Table 2-8 shows, of the 6,000 respondents, 135 owned and used gensets. Nearly 20 percent of all mining and farming respondents had gensets, while 10 percent of all commercial establishments owned and used gensets.

Table 2-8. Diesel and Petrol Generating Sets by Sector: ZESA-DOE/ESMAP Survey (1998)

Sector	*Area*	*Total gensets used*	*Total surveyed*	*% Gensets of total surveyed*
Domestic	Rural	3	1,397	0.2
	Urban	2	3,042	0.1
Commercial	Rural	19	278	6.8
	Urban	4	150	2.7
Farming	Rural	44	606	7.3
Peri	Urban	7	58	12.1
Mining	Rural	53	269	19.7
Industry	Rural	3	70	4.3
	Urban	0	128	0.0
Total		135	5,998	2.3

Source: ZESA/DOE.

2.43 As with the ZESA-DOE/ESMAP survey information on car batteries and other energy use in the non-domestic sector, the absence of overall census or registration information precludes a statistical extrapolation of the number of mines, commercial farms/ranches and commercial establishments. That is, without a complete registry of establishments in these sectors, it is not possible to extrapolate to the total number of establishments with gensets. Moreover, the mining and commercial farming/ranching surveys were not selected on a random stratified basis, unlike rural and urban households. Rather, in these sectors, every establishment in the survey area was interviewed. Therefore, it can easily be said that, with approximately 1,000 mines (19.7 percent genset use) and just over 5,000 commercial ranches and farms (19.4 percent genset use), including approximately 1,200 households, the survey indicates at least 1,200 gensets in use in these sectors in rural Zimbabwe. This corresponds with the minimum estimate of the ZESA area managers' survey.

2.44 The DOE followed up the large survey with interviews of 82 of the 135 gensets found during the large National Energy Survey. This showed that gensets in the mining and commercial farming/ranching sectors averaged 35 kVA. The size for gensets in the commercial sector averaged 3 kVA. This would indicate that the 1,200 gensets in the mining and farming/ranching sector account for at least 40 MW of installed capacity.

2.45 The Confederation of Zimbabwe Industries (CZI) and the Zimbabwe Chamber of Commerce estimate that there are some 20,000 commercial establishments (e.g., general stores, bottle stores, restaurants, bars, hotels, bakeries, mills, welding shops, butcheries) in rural Zimbabwe. This number, combined with the ZESA/DOE survey information, indicates that more than 1,300 commercial enterprises (6.8 percent genset use) in rural Zimbabwe have gensets. The supplier information provided by the two largest genset suppliers further indicates that more than 1 MW of genset capacity is being sold into the rural sector each year. These estimates, then, indicate another 4 to 5 MW in the rural commercial sector.

2.46 Given the Ministry of Local Government and Housing's survey information on institutions' genset capacity for four provinces, a conservative estimate for independent, autonomous rural generating capacity in Zimbabwe is on the order of more than 50 MW, as shown in Table 2-9.

Table 2-9. Bottom-Up Estimate of Independent Rural Generating Set Capacity, 1998

Sector	*Est. number*	*% with gensets*	*Estimated No. establishments with gensets*	*Avg. capacity (kVA)*	*Total (kVA)*
Mines	1,000	19.7	197	35	6,896
Commercial farms/ranches	5,200	19.3	1,005	35	35,180
Commercial enterprises	20,000	6.8	1,367	3	4,101
Institutions	-	-	-	-	6.0
Estimated total					46,183

- data not available.
Source: ZESA Area Managers, ZESA Energy Use Baseline Survey, Ministry of Local Government and Construction, Zimbabwe Farmers' Union, others.

2.47 The DOE/ESMAP team visited the Honda dealer in Harare. The dealer had fifteen different models on display, which suggests a reasonably sized active market. In addition, as Table 2-10 shows, a considerable quantity and capacity of petroleum gensets were supplied in 1997.

Table 2-10. Gensets Supplied in Zimbabwe in 1997

Supplier	*Number supplied*	*Average capacity (kVA)*	*Max. capacity (kVA)*	*Min. capacity (kVA)*	*Total (kVA)*
Honda	377	3.05	8.5	0.35	1,150
Hawker Siddeley & other manufacturers	17	69.8	232	10	1,186

Source: ZESA-DOE/ESMAP rural energy survey.

2.48 This level of activity suggests that the ZESA and survey figures presented are probably conservative estimates, although no concrete data are available to confirm this. Unfortunately, official import statistics record the value of genset imports (along with their weight) rather than the number in any Standard International Trade Classification (SITC) category.

Therefore, estimates care made on the basis of supplier information, ZESA area manager statistics, Ministry of Local Government and Construction statistics, and information obtained from the ZESA-DOE/ESMAP baseline survey.

Petroleum Mechanized Power

2.49 The most extensive use of petroleum for non-transport applications in Zimbabwe is in diesel-driven grain milling. An estimated 8,500 maize mills are in operation throughout rural Zimbabwe, meeting the needs of millions of rural Zimbabweans who bring their grain for milling. Of these mills, an estimated 65 percent are operated by grid electricity, while the remaining 3,000 are powered with diesel fuel.[5] Several prototype grain mill-battery charging stations have been set up in the country. However, they have not enjoyed particular commercial success primarily due to management and technical issues.

Grid Electricity

2.50 Zimbabwe's grid was originally extended beyond urban areas to rural mines, agricultural processing factories, and commercial farms and ranches starting in the 1920s. A few rural church missions, hospitals and clinics were also connected to the grid prior to 1980. Virtually all commercial farms and ranches are connected, as are most medium to large mines (Wankie Colliery is also the location of the country's largest fossil-fuel generating station). However, rural electrification for trading centers and the domestic sector did not begin in earnest until the 1980s. Since that time, more than 10,000 rural households, and a large number of commercial and institutional consumers, have been connected to the grid (Table 2-11) at considerable national cost.

Table 2-11. Zimbabwe Electricity Production, 1990–1996 (TWh)

Source	*1990*	*1991*	*1992*	*1993*	*1994*	*1995*	*1996*
Generation from coal	5.949	5.772	5.076	5.95	4.964	4.964	5.559
Generation from hydro	3.523	3.152	3.161	1.693	2.37	2.372	2.317
Imports	0.879	1.208	2.044	1.921	1.718	1.716	1.707
Exports	0.005	0.032	0.018	0.003	0.001	0.001	0
Total production	9.47	8.92	8.24	7.64	7.33	7.34	7.88
Residential consumption	1.528	1.542	1.621	1.489	1.403	1.404	1.486
Residential consumption as % of production	16.1%	17.3%	19.7%	19.5%	19.1%	19.1%	18.9%

TWh: terawatt-hours.
Source: ZESA and IEA.

Coal

2.51 Zimbabwe is a large producer of coal, and coal is a major source of power generation in the country, serving the power stations at Hwange (Table 2.12 shows that over 90 percent of all coal is sold to ZESA), Munyati, Bulawayo and Harare. The agriculture sector accounts for the next-largest source of demand for coal. A limited amount of this coal, probably no more than several thousands of tons per year, is utilized on large farms for domestic use (i.e., supplying farm workers

[5] A 1994 survey found an estimated 6,581 grinding mills in all eight provinces; the largest supplier of mills had sold 110 mills (Nick Murgatroid, *Final Report on Rural Energy Use* [British Overseas Development Authority, December 1994]).

with coal for cooking and heating). This is the only instance where coal is recorded being utilized to any appreciable extent in Zimbabwe's entire domestic sector. Zimbabwe's mines account for a large portion of sales. Brick production is a major user of coal. Wankie Colliery estimates that 25 percent of its coal sales to the brick industry goes to rural brick production, the rest being utilized in urban industrialized brick production. Finally, coal is utilized by virtually all large-scale tobacco producers for curing tobacco, and an estimated 25 percent of the small tobacco producers.

Table 2-12. Wankie Colliery Rural Coal Sales: 1992–1997 (tons)

Consumer	*1992*	*1993*	*1995*	*1996*	*1997*	*Avg. 1992-97*
ZESA	2,596,918	2,683,659	2,900,482	2,579,474	2,529,477	2,658,002
Mines	67,268	50,586	71,201	75,091	64,860	65,801
Bricks	12,135	8,913	12,081	12,830	11,883	11,569
Sugar	14,098	15,342	34,853	26,257	37,969	25,704
Tobacco	23,282	17,269	18,338	15,293	9,625	16,761
Gen. Agriculture	350,729	381,801	611,144	547,861	502,486	478,804
Total Rural	3,064,430	3,157,570	3,648,099	3,256,806	3,156,300	3,256,641

Source: Wankie Colliery Sales Department.

2.52 Coal has limited uses in the rural domestic (household) sector. It is estimated to be used in only a few thousand rural households, primarily on commercial farms/ranches, and on mining and industrial estates. However, coal is very important for electricity generation in Zimbabwe. Therefore, it figures into the country's final energy demand as electricity.

Sectoral Demand

2.53 Table 2-13 shows the principal activities giving rise to energy demand in each of the principal demand sectors, along with the associated end-use appliances.

Table 2-13. Rural Energy Demand, by Sector

Demand Sector	*End Uses*	*End Use Appliances*
Domestic	Cooking, heating, lighting, powering	Stoves, open fires, lamps, candles, radio, TV
Commercial	Cooking, heating, lighting, powering	Stoves, furnaces, boilers, lamps, TV, radio, refrigerators
Institutional	Cooking, heating, powering	Stoves, furnaces, boilers, lamps, refrigerators
Agro-industry and commercial farms	Drying, process heating (e.g., steam), powering, heating, lighting	Furnaces, curing & drying barns Furnaces, boilers, soap making, brick making, smithing, machinery
Mining	Powering, heating, lighting	Machinery

Source: DOE/ESMAP team.

Domestic

2.54 Demand for energy in the rural domestic sector arises from cooking, heating, lighting and powering (e.g., radios, televisions, refrigerators).

2.55 For the entire country, ZESA has 260,000 metered, and 128,000 load-limited, domestic consumers. Of these 388,000 domestic consumers, ZESA estimates that no more than

12,000 are "rural" domestic, with the remaining rural connections to commercial farms and ranches, commercial establishments, mines and rural industries.[6] However, the ZESA-DOE/ESMAP survey revealed that more than 80,000 rural households use grid electricity. This discrepancy is largely attributable to the fact that ZESA employs bulk (or group) metering of rural households where a number of households draw supply from a single metered point. This is a credible estimate given the fact that there are more than 5,000 large-scale commercial farms and ranches in Zimbabwe, employing more than 100,000 rural Zimbabweans. There are also several hundred medium- and large-scale mines, employing more than 30,000 rural workers. Most of these enterprises supply domestic residences for their workers using ZESA bulk meters. Therefore, the ZESA-DOE/ESMAP survey result showing more than 80,000 rural households connected to the grid is realistic. This was confirmed in discussions with ZESA.

2.56 Yet even this higher number of connections still reflects very limited access to the electricity grid for rural Zimbabweans (i.e., less than 5 percent). ZESA connected 800 rural households during 1997–98, with the bulk of those in "growth centers"[7]. In the absence of significant grid expansion to meet rising demand, rural dwellers have made use of a wide variety of traditional and innovative energy supply options to satisfy their needs, such as gensets, car batteries and PV solar home systems.

2.57 Table 2-14 presents an estimate of rural energy demand, which is illustrated in Figure 2-1. The information in the table is based on data collected during the survey work where possible. Some figures are a less accurate estimate. For example, the biomass energy demand is based on population figures and the estimated wood biomass use per person. The World Bank Regional Program on the Traditional Energy Sector (RPTES) is currently working in Zimbabwe and will develop a much more accurate analysis of biomass energy use in rural areas.

Table 2-14. Rural Household Final Energy Demand, by Supply Source

Source	*Number hseholds*	*Supply/end use units*	*Total no. units*	*Supply (TJ)*	*Final demand (TJ)*	*% Total*
Biomass	1,524,124	tons	8,344,581	133,513	13,351	91.3%
Kerosene	1,295,506	tons	40,857	1,675	670.1	4.6%
Car batteries	239,108	GWh	26.18	94.26	94.26	0.6%
Grid Electricity	82,935	GWh	99.52	358.28	358.28	2.4%
Gas/lpg	13,190	tons	1,419	57.8	40.4	0.3%
Coal	6,925	tons	8,847	265.4	39.8	0.3%
PV	75,188	GWh	8.20	29.50	29.50	0.2%
Diesel Gensets	400	tons	582.0	23.9	23.9	0.2%
Petrol Gensets	800	tons	388.0	15.1	15.1	0.1%
Dry cell batteries	726,626	GWh	1.45	5.23	5.23	0.0%
Total	n.a.	n.a.	n.a.	136,037.9	14,628	100.0%

n.a. not applicable.
Source: DOE/ESMAP team.

[6] ZESA Marketing Department communication, September 1998.

[7] ZESA concentrates its rural electrification on Growth Centres, which are villages with a thriving commercial centre containing workshops, businesses, and so on.

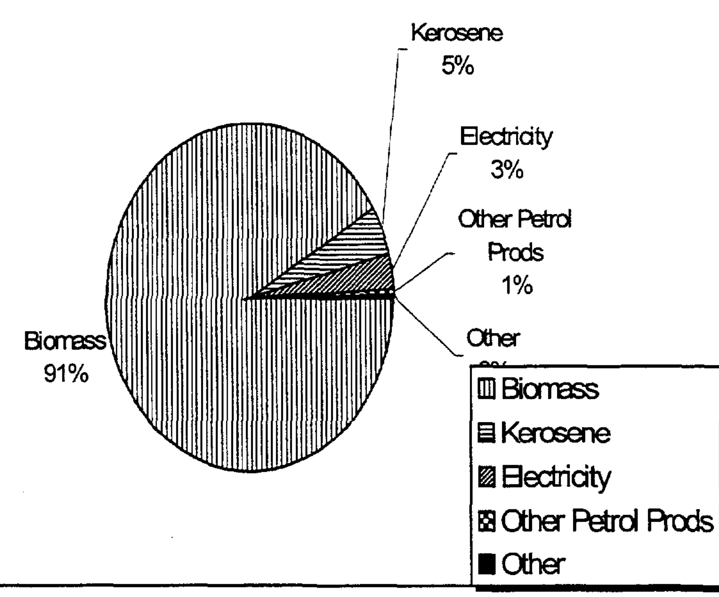
Commercial

2.58 Commercial ventures such as general stores, bakeries, butcheries, workshops, and grinding mills require energy for cooking, heating, lighting and powering.

2.59 Such enterprises have a greater demand for energy than individual households, and an effective and stable supply of energy is extremely important for business. Radio and television for entertainment to attract customers, refrigeration to increase product range and storage life and lighting to extend opening hours are examples major elements of commercial energy demand.

2.60 As with the household sector, rural Zimbabwean entrepreneurs have demonstrated innovation in order to satisfy their energy demand. The ZESA-DOE/ESMAP survey found an increasing number (currently 6.8 percent) of commercial operations using petrol or diesel gensets. Additionally, over 5 percent of all rural commercial establishments use a PV system.

Figure 2-1. Share of Rural Household Demand, by Energy Source (1977)



Source: DOE/ESMAP team.

2.61 Unlike the domestic sector, the some commercial operations require mechanical power. Grain-milling is one example. Where grid electricity is not available to drive the grain miller, diesel-driven grain milling is often used. It is estimated that 3,000 rural grain mills (of a total of 8,500) are diesel powered, constituting the greatest non-transport demand for diesel fuel in the country.

Institutional

2.62 The institutional sector (schools, hospitals, clinics, prisons) in rural Zimbabwe is a major consumer, requiring energy for cooking, heating and powering lights and other equipment (medical, educational). The team's methodology for obtaining energy consumption statistics included official data from the Ministries of Health and Education (hospitals, clinics and schools) and the Office of the President (prisons). This information was supplemented and cross-verified by sales information from ZESA for electricity, from coal distributors and Wankie Colliery for coal, and from site visits to 47 boarding schools, hospitals and clinics. The Prisons Department maintains extensive records on energy expenditure and made them available for purposes of this study.

Rural Health

2.63 As Table 2-15 shows, there were 1,183 rural clinics and 146 rural hospitals in Zimbabwe in 1995. No energy estimates were made for clinics because this information is very difficult to obtain and energy consumption in clinics is relatively unimportant. Hospitals, on the other hand, have relatively high energy consumption. The Ministry of Health provided information on hospital beds and bed occupancy in rural areas.

Table 2-15. Clinics and Hospitals: National and Rural, 1995

Province	*No. Clinics*	*No. Hospitals*
Manicaland	254	38
Mashonaland Central	116	14
Mashonaland East	181	26
Mashonaland West	174	25
Masvingo	167	24
Matabeleland North	95	17
Matabeleland South	120	19
Midlands	226	33
Harare City	60	8
Bulawayo City	27	10
Total (national)	1420	214
Total (rural areas only)	1183	146

Source: Ministry of Health.

2.64 This provided a figure of just over 2.7 million patient days (occupancy) in rural hospitals in 1995. From information provided by the Ministry of Health and from field visits and interviews, average wood, coal, kerosene and electricity consumption was estimated. The estimates for electricity were verified by ZESA, and the estimates for coal were verified from coal sales figures. Wood consumption was estimated on a basis of 15 kg per patient day, including all cooking, heating, sterilizing and supply of energy to hospital staff.

Rural Education

2.65 As Table 2-16 shows, there were 30 primary and 141 rural boarding schools in rural Zimbabwe in 1995. All other schools were non-boarding. From Ministry of Education (MOE) information and team site visits, it was determined that energy consumption in non-boarding schools was important, but not as significant as energy consumption in boarding schools. Moreover, information on energy consumption for non-boarding schools is not readily available. Even in schools that have boarding facilities, fewer than 15 percent of the students actually board; the rest are local students.

Table 2-16. Primary and Secondary Boarding Schools, by Province (1995)

Province	*Primary*	*Secondary*	*Total Boarders*	*Total Students*
Matabeleland South	4	19	1,125	9,891
Matabeleland North	0	13	847	7,675
Mashonaland East	8	25	2,319	19,963
Mashonaland Central	0	9	917	5,059
Mashonaland West	8	8	1,117	5,728
Masvingo	0	18	1,016	9,330
Manicaland	4	28	1,320	16,871
Midlands	6	21	1,758	15,238
Total	30	141	10,419	89,755

Source: Ministry of Education.

2.66 On the basis of MOE information on number of boarding students, and their estimates for energy expenditures, the team made preliminary estimates of energy consumption. Furthermore, ZESA was consulted to obtain electricity sales figures, and coal suppliers were consulted to obtain coal estimates. The team then made visits to a number of schools to verify consumption.

2.67 MOE figures indicate approximately 2.8 million student boarding days (and nights) during 1995. Wood consumption for heating and cooking was calculated as 15 kg per student boarding day.

Rural Prisons

2.68 There were 38 prisons and prison establishments in rural Zimbabwe in 1995. The Office of the President provided detailed information on coal, wood, electricity and kerosene purchases (and measures) for the years 1995 to 1998 for the study. During 1995, there was an average of 21,000 prisoners in rural institutions, for a total of 7.67 million prisoner days during that year.

2.69 As Tables 2-17 and 2-18 show, wood accounts for the highest proportion, both on a weight basis as well as on an energy value basis for all institutions. More than 60,000 tons of wood were estimated to have been consumed by all rural institutions in 1995. This represents approximately 50 percent of total energy use.

Table 2-17. Overall Institutional Energy Demand, 1995

Fuel Source	*Tons/GWh*	*GJ*
Hospitals		
Wood (tons)	41,440	663
Electricity (GWh)	5.53	199
Coal (tons)	9,500	285
Kerosene (tons)	2,447	100
Hospitals Sub-Total		1247
Schools		
Wood (tons)	42,783	685
Electricity (GWh)	2.85	103
Coal (tons)	6,500	195
Kerosene (tons)	2,527	104
School Sub-Total		1086
Prisons		
Wood (tons)	3,304	53
Electricity (GWh)	15.71	566
Coal (tons)	2,616	78
Kerosene (tons)	3	0.14
Prisons Sub-Total		697
Total institutional		3,030

Source: Ministry of Education, Ministry of Health, Office of the President, site visits and interviews.

Table 2-18. Summary Rural Institutional Energy Use, 1995 (Units of Measure and GJ)

All Institutions	*Tons/GWh*	*GJ*
Wood (tons)	87,527	1,400
Electricity (GWh)	24	867
Coal (tons)	18,616	558
Kerosene (tons)	4,977	204
Total Institutional		3,030

Source: Min. of Education, Ministry of Health, Office of the President, site visits and interviews.

Agro-Industrial

2.70 Agriculture employs over 75 percent of Zimbabwe's population. It contributes some 16 percent of the value of GDP (compared to 23 percent for manufacturing), and is one of the most energy-intensive agricultural sectors in Africa (after South Africa). The rural agro-industrial sector reflects the highly dualistic nature of the overall economy. That is, there are large, multi-national, internationally-integrated industries in the rural sector whose organization and energy consumption parallels that of urban areas, while there are numerous smaller, often informal rural industries that co-exist side-by-side.

2.71 Slightly more than 5,500 commercial farms and ranches control over 38 percent of all agricultural land in Zimbabwe. As shown in Table 2-19, more than 1 million households farm on approximately 50 percent of the land in communal areas, while nearly 200,000 have moved into resettlement areas since Independence in 1980.

Table 2-19. Distribution of Rural Land in Zimbabwe (millions of hectares)

Type	Total area (million ha)	% Total	% Agricultural land
Agricultural			
Commercial	12.82	32.8	38.6
Small-Scale Commercial	1.42	3.6	4.3
Communal	16.35	41.8	49.2
Resettlement	2.64	6.8	7.9
Sub-Total	33.23	85.1	100.0
Non-Agricultural	5.84	14.9	
Total	39.07	100.0	

Source: World Bank, Moyo & Katerere, Zimbabwean Energy Research Organization, "Assessing the SADCC Woodfuel Problem", 1991.

2.72 Large-scale rural agro-industries require energy for their processes both as direct input (e.g., steam as process heat) and for driving the process machinery. To a lesser extent rural industrial energy demand arises from lighting and heating requirements.

2.73 The large-scale commercial farms and ranches are all tied to the ZESA grid. They use large quantities of coal and run their farm equipment with diesel fuel. Almost all large-scale farms and ranches have back-up diesel and petrol gensets.

2.74 The large-scale timber industries of the Forestry Commission, Border Timbers and The Wattle Company utilize a small amount of wood waste for energy, while the bulk of their energy is either purchased commercially from ZESA (for electricity) and the coal companies (for process heat).

2.75 Similarly, the two sugar processing companies utilize the bagasse produced as waste, while also consuming large quantities of coal and electricity. Neither company generates electricity for sale into the ZESA grid, although both have considered this. This is not only technically feasible, but would be good for the overall national economy.

2.76 The tea factories grow their own eucalyptus wood on plantations. They use the wood to raise steam for processing their green tea. However, they are all connected to the grid and do not use wood for electricity generation. The coffee industry produces large quantities of waste, but does not consume any of it. Production is highly decentralized, making utilization for heat or electricity generation difficult under current conditions.

2.77 Rural dairy production is primarily concentrated in the large-scale commercial farms, although smallholders are of increasing importance. Dairy processing occurs almost entirely in the urban areas where the milk is taken for processing through the Dairy Marketing Board.

2.78 Small-scale farmers are tied into traditional energy use. A growing number of medium-scale farmers in resettlement areas have mechanized their production, but they account for very little rural energy consumption. Small-scale traditional farmers use virtually no commercial energy for production, and only use commercial energy (electricity and diesel) to grind their grain at various milling centers.

Tobacco

2.79 The major exception to this pattern is the tobacco sector. Zimbabwe is the world's second largest tobacco exporter. Tobacco is the most important cash crop in the country, accounting for over 6 percent of GDP and 40 percent of exports (more than US$400 million in 1997), and directly employing half a million people. Estimated 1997 flue-cured production was 186 million kilograms (186,000 tons), based on 91,000 hectares at a yield of 2,044 kg/ha.

2.80 Some 1,750 large tobacco producers and 2,300 smallholders produced tobacco in 1997. Smallholders produced on about 4,200 hectares of land. Of these smallholder farmers, 75 percent (about 1,725 farmers) cure their tobacco using wood, while the remainder use coal. All large tobacco farmers cure their tobacco with coal (more than 9,600 tons in 1995). The Zimbabwe Tobacco Association estimates that the average smallholder obtains a yield of 800–1,200 kg per hectare (less than one-half what large producers harvest). They estimate the fuelwood requirement at 0.3 hectares of eucalyptus per hectare of tobacco harvested.

Tea

2.81 Tea is grown on three major private estates and on estates owned by the Agricultural and Rural Development Authority (ARDA). Tea is of growing importance to Zimbabwe's economy, and has become an important export crop.

2.82 Tea is processed on the private estates on a sustainable basis with fuelwood produced on the estates own plantations. Some wood is also bought from outgrowers who have their own plantations. The ARDA estates process their tea using coal boilers. Both private and ARDA tea processors also use significant amounts of diesel fuel for standby/back up generating sets, although they are all connected to the ZESA grid. Given the demanding requirements for tea production, electricity must be totally reliable. Given ZESA's recent problems, all tea estates have grown increasingly reliant on their own diesel gensets.

Coffee

2.83 Coffee is also of growing importance in Zimbabwe. Four major coffee producers account for the bulk of Zimbabwe's coffee production, along with ARDA, which grows coffee along with tea and other cash crops. Their Katiyo tea estate uses boilers for tea production. Table 2-20 shows the coal consumption by ARDA from 1990 to 1997.

Table 2-20. ARDA Coal Consumption, 1990 to 1997 (tons and GJ per year)

Year	Tons/year	GJ/year
1990	1,295	38.85
1991	1,262	37.86
1992	1,229	36.87
1993	1,095	32.85
1994	1,110	33.30
1995	985	29.55
1996	1,248	37.44
1997	1,294	38.82

Source: Agriculture and Rural Development Authority.

2.84 The four largest coffee growers consume large amounts of commercial energy.[8] As Table 2-21 shows, the coffee sector consumes relatively small amounts of firewood. This is almost entirely for domestic consumption on the large estates. Diesel fuel is used primarily for production (tractors), and for backup/standby electricity generation. All estates are connected to the ZESA grid.

Table 2-21. Energy Expenditures in the Coffee Sector, 1992–1997 ('000 Z$)

Energy Source	1992–93	1993–94	1994–95	1995–96	1996–97
Electricity	115,746	78,007	77,395	272,885	426,735
Firewood	9,225	5,394	11,682	22,751	10,486
Diesel	86,054	20,014	22,642	53,768	56,804
Total	211,025	103,415	111,719	349,404	494,025

Source: DOE, coffee estate interviews and site visits.

Other Agricultural Crops

2.85 Zimbabwe has a large commercial agricultural sector. More than 200,000 tons of diesel fuel and more than 600,000 tons of coal were consumed in the commercial agricultural sector (excluding tobacco) in 1997. Zimbabwe has become a world-class exporter of horticultural crops and specifically cut flowers. These have high energy requirements. Zimbabwe's large commercial farms use considerable energy for producing, harvesting and processing grains and other crops. With the exception of tobacco, however, smallholder agriculture in Zimbabwe has very low energy requirements.

Forestry

2.86 Forestry is a major economic sector in Zimbabwe. It is a net supplier of energy. Over 95 percent of all households in rural Zimbabwe and nearly one-quarter of all urban households depend on the forestry sector to provide them with fuelwood. However, almost all of this demand is met by informal suppliers, either traditional (non-cash) or through small-scale producers, transporters and suppliers.

[8] The four largest producers, in addition to ARDA, are New Year's Gift, Jersey, Avontuur and Petronella.

2.87 In contrast to the rural domestic sector, little use is made of wood for energy. Some wood waste is used to provide process heat, but much of the waste is left to rot or be disposed of. Given that the major forestry industry processing plants are grid-connected, an opportunity exists for these plants to generate and export electricity.

Mining and Other Rural Industry

2.88 Mining is an important rural sector. However, while there are hundreds of small mines, they are still integrally linked into the cash economy. Many are not connected to the ZESA grid, and nearly all have diesel or petrol generators. Indeed, after commercial establishments and institutions, mines make up the largest users of diesel and petrol gensets. Both large and small mines also use a large amount of coal. As Table 2-12 showed earlier, Wankie Colliery sells an average of more than 65,000 tons of coal directly to the mining sector. One-half that amount is supplied again through a dozen coal distribution companies. It is estimated that the mining sector uses as much as 30,000 tons of wood, primarily for providing fuel for cooking and heating for its workers.

2.89 One of the largest rural industries is brick-making. The large-scale brick producers are primarily in urban areas, while the informal sector brick producers are located in rural areas. Approximately 35 percent of their energy consumption derives from coal, while the rest is obtained from wood. An estimated 100,000 tons of wood was used to produce bricks in rural Zimbabwe.

2.90 Rural brewing of beer is entirely small-scale, informal and artisanal. Although large quantities of wood are consumed for this activity, only general usage estimates are possible. Rural baking is of growing importance. However, DOE estimates that until recently 85 percent of all rural bakeries used electricity, including electricity from diesel generating sets.

3

Trends and Opportunities

Grid Electricity

3.1 ZESA has set itself a difficult target with regard to providing electricity to rural Zimbabweans, not least through its mission statement "to provide access to electricity to all". In order to achieve this target and fulfill its mission, ZESA must overcome a number of constraints.

3.2 Because electricity demand already exceeds the supply capacity of the grid, ZESA is being forced to import as much as 25 percent of its electricity. Electricity prices have increased fairly significantly over the past several years but, due to the collapse of the currency, are still below the long-run marginal cost.

3.3 Also, ZESA faces severe financial restrictions. It is unable to invest in new system infrastructure (network and generating plant) and its importation of electricity generated in Mozambique and South Africa represents a major expense. ZESA and the Government of Zimbabwe are currently working to resolve this. The options being considered are power sector restructuring and more private sector participation, either through public/private joint ventures or independent power producers (IPPs).

3.4 Although ZESA is beginning to be more proactive in extending the electricity grid, it is also accepting the reality that other supply alternatives need to be considered. Rural electrification planning needs to begin with accurate statistics about the existing network and rural customers. This ZESA-DOE/ESMAP survey has revealed that ZESA's database needs updating. The very act of carrying out the survey has supplied new information to ZESA, which will help its planning function.

3.5 ZESA has accepted the view that alternative supplies of electricity (e.g., car batteries, PV or small generating sets) can be viewed as pre-electrification. Encouraging small-scale, low-power electricity use can prepare households and other consumers for future grid-connections and develop electricity demand so that the economics of future grid-connection can be justified.

3.6 The advent of the Southern African Power Pool (SAPP) may help to reduce the cost of imports. The rehabilitation to full capacity of the Cahora Bassa hydropower station in Mozambique will increase regional electricity availability and reduce energy costs. Together with other Southern Africa Development Conference (SADC) Governments and utilities, ZESA are playing an active role in the development and implementation of the SAPP.

Non-Grid Electricity and Household/Small Commercial Use

3.7 ZESA's enlightened attitude towards alternative, non-grid electricity supplies have led it to offer support to the wind electricity pilot project in Temaruru (see Annex 8) and opened the organization up to developing innovative "mini-grids", battery charging systems and other independent power systems. The Temaruru Community Power Trust is a novel renewable energy project currently taking place in the Eastern Highlands of Zimbabwe. In contrast to Government- and donor-initiated renewable energy projects, which underestimate the ingenuity and determination of rural people to obtain electrical power through do-it-yourself means, responsibility and ownership of the Temaruru system will lie with the community, which will operate, administer and manage the system along commercial lines. The system incorporates

- a 230-Vac mini-grid supplying about ten businesses and
- a battery charging station for local battery users.

3.8 The Trust brings together stakeholders from all sectors with the aim of providing a sustainable energy supply to the local community. ZESA sits on the Board of Trustees alongside community members and representatives of Government, industry and NGOs, amongst others.

3.9 In addition, ZESA has worked closely with the UNDP/GEF PV project and the Agricultural Finance Corporation (AFC) to provide innovative finance and technical services to nearly 1,000 rural households. ZESA signed a memorandum of understanding with the Government of Zimbabwe and the UNDP in April 1997. Its role involves amortizing the cost of solar home systems over a period of 10 years. The customer pays back to ZESA at intervals that suit the customer. Annual payments have been found to be appropriate for many rural dwellers whose cash flow is influenced by seasonal agricultural activities.

3.10 The UNDP/GEF funds allocated to ZESA for the scheme cover all the system costs. ZESA agreed to contribute all overheads associated with running the scheme. Training sessions were held to introduce ZESA staff to UNDP/GEF system components and installation standards.

Batteries, Battery Charging, SHSs, PV Lanterns, and High-Efficiency Kerosene

3.11 Car battery users pay very high prices for their electricity. Their opportunity costs for that electricity are also high. A typical car battery user will pay approximately US$1.00 per charge. She/he will also spend, on average, the same amount on transporting the car battery to a charging station. Because all charging stations are connected to the grid, car battery users often take their batteries 10, 20 or more kilometers for a charge. Depending on use, a car battery user will charge the battery as often as once a week. A typical household will charge the battery once or twice a month. This leads to effective kilowatt-hour costs of anywhere from US$1.00 to US$3.00 per kWh, counting transport and battery depreciation.

3.12 More than one-half of all battery users buy their batteries second-hand, but still pay of the order of US$20-40 for a used battery. The 40 percent or more who purchase new car batteries can pay as much as US$100 per battery. The fact that more than 225,000 users are in this market indicates their strong willingness, and their ability, to pay for such basic electricity services. An entire "industry" has grown up around car batteries for rural electrification. This shows both innovation and willingness, and it provides some good indications about how future rural electrification programs could be structured.

Petroleum Products and Self-Generation

3.13 The ZESA-DOE/ESMAP survey indicated large numbers of petrol/gasoline and diesel gensets. Many commercial establishments utilize gensets regularly, as do most rural industries and mines not connected to the ZESA grid. Sales figures for 1997 show significant numbers of gensets (representing more than 2.3 MVA of capacity) entering service, which could be attributed partly to ZESA's difficulties in extending the grid.

3.14 As observed in other parts of the world, most gensets have been purchased as needed, on an ad-hoc basis. There is no "rationalization" of purchase whereby more than one user would co-finance purchase of a genset and then share the electricity. This is partly the result of past prohibitions on the non-ZESA sale of electricity and partly the result of dispersed demand, but also partly a result of lack of awareness of the financial and technical benefits of procuring systems with better load configurations (i.e., more consumers). The fact that there are so many gensets in rural Zimbabwe, and that many are oversized for most household needs, indicates good scope for rationalizing the system and promoting "mini-grids", or even small utilities, to sell to other consumers, and obtain higher efficiency from existing genset use.

3.15 In addition, many rural industries, for which reliable electricity supply is crucial, have stand-by diesel or petrol generation.

3.16 Both private and ARDA tea processors (see Chapter 2) use significant amounts of diesel fuel for standby/back up generating sets, although they are all connected to the ZESA grid. Given the demanding requirements for tea production and ZESA's recent problems, all tea estates have grown increasingly reliant on their own diesel gensets. Similarly, the major coffee estates including ARDA (see Chapter 2) use diesel fuel primarily for production (tractors) and for backup/standby electricity generation. Like the tea estates, all coffee producers are connected to the ZESA grid.

3.17 With the right incentives, tea and coffee plantations and other rural industries could be encouraged to invest further in sufficient plant to generate electricity, not only for their own needs (and those of their workers) but also to export into the grid. This would provide ZESA with excess generating capacity at crucial locations around the country.

Non-Petroleum Self-Generation in the Large Commercial, Agricultural, and Industrial Sectors

3.18 Several private initiatives, both existing and new, are under way in Zimbabwe in the field of renewable energy development. The private sector—particularly the large-scale–plantation, multinational sector—has been one of the most active participants. The big wood companies (including the timber, and pulp and paper companies) employ tens of thousands of rural Zimbabweans, and the industry represents one of the most efficient wood industries in the world, exporting a large part of its production. Continuing the trend for innovation and active participation in rural energy supply, the timber industry would like to rehabilitate the power plant at Mutare and generate electricity from wood wastes. Discussions are currently taking place. The generation of electricity from wood waste would be a great asset to ZESA. It would reduce import requirements and strengthen the opportunities for grid-extension around Mutare.

3.19 Tea is processed on the private estates on a sustainable basis with fuelwood produced on the estates own plantations. Some wood is also bought from outgrowers who have their own plantations. The ARDA estates process their tea using coal boilers. As with the diesel generation available within the tea industry, the right incentives may encourage the plantations to invest in steam generating plan and to supply the ZESA grid.

Biomass (Bagasse and Crop Residues), Wind, and Small Hydropower

3.20 Zimbabwe is an important sugar producer (see Table 3-1). The producers meet their energy needs during the crushing season by burning bagasse to raise steam. They could not only be self-sufficient (overall) to meet their energy demands, but could also export an estimated 90 GWh of electricity into the ZESA grid each year, if only were they able to invest in the required equipment.

Table 3-1. Electricity Production and Potential Exports, 1998

Establishment	*Triangle*	*Hippo Valley Estates (HVE)*
Installed capacity (MW)	33	23
Effective generation capacity (MW)	22	13
Electricity exported to ZESA	Under discussion	Under discussion
Cane crushing capacity (tons/hour)	485	600
Ethanol production	Exported	None

Source: Triangle, HVE and ZESA.

3.21 In the past, considerable interest has been shown in developing small-scale hydropower in Zimbabwe. Few than 10 of the several hundred potential sites (dams used for drinking and irrigation water) have been exploited. Studies have shown that considerable opportunity exists for developing more of those sites.

3.22 The most thorough study of the many dams was conducted in 1990 and 1991 with support from GTZ to the then Ministry of Energy and Water Resources. The investigations concluded that only six sites were economically feasible.

3.23 Today, however, there is good reason to revisit this study and the economics of these sites. The 1991 study pointed out that several sites could be developed for *local* electricity demand—and that, if local economic factors were considered rather than grid supply factors, a number of other sites could be considered economically viable. Considering the price rural dwellers pay for diesel-generated electricity, for batteries and battery charging, and for photovoltaics, the assumption that several more of these sites could be economically developed to meet off-grid rural demand could prove valid.

4

Issues

Affordability, Quality of Service and Potential Markets

4.1 ZESA's domestic (E.1) tariff structure for 1997–98 is as follows:

- *E1.1 Conventional meter.* The fixed monthly charge is Z$20.00. Energy charges are 23.64 cents per kWh for the first 300 hours and 67.27 cents per kWh thereafter.
- *E1.2 Prepayment meter.* Energy charges are 48.04 cents per kWh consumed.
- *E1.3 Load-limited domestic customers.* Ratings and charges are as follows:

Rating (Amps)	*Monthly Charges (Z$)*
1.0	30.00
2.5	45.00
5.0	70.00
7.5	90.00
10.0	145.00
15.0	200.00
22.5	286.00
30.0	353.00

4.2 In urban areas the E1.1 and E1.2 tariffs predominate. Conventional metering provides the most flexible form of supply arrangement for the customer whilst pre-payment metering allows flexibility within a controlled energy budget. Both types of metering require regular attention by ZESA metering staff and, because there is a significant cost related to the regular reading of each meter, the utility prefers only to encourage these meters in urban and peri-urban areas.

4.3 In the rural setting, it is difficult and expensive (relative to sales revenue) for ZESA to read meters. In rural areas, load-limited supplies with a fixed monthly charge can prove to be much more cost-effective.

4.4 Inflation in 1998 averaged over 50 percent per annum; as of mid-1999 it was about the same. The Zimbabwe dollar has suffered substantial depreciation against all major currencies during the past two years, Table 4-1 shows versus the U.S. dollar.

Table 4-1. Exchange Rate: Zimbabwe Dollar vs. U.S. Dollar, 1992–February 2000

Year	Z$ = US$1
1992	6.25
1993	6.47
1994	8.15
1995	8.66
1996	9.92
1997	11.89
1998 avg	30.25
Feb-99	38.6
Mar-99	38.2
Apr-99	38.2
May-99	38.2
Jun-99	38.1
Jul-99	38.2
Aug-99	38.2
Sep-99	38.3
Oct-99	38.1
Nov-99	38.2
Dec-99	38.2
Jan-00	38.2
Feb-00	39.2

Source: World Bank.

4.5 This has had a major effect on household incomes throughout the country. However, as was seen in many parts of Asia in the wake of the financial crisis of 1997, rural households have tended to fare much better than their urban counterparts. This stems partly from the fact that they meet so many of their basic needs (food, energy) from local, rural sources. It also stems from the fact that the terms of trade, based primarily on agriculture and the sale of wood energy to urban areas, has shifted (at least temporarily) in their favor.

4.6 Nonetheless, rural Zimbabwean households—particularly those in the communal areas, which are largely based on subsistence farming—have suffered as the price of every purchased basic commodity (from maize meal to sugar) has soared. The prices of kerosene, dry-cell batteries and other basic non-biomass energy supplies have soared, hitting subsistence households particularly hard. With a per capita income of less the US$400 per annum, these households are in no position to move "up the energy ladder" to electricity, regardless the source.

4.7 On the other hand, rural Zimbabwean households tied into the cash economy, particularly small-scale rural commercial farmers, have not suffered as much as either the communal households or the poor urban household. With per capita income ranging from US$800 to US$3000 per annum, these households, who generally produce a surplus of commodities for urban consumption and export, have not witnessed a deterioration in their terms of trade vis-à-vis the urban sector. They too have been hit by the high price of imports, or commodities with high import content (e.g., kerosene, car batteries, PV modules). Data are not currently available to indicate the scale of the impact on these households' purchase and use of these energy commodities.

Geographic Disparity and Infrastructure

4.8 Considerable disparities exist in rural Zimbabwe. The large-scale commercial farming and ranching sector is a world away from the communal small-holder sector in nearly every aspect, not least in terms of energy use and consumption. Large-scale farms and ranches more closely resemble urban or modern patterns than rural, developing-country patterns, whereas the energy consumption in rural subsistence communal households closely resembles other parts of rural, non-monetized Africa.

4.9 Geographic disparities also exist, although several anomalies can be observed in the energy sector. The northeast heartland of Mashonaland (Mashonaland Central), with its large concentration of commercial farming (both large-scale and small-scale) has far higher energy consumption, particularly "modern" energy (e.g. kerosene, grid electricity, car batteries) than the southern part of the country, particularly southern Manicaland. However, southwestern Matabeleland (particularly Matabeleland South), with its large number of migrant laborers in South Africa and urban Zimbabwe, has a surprisingly high concentration of "modern" energy supplies, including PV, kerosene and car batteries. Remittances from urban areas to rural areas are important throughout Zimbabwe, but remittances from South Africa (particularly the mines) are particularly important in southwestern Zimbabwe. The concentration of household PV systems in this geographic area is only matched in the northeast, in the areas around Harare.

4.10 Other services, including financial and technical services, match this pattern. Northeastern Zimbabwe (particularly Mashonaland Central and East Provinces), which is relatively close to the capital, Harare, is relatively well-served by the financial sector (banks, insurance companies, pension funds). Southeastern Zimbabwe (particularly Matabeleland South) with the industrial center of Bulawayo, and with its large number of migrant workers and families in South Africa, is also relatively well-served by the financial sector. In both cases, technical services, such as suppliers of agricultural equipment and other machinery (including PV distributors), are considerably better than most of the rest of the country. The Eastern Highlands, with their concentrations of high-value crops such as tea, coffee and timber, are also relatively well served by these financial and technical services, although there exist great disparities in income distribution here.

Cost of Supply Alternatives

4.11 In general, the price per kilowatt-hour that rural Zimbabweans are prepared to pay for off-grid electricity exceeds by far ZESA's electricity tariffs.

Car Batteries

4.12 With the minimum cost of battery charging at around Z$35, once transportation costs have been included the cost of electricity supplied by a car battery can exceed Z$70/kWh. (Because transportation costs vary considerably, a low estimate was used in the analysis to provide a conservative estimate.) More than 230,000 rural Zimbabweans access electricity using this method. Tables 4.2 and 4.3 provide estimates for the costs of electricity from batteries.

Table 4-2. Estimated Cost of Used Battery (US$)

Recycled Battery System	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*
Battery	25	25	25	25	25	25	25	25
Charging		52	52	52	52	52	52	52
Transport		39	39	39	39	39	39	39
Electronics								
Installer								
Total costs	25	116	116	116	116	116	116	116
kWh yield/yr		26	26	26	26	26	26	26
Cost per kWh	2.11							

Note: 0.5 kWh per battery, charge once a week $1; transport $0.75 per week; battery lasts one year.
Source: ESMAP team.

Table 4-3. Estimated Cost of a New Battery (US$)

New Battery system	0	1	2	3	4	5	6	7
Battery	50		50		50		50	
Charging		52	52	52	52	52	52	52
Transport		39	39	39	39	39	39	39
Electronics								
Installer								
Total costs	50	91	141	91	141	91	141	91
kWh yield/yr		39	39	39	39	39	39	39
Cost per kWh	1.43							

Note: 0.75 kWh per battery, charge once a week $1; transport $0.5 per week; battery last 2 years.
Source: ESMAP team.

4.13 A current limited supply of 1.0 A costs Z$30 (see section 4.1) and would provide much better service to a rural household than a car battery, as well as doing away with the inconvenience of recharging and transport.

Photovoltaics

4.14 Most solar units reported in the survey were estimated to cost more than Z$3000 (US$80), with a mean price of Z$5000 (US$140) and deluxe systems costing Z$14,000

(US$400). Tables 4.4 and 4.5 calculate the kWh cost of electricity for a deluxe and a small solar home system. The cost of electricity is estimated at between US$0.69 and US$0.93 per kWh. This is, again, greatly in excess of the cost of grid electricity. The cost of electricity from small PV systems is higher.

Table 4-4. Estimated Cost of PV Electricity, Large System (US$)

50-watt deluxe	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*
Panel	400															
Battery	100			100			100			100			100			
Electronics	75															
Installer	50															
Total cost	625	0	0	100	0	0	100	0	0	100	0	0	100	0	0	0
kWh yield/yr		73	73	73	73	73	73	73	73	73	73	73	73	73	73	73
Cost per kWh	0.69															

Note: Battery lasts 3 years.
Source: ESMAP team.

Table 4-5. Estimated Cost of PV Electricity, Small System (US$)

12-watt Handyman Special	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*
Panel	100															
Battery	45			45		45			45		45			45		45
Electronics																
Installer																
Total costs	145	0	0	45	0	45	0	0	45	0	45	0	0	45	0	45
kWh yield/yr		17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5
Cost per kWh	0.93															

Note: Battery lasts 2.5 years.
Source: ESMAP team.

Diesel/Petrol Generating Sets

4.15 The ZESA-DOE/ESMAP survey found very few rural households making use of gensets to provide electricity. It is estimated that around 6.8 percent of all commercial organizations have a genset. The estimated cost of electricity delivered by a small generating set, between US$0.28 and US$0.41 per kWh (Tables 4.6 and 4.7) is less than that supplied by both PV electricity and car battery. However, the up-front cost for a genset is higher than for a PV system, and the amount of electricity used is higher as well.

Table 4-6. Cost of Electricity Produced by a 1.5-kVA Generating Set (US$)

1.5 kVA generator	*0*	*1*	*2*	*3*	*4*	*5*
Equipment	1000					
Fuel (4 hrs/day)		735.8	735.8	735.8	735.8	735.8
O&M, spares		50	50	50	50	50
Total costs	1000	785.8	785.8	785.8	785.8	785.8
kWh yield per yr		1752	1752	1752	1752	1752
Cost per kWh	0.41					

Note: 0.42 l per kWh; $1/l; O&M 2 percent of equipment cost.
Source: ESMAP team.

Table 4-7. Cost of Electricity Produced by a 15-kVA Generating Set (US$)

15-kVA generator	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*
Equipment	7500							
Fuel (4 hrs/day)		5782	5782	5782	5782	5782	5782	5782
O&M, spares		375	375	375	375	375	375	375
Total costs	7500	6157	6157	6157	6157	6157	6157	6157
kWh yield/yr		17520	17520	17520	17520	17520	17520	17520
Cost per kWh	0.28							

Note: 0.33 l per kWh; $1/l; O&M 2 percent of equipment cost.
Source: ESMAP team.

4.16 From ZESA's point of view, electricity supplied by genset could be considered the best form of pre-electrification. The supply is ac, which means that wiring and appliances are appropriate for use with a grid supply. In addition, because gensets generally deliver more power than a battery or PV system, genset users develop a greater need for electricity and are "better" new grid consumers. (The grid can also provide electricity in a cleaner and quieter way than a genset.) For these reasons, it would be appropriate for ZESA to consider supporting the promotion of gensets to domestic as well as commercial and other organizations.

5

Institutional and Regulatory Framework and On-going Activities

Government

Institutional Setting

5.1 Except for certain specific issues, responsibility for energy sector research, development, regulation and price setting (for liquid fuels and electricity) in Zimbabwe rests with the Department of Energy (DOE) in the Ministry of Transport and Energy (MTE). The Assistant Director for Research and Development of the DOE's New and Renewable Energy Division is responsible for coordinating renewable energy policies. Some renewable energy activities are carried out by the Energy Planning and Conservation Division of the DOE.

5.2 The Ministry of Mines takes responsibility for coal and the Forestry Commission for fuelwood. The environmental impact of energy use is the concern of the Ministry of Tourism and Environment (Department for Natural Resources). The Finance Ministry and the National Economic Planning Commission hold a supervisory function with regard to investment decisions and financing parastatals. It is intended that the effectiveness of this institutional set-up will be subjected to periodic reviews, particularly with respect to energy sub-sector pricing policies.

National Energy Policy

5.3 In 1994, the Cabinet approved the National Energy Policy. This document guides the Department of Energy and the responsible Minister in energy sector decision making. At the time of drafting the major constraints in the energy sector, as the Government perceived them, were:

- low capacity in the electricity sector,
- insufficient grid coverage, especially in the rural areas,
- insufficient reticulation for urban areas,

- high transport costs for coal,
- high transport costs for fuelwood, and
- high capital costs for solar systems.

Within this context, the policy document's objectives were to:

- ensure accelerated economic development,
- facilitate rural development,
- promote small-medium scale enterprises,
- ensure environmentally friendly energy development, and
- ensure efficient utilization of energy resources.

5.4 Notably, these objectives provide a significant platform for the support of rural energy development. The National Energy Policy acknowledges the fact that rural development is dependent on increased energy supplies to rural areas—especially coal, electricity and new and renewable sources of energy—to promote growth and arrest environmental degradation caused by deforestation. The policy further indicates that woodlot programs, improved supply and end-use techniques and fuel substitution will all be used to tackle fuelwood problems.

Parastatals

5.5 There are two energy parastatals, the Zimbabwean Electricity Supply Authority (ZESA) and the National Oil Company of Zimbabwe (NOCZIM). The Forestry Commission (FC) is the parastatal responsible for commercial wood production (primarily timber, pulp and paper) from the public estate. Under the National Energy Policy, ZESA and NOCZIM are to be given greater autonomy. This autonomy will be accompanied by the requirement for the organizations to become more accountable and transparent. It is believed that these steps will lead to better overall performance and efficiency.

5.6 ZESA operates under the Electricity Act of 1985. The Electricity Act is currently under review, and the third set of amendments to the Act is currently with the Attorney General's Office. Under the Act, ZESA is the only legal entity with the right to transmit and generate electricity. It can license independent power producers (IPPs), but it sets the purchase price for any electricity bought from licensed IPPs. Currently, neither third party access (TPA) nor "wheeling"[9] nor other uses of the grid by third parties is permitted under the Act. The Act establishes uniform national tariffs approved at Cabinet level. "Lifeline" tariffs have been a part of the Government of Zimbabwe's social service program since Independence.

5.7 Although the bulk of ZESA's rural electrification program has been grid-based, it has also been active in supporting innovative solutions to rural electrification. From 1996 to 1998 ZESA worked closely with the UNDP/GEF Solar PV Project and the Agricultural Finance Corporation (AFC) to provide innovative finance and technical services to nearly 700 rural households. Although ZESA acknowledges the delivery under this program has been expensive,

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[9] Electricity suppliers are *wheeling* when they pool electricity into a network, then deliver to the end-user through this network.

it also realizes that it has gained good insights into various options for rural electrification. A primary purpose of ZESA's energy use survey was first, to determine how best to promote electricity use to poorer households in urban areas. Second, ZESA is keen to develop programs that disseminate electricity to wide areas in order to

- prepare households and other consumers for future grid connections and
- develop electricity demand in these areas so that the economics of future grid connections can be justified.

5.8 Thus, ZESA takes an enlightened attitude towards rural electrification, and has been discussing such issues as power generation from wood wastes in Mutare and generation and sales to the grid from bagasse at Triangle and Hippo Valley (HVA). ZESA provided support to ESMAP and DOE for a pilot wind project at Temaruru, in Rusape. During discussions for this study, ZESA stated its openness to supporting the development of innovative off-grid solutions such as "mini-grids", battery charging systems and other independent power systems in light of its mission statement, mandate and future strategic position.

5.9 ZESA's financial situation has deteriorated dramatically since the decline of Zimbabwean currency that began mid-1998. Although tariffs have been increased by about 92 percent since September 1998, further tariff increases are required to restore ZESA's financial viability. The Government has agreed to a schedule of further increases (20 percent on a quarterly basis) necessary to restore and maintain ZESA's financial situation.

Draft National Energy Strategy

5.10 Zimbabwe's energy situation has changed markedly since 1994 when the National Energy Policy was enacted. In 1996 the Ministry of Transport and Energy headed up a multi-ministerial and multi-sectoral committee to set out a national energy strategy. This resulted in a draft presented for review to all key stakeholders in 1997. The draft has yet to be approved. Even though the draft national energy strategy deals with rural energy issues, much more attention needs to be paid to this area of Zimbabwe's energy economy. Given the importance of the rural sector, developing a sound rural energy strategy is of major importance if government, donors and NGOs wish to see the sector developed in an economically efficient and equitable manner.

Draft National Biomass Strategy

5.11 The Government also formed a multi-ministerial and multi-sectoral committee to draft a national biomass strategy. As with the draft national energy strategy, the draft national biomass strategy was completed and circulated for comments. Thus far, this strategy has not been enacted. It contains many elements pertinent to the rural sector. Given the importance of woody biomass to rural households and small enterprises, defining a strategy that optimizes the economic use of this resource in the most equitable manner is of key importance. Because Zimbabwe has a large and important commercial biomass sector (timber, pulp and paper, sugar and bagasse), it is also important to set out strategic priorities for encouraging least-cost development and utilization of biomass resources in these sectors.

Donors (Multilateral and Bilateral) and NGOs

5.12 A number of donor- and NGO-supported rural energy programs and projects have been undertaken in Zimbabwe over the past two decades; following are the most significant in terms of size, scope and impact.

5.13 Silveira House, Biomass Users Network (BUN) and GTZ have all supported rural biogas. Perhaps 200 units have been installed, although it is unclear how many are operational.

5.14 As noted elsewhere, GTZ and the DOE have pilot-tested solar pumping schemes since the late 1980s. However, solar pumping has not spread for a variety of reasons including lack of cost-effectiveness.

5.15 The Biomass Users Network has been active in a number of fields, from wood-waste briquetting with the Forestry Commission in Mutare, to improving rural household stoves. The Zimbabwean Energy Research Organization (ZERO) has been active in the field of wind electricity, and has worked with several communities on a pilot basis. With Dutch Embassy assistance, ZERO is currently developing several more wind electricity systems as well as setting up a national database. The Intermediate Technology Development Group (ITDG) has worked with a local community to develop Zimbabwe's first community-based small hydropower system. The system utilizes a cross-flow turbine, based on Nepalese experience. ITDG has also been active in promoting rural energy efficiency both through education, seminars and dissemination and through pilot stove projects, as have ZERO and BUN. A number of other indigenous NGOs have been active in promoting improved rural stoves, although the success of these programs is open to question.

5.16 In the late 1980s the British Overseas Development Administration (ODA, now the Department for International Development or DFID) supported improved wind-pump production in Zimbabwe. Although this program has ceased, wind pump production has accelerated in recent years, and the ITDG design promoted through the original ODA program is in wide use.

5.17 The Japanese International Co-operation Agency (JICA) is currently undertaking a pilot PV program. This focuses on 100 households in several communities, with intensive monitoring and evaluation of all facets, from product delivery to servicing.

5.18 The UNDP/GEF Solar PV project has been the most extensive PV programs in Zimbabwe, and one of the largest donor-funded PV programs in the world. The program estimates variously that it has been instrumental in the installation of between 8,000 and 10,000 solar home systems. The failed Zimbabwean currency has, however, undermined the program and the revolving fund has eroded to the point that most activities have come to a stop.

5.19 In addition, Zimbabwe was involved in the first phase of the UNDP's Financing Energy Services for Small-Scale End-Users (FINESSE) initiative. Under the FINESSE program, small-scale energy investments will be organized into project schemes that can then qualify for funding through large loans supported by local and international financing agencies. Technology and market assessments have been carried out under the program. Unfortunately, these studies are the only output to date, and none of the business plans has led to project implementation on the ground.

Private Sector

5.20 Several private initiatives are under way in the field of new renewable energy development in Zimbabwe. The private sector, particularly the large-scale plantation, multi-national sector, has been one of the most active sets of players in rural energy development and exploitation in Zimbabwe. The big wood companies, including the timber, and pulp and paper companies, employ tens of thousands of rural Zimbabweans in their work, and the industry represents one of the most efficient wood industries in the world, exporting a large part of its production. Beyond selling or distributing some of its wood as by products, it has also attempted to develop wood waste briquettes. The timber industry would like to rehabilitate the power plant at Mutare in order to generate electricity from wood wastes. This, however, is still in the discussion phase.

5.21 The sugar industry has developed the ethanol-for-energy program. However, given current world and local prices, it finds it more profitable to export the ethanol that has been, in the past, blended with motor petrol/gasoline to reduce Zimbabwe's near-total dependency on imported petroleum products. In addition, the sugar industry produces its own energy for raising steam to process and refine sugar. It also produces electricity that it could, given the right financing and investment mechanisms, sell to the ZESA grid or elsewhere.

5.22 The tea industry is relatively self-sufficient in energy. It plants and harvests its own trees to drive its boilers. It could become invest further in such plant to generate electricity to cover its needs (and those of its workers) and to export into the grid if the incentives were right.

6

Energy Supply Recommendations

Grid Electricity

6.1 Extending the electricity grid to rural areas in Zimbabwe, as in many other Africa nations, is an extremely high-cost option for bringing a modern energy supply to rural populations. ZESA, through its very strong mission statement, has set itself a difficult task in view of its major capital and financial constraints. Recently, the organization's own work has shown that other, non-grid, autonomous solutions can be more cost-effective. This report supports these findings by presenting the survey results. The recommendations in this chapter are based on this premise.

Grid Recommendations

6.2 Given these facts—and the demonstrated independent ability of rural Zimbabweans to self-finance novel, innovative rural electrification activities (e.g., battery charging, PV home systems, diesel and petrol gensets—it is recommended that:

- ZESA rethink its priorities for rural electrification in order to capitalize on these efforts;
- Non-grid options be viewed positively as accelerating rural electrification and, ultimately, increasing future demand for ZESA's goods and services; and
- Support be provided to small-scale power solutions, whether from wood waste, wind, PV, battery charging stations or other sources.

6.3 The following paragraphs outline the kind of support that would benefit individual off-grid options.

Recommendations for Non-Grid and Household/Small-Scale Commercial Generation

PV Systems

6.4 The existing extensive use of PV systems in Zimbabwe indicates that the technology is acceptable to the rural population. Considerable effort has been put into promoting PV systems through the UNDP/GEF and it is believed that at least 50 companies are currently active in PV. In this regard, it is felt that there is no real need for any further demonstrations.

6.5 The major recommendations for PV are as follows:

- The Government should move quickly to exploit the current dynamic in the PV market.
- The removal of tariffs, duties and taxes on the import and sale of PV panels, cells, modules, and regulators should be extended to all PV activity, not just that falling within the scope of the UNDP/GEF project. This would further promote the industry and help accelerate PV solar penetration in isolated areas. It is an anomaly that a project is granted tariff and duty relief while private enterprises directly importing such equipment (and on a larger-scale) are not.
- ZESA, the Government and donors should encourage innovative means of finance and support to help overcome the high first-cost barriers for consumers. Innovative financing, leasing, purchase hire, and other schemes should be pilot tested to accelerate the commercialization of PV in rural areas. Extending financial support to entrepreneurs wanting to initiate PV retailing in rural areas should also be considered.
- In this regard, consideration should be given to using the remaining UNDP/GEF funds to seed financial support mechanisms for private (retail and purchase) activities in PV.

Solar Water Heating

6.6 Solar water heating has been shown, in a number of countries, to be quite cost-effective in reducing peak grid electricity demand. Moreover, solar water heating production capability already exists in Zimbabwe. Therefore, given ZESA's financial situation, it is recommended that this be pursued more actively. This could involve incentives for end-users and/or manufacturers.

Mechanized Power

6.7 The opportunity exists to extend the scope for mechanized power by introducing electricity generating equipment, primarily for battery charging, to grain-grinding mills. Pilot efforts have been made in this area, but these activities have lacked a strong commercial focus. Therefore, it is recommended that a greater effort be made to develop a marketable, technically sound solution involving the use of commercial diesel grinding mills to charge batteries for home systems. This activity should have a strong commercial focus rather than an NGO, community-service bias. Given the large number of diesel powered grinding mills in Zimbabwe, and the rapidly growing number of car batteries, it makes strong economic and commercial sense to develop a network of integrated mills/charging stations. The concept could easily be franchised, and would have widespread application.

Recommendations for Batteries and Battery Charging

Dry Cell Batteries

6.8 Dry cell batteries are a familiar energy source in nearly one-half of all rural households. Extensive battery use does, however, bring environmental problems. With this in mind, the following is recommended:

- Efforts should be made to encourage the use of rechargeable batteries, whether they be lead-acid (car) batteries, nickel-cadmium or others. The considerable growth in the use of car batteries over the past several years suggests that smaller rechargeables (for powering radios and torches) would also be accepted;
- The promotion of rechargeable batteries should go hand-in-hand with the development of the infrastructure to support them (i.e., battery recharging stations); and
- Battery outlets should be able to recycle used non-rechargeable batteries as well as spent rechargeable batteries.

Car Batteries

6.9 The ZESA survey shows that car batteries are, next to dry cells, the most widely used form of electrification in rural areas. They provide electricity for radios, radio/cassette players, televisions and videos, as well as for some lighting. They improve the competitive position of many rural enterprises, while providing nearly 230,000 rural Zimbabweans with increased access to the outside world. They should be promoted by:

- helping to support the establishment of more rural battery-charging enterprises, either through the use of renewable energy resources, or through more efficient use of petrol and diesel generating sets (the enterprises should also include a battery recycling facility);
- making credit and technical assistance available to rural entrepreneurs to establish battery charging enterprises in remote areas.

6.10 This support for establishing battery charging stations should be an integral part of any grid-extension that ZESA undertakes. Arrival of the grid at a growth center would enable battery charging to be made more accessible to the immediate rural communities to whom the grid remains inaccessible.

Recommendations for Petroleum Products and Self-Generation

Generating Set

6.11 ZESA is understandably reluctant to support actively the importation and use of generating sets. However, it is a fact that imports will continue as long as ZESA supplies are limited and reliability is constrained. At present, imports and installations take place in an ad hoc, highly decentralized manner. ZESA should seize the opportunity to reduce the pressure to extend the grid to rural areas by supporting electrification using generating sets. Consumers who begin using electricity provided by genset operators will be potential future customers for ZESA. The following is recommended:

- ZESA and the Government should encourage more-rational installation of generating sets by (1) incorporating existing generating sets into rural electrification planning and (2) promoting the installation of new generating sets in areas unlikely to be grid-connected in the foreseeable future.
- ZESA should, through legislation and innovative financing mechanisms, support independent power producers, which could be licensed to sell at prices agreed between suppliers and consumers, over agreed contractual terms and time periods.
- ZESA or approved technicians should provide assistance to entrepreneurs wishing to install new generating plant and supply local consumers or connect new consumers to existing generators. In other words, they should support the establishment of genset-powered mini-grids.

6.12 Furthermore, work should be undertaken to identify pilot areas for mini- and micro-grid activities utilizing existing private diesel generators. Part of this pilot activity should include detailed studies of the designs for such grids, and of ways to reduce supply, distribution and connection costs. Moreover, careful attention should be paid to consumer willingness to pay, with particular attention paid to the scope for charging high-volume consumers (e.g., mills, general stores) at differential tariffs in order to support uses that are more socially oriented (e.g., public lighting, schools, clinics). This could help improve the acceptability of such systems and promote local authority participation.

Recommendations for Non-Petroleum Generation (Biomass, Wind, and Small Hydropower)

Biomass

6.13 There is considerable scope for generating electricity from biomass resources. Zimbabwe has sizeable forestry/timber, sugar and other agricultural industries, which produce considerable quantities of waste products. Currently, these waste products are under-utilized. At best they are an inconvenience; at worst they constitute a serious environmental problem.

Woody Biomass

6.14 In 1997, waste production from the two largest forestry companies in Zimbabwe (Border Timbers and the Wattle Company) amounted to more than 0.5 million tons. Although the companies do make use of some of this waste for their own energy purposes (heat, mainly), most is not used. It is recommended that

- The forestry companies be given incentives to make use of the wood waste. This could be achieved by stimulating the companies' investment in electricity generating plant fuelled by wood waste.
- The biomass combined heat and power station in Mutare should be developed either as an independent power producer (IPP), a joint venture between ZESA and others, or as a ZESA project

6.15 It is likely that these ideas would be exclusive because insufficient wood waste would be available to fuel several generating plants. The aim of either approach would be to use the abundant wood waste and improve Zimbabwe's indigenous electricity supplies.

6.16 In addition, ZESA should offer long-term purchase contracts, and perhaps even premium prices (front end, limited in duration by contract, and diminishing over time), to investors in electricity from wood waste.

Bagasse

6.17 The major players in the sugar industry, Triangle and HVA, make better use of their main waste product (bagasse) than the forestry companies do of their wood waste. Bagasse is used to provide process heat and to generate electricity for auto-consumption. Both companies have explored the possibility of increasing their generating capacity and supplying electricity to the ZESA grid.

6.18 This opportunity fits neatly into the more open approach to electricity generation and supply, which ZESA needs to adopt if it is to overcome the various performance constraints under which it currently operates. To capitalize on this opportunity,

- both Triangle and HVA should be encouraged both to increase the production of bagasse and to invest in plant to generate surplus energy for external sale; and
- ZESA should offer long-term purchase contracts, perhaps even premium prices (front end, limited in duration by contract, and diminishing over time) to investors in electricity generated from bagasse.

Small Hydropower

6.19 A thorough study of Zimbabwe's many dams was conducted in 1990–1991 with support from GTZ to the then Ministry of Energy and Water Resources. A total of 40 sites were identified at the first stage of this study. From these, 20 sites were chosen for further investigation. A number of these were dropped from consideration for a variety of reasons. From the remaining sites, relatively thorough economic and technical investigations were conducted, primarily from the perspective of determining their viability for development to generated electricity for ZESA. After these investigations, only six sites were deemed to be economically feasible, as shown in Table 6-1.

Table 6-1. Most Promising Hydro Sites on Existing Dams (US$)

Dam	*kW*	*GWh*	*Total Cost ('000 $)*	*Cost/kW*
Mutirikwi (Kyle)	4215	36.95	4,951	1,175
Bangala	1037	9.09	1,939	1,870
Ngezi (Palawan)	267	2.34	811	3,037
Ruti	283	4.24	1,521	5,375
Siya	526	4.61	3,555	6,759
Manyuchi II	170	n/a	n/a	n/a
Total	6,498	57.23	12,777	3,643

Source: MoE&WR&D, GTZ, Alexander Gibb & Partners, 1991.

6.20 Today, there are several reasons to revisit this study and the economics of these sites. Electricity prices have increased fairly significantly over the past several years. ZESA is being forced to import as much as 25 percent of its electricity from abroad to meet current demand. There are significant shortfalls in supply (as witness the number of generating sets/gensets imported into the country).

6.21 The 1991 study pointed out that several sites could be developed for local electricity demand, and that, were local economic factors considered rather than grid supply factors, a number of other sites would be economically viable for development. Considering the price paid by rural dwellers for diesel-generated electricity, for batteries and battery charging, and for photovoltaics, the assumption that several more of these sites could be economically developed to meet off-grid rural demand could prove valid.

6.22 The following is recommended:

- The earlier work of the MoE&WR&D on small hydropower sites should be revisited in light of current scarcities in ZESA electricity supply and the concomitant increase in ZESA tariffs. The economics of the top sites surveyed should be reviewed; if they prove more promising than before, efforts should be made to promote hydroelectricity investments at those sites.
- As with electricity from bagasse, wood wastes and other renewable sources, ZESA should offer long-term purchase contracts, perhaps even premium prices (front end, limited in duration by contract, and diminishing over time) to investors in small-scale hydropower.
- Technical assistance and co-financing should be made available to support the development of economically viable and environmentally sound small hydroelectric projects.

Wind

6.23 Although mean wind speeds are relatively low in southern Africa and current wind generation technology is generally not effective in the prevailing wind regime, there have been recent attempts to improve wind turbine design (see Annex 7).

6.24 These developments mean that electricity generated by wind power in certain areas can be considered for rural electrification purposes. Although this is of lower priority than the promotion of biomass- or solar-powered electricity generation, the following is recommended:

- The Government should offer tax incentives to wind turbine manufacturers as well as investors in wind electricity generators;
- The provision of technical assistance and up-front funds to co-finance investments in wind electricity in isolated rural sites should be considered;
- ZESA should offer long-term purchase contracts, perhaps even premium prices (front end, limited in duration by contract, and diminishing over time), to investors in wind electricity generation.

7

Conclusions

7.1 At the request of the Government of Zimbabwe, the World Bank, through the ESMAP team, worked closely with the Department of Energy and ZESA to collect detailed data on energy use patterns in rural Zimbabwe.

7.2 The ZESA-DOE/ESMAP survey found that rural energy use mirrors the economic dichotomy of the rural areas. Large-scale rural industries and commercial entities and, to some extent, rural institutions are tied into to the monetized energy economy. These organizations are, generally, grid-connected and use "modern" fuel sources such as coal or petroleum products to satisfy their energy needs. In contrast, the large majority of the rural population—mainly rural households and small-scale businesses such as bakeries and general stores—relied heavily on freely-gathered wood as a primary source of energy.

7.3 Strikingly, the survey revealed that rural Zimbabweans have shown great initiative in trying to better their energy situation. Notably, there is much activity centered around the provision of electricity to rural households. Whether car batteries, PV home systems or generating sets for rural commercial uses (and to a lesser extent, for rural households), it is clear that the Government should build on these efforts to further improve rural access to electricity.

7.4 The most significant and global recommendations made by this report are the following:

- ZESA should rethink its priorities for rural electrification in order to capitalize on these autonomous, individual efforts for electrification;
- Non-grid options should be viewed positively as accelerating rural electrification and, ultimately, increasing the future demand for ZESA's goods and services; and
- Support should be provided for small-scale power solutions, whether from wood waste (e.g., in Mutare), wind, PV, battery-charging stations or other sources.

7.5 The survey and information gathering work has indicated that this process is already under way. Through its involvement in the UNDP/GEF project and community-based projects such as the Temaruru project, ZESA has indicated its willingness to diversify its approach to providing rural energy by seeking viable alternatives to grid connection. As Zimbabwe takes the next step in formulating a coherent policy for rural energy and electrification, now is the time for all key stakeholders to take the process forward and to consider the policy elements recommended in this document.

Annex 1

Detailed Methodology for ESMAP-DOE Supply Side Surveys

Summary

The Department of Energy worked with the ESMAP team to develop a series of questionnaires (Annex 3) for conducting supply side surveys in urban and rural Zimbabwe.

Detailed Methodology

The following methodology was adopted by the Department of Energy to obtain extensive information for this Rural Energy Strategy.

1. **Biomass**

1.1 **Forestry Commission:** The following information was provided by the Forestry Commission, The Wattle Company and Border Timbers:

1. The total area of woodlands in Zimbabwe, with maps with vegetation cover, showing where the highest concentrations of wooded areas are located,
2. annual allowable yield for all woodlands in all categories of use and settlement;
3. annual volume of wood for: commercial purposes (pulp and paper, timber, etc.) preferably by district or province;
4. annual volume of wood consumed for firewood (preferably by province, and if possible, by district);
5. areas with deficits in allowable yield and wood consumption,
6. consumption figures and studies on the consumption of firewood, building materials, etc. for households, commercial establishments, industries (particularly small and medium enterprises/SMEs);
7. prices of firewood in Harare, Bulawayo, Mutare and other key areas over the past five years;

8. Forestry Commission programs and plans for programs to promote local management and production of wood, particularly for commercial wood products such as firewood and others.

1.2 **Tea Estate Wood:** The tea companies and ARDA provided information on:

1. the number of tea estates operating their own plantations;
2. the area under plantation for energy;
3. amount of additional wood purchased for their operations;
4. the volume of wood used annually for their operations, over the past five years;
5. electricity produced from wood during their operations;
6. plans for expansion of wood plantations;
7. other energy sources, particularly fuel oil or coal, used in their boilers, the quantities of such, and the prices paid, over the past five years.

1.3 **Wood Industry Wood**: Given the fact that there are a number of wood industries in Zimbabwe, including pulp and paper, saw mills, furniture factories, etc. information was obtained on wood for rural energy use. For the major enterprises, information was obtained to:

1. identify all industries producing and processing wood, listed by name, and by location (with full addresses, telephone numbers, persons to contact, etc.);
2. amount of wood utilized annually by each of the major enterprises over the past five years;
3. source of wood utilized annually (i.e., own plantations, national forests, Forest Commission land, etc.);
4. amounts paid for wood utilized (by the cubic meter standing volume, stacked, hectare, etc.);
5. amount of waste produced each year for past five years by industry (e.g., in tons of sawdust, in cubic meters of waste, etc.);
6. use of waste produced each year (e.g., to run boilers, sold to other consumers, left to rot, etc.);
7. if waste is consumed, by whom and at what price/cost over past five years by industry;
8. if sold, to whom, at what price over past five years;
9. whether used, sold or consumed, what is their perception of how, if at all, this could be improved (e.g., made more efficient, used more extensively, etc.).

1.4 **Wood Industry Other:** Charcoal is produced by the Wattle Company in Mutare as a by product of tannin for tanning leather, extraction. The Wattle Company also sells coal and coke. The Wattle Company, in conjunction with the Department of Energy, provided information on:

1. how much wood they harvested or took in for tannin production from 1992 to 1997;
2. how much of that wood was pyrolized for charcoal over the same period;
3. the cost per ton of charcoal produced over the same period;
4. where the charcoal was sold over the same period;
5. who are the major customers who bought charcoal over the same period (by individual client or by customer category such as restaurants, supermarkets, industries, etc.).

1.5 **Sugar:** Sugar provides energy for Zimbabwe in two forms, bagasse for heat and electricity generation, ethanol for fuel additives. There are two major groups of producers, Triangle (and associated ethanol plant) and Hippo Valley. Information was provided by both companies concerning:

1. area planted to sugar from 1992 to 1997;
2. yield of cane over the same time period;
3. amount of bagasse produced over the same time period;
4. amount of bagasse burned to generate heat and electricity over the same time period;
5. amount of electricity they consumed from ZESA over the same time period;
6. the amount of electricity they sold to ZESA over past five years, and at what cost per kWh;
7. plans for expansion, included expanding electricity generation and sales to ZESA;

1.6 **Ethanol:** The team obtained information on:

1. how much ethanol has been produced from sugar from 1992 to 1997;
2. the cost of production of ethanol over the past five years;
3. the selling price of ethanol over the past five years;
4. the major customers of ethanol over the past five years (if not by name, then by category such as surgical spirits, alcoholic drinks producers, petrol companies, etc.)
5. any plans for expansion and, if so, by what amount (in terms of liters per annum).

1.7 **Other Biomass**

The team examined wood and agricultural waste use in other sectors including the following:

1. **Brick production**: Considerable quantities of wood (and some coal) are used for small-scale brick production in Zimbabwe. The team reviewed studies carried out in this field including ZERO, ITDG in other countries, etc.
2. **Charcoal production:** Small-scale charcoal production is undertaken in several isolated areas of the country, primarily to provide charcoal to urban maize vendors (who roast maize using charcoal). The FES and Forestry Commission provided information on this;
3. **Coffee husks:** The team made contacts with the Coffee Growers Union, the Coffee Board, and several estates to determine whether coffee husks have been used, or are being used for energy (they are not to any appreciable extent). Furthermore, the team estimated coffee husk production for potential energy supply.

1.8 **Schools and hospitals:** Schools and hospitals consume considerable quantities of wood and biomass. Information for rural schools and hospitals was obtained from the Ministries of Education and of Health. A number of schools and hospitals were visited by the DoE team. The team visited several schools, and obtained local and national figures on consumption of wood per pupil. The Ministry of Health also gave information on the number of hospitals in the country, with consumption of all energy sources, including wood, electricity, diesel and coal.

1.9 **Prisons**: Similar, detailed information on wood, coal, diesel and electricity consumption was obtained from the Prisons Department for 1992 to 1997 for all prisons in the country.

1.10 **Military:** Information on diesel generating sets was provided by the Ministry of Local Government for all military and other institutional establishments. Information on schools and hospitals was compared with information from other sources (above).

1.11 **Biogas**

1. The DoE team reviewed the Biogas programs of the Ministry of Transport, the Biomass Users' Network (BUN) and Silveira House. Information was obtained on:

- the number of units installed;
- the prices paid for the units;
- the agencies or companies who installed them;
- the size of the units;
- the amount of methane produced.

Several reports are available to provide good information on biogas to answer these questions.

2. **Small Hydropower**

A thorough inventory of all existing small hydropower (less than 10 MW) electricity generating plants in Zimbabwe was obtained with information on:

1. when they were constructed
2. the flow rates, and are these constant, seasonal, perennial;
3. the capacity (power, in kW) for each, and for all;
4. their location (provinces and districts, on commercial farms, resettlement areas, communal lands, etc.)
5. ownership;
6. operational status;
7. connection to ZESA;
8. amount of electricity they sold between 1992 and 1997;
9. information on energy production for the two plants not connected to ZESA, with information on who do they supply, at what levels, and at what prices.

Additionally, the DoE team obtained information on the hydro potential from all dams and weirs in the country primarily based on the Gibb's study showing:

1. the number of dams and weirs which are presently not utilized for energy production;
2. the which could potentially be used to generate electricity;
3. the flow rates of these, and are their reliability;
4. their capacity (power, in kW);
5. where are they located (which provinces and districts, on commercial farms, resettlement areas, communal lands, etc.)
6. ownership;
7. studies carried out on developing energy on them, and, if so, what are the results;

8. proximity to demand centres (e.g., rural business centres, schools, etc.);
9. estimated costs of development.

3. **Petroleum Generated Rural Electricity**

The DoE team estimated the number of diesel and petrol generators operating in Zimbabwe, their location, and the loads they are supplying.

The team first tried to obtain information from the Ministry of Finance, Customs and Excise. However, generating sets (gensets) are not disaggregated on a quantity basis. Rather, records are kept on value of imports, and on the weight of the imports. This information was of no use to the study.

Simultaneously, the DoE team approached genset imports and supplies in the following manner. They went to all major suppliers and interviewed the two most important (Hawker Siddley and Honda) for sales to private and public entities. They also went to ZESA, who, in turn, sent out a questionnaire to all ZESA Area Managers to provide estimates, or exact information on the number and size of generating sets in each area. The Ministry of Local Government provided information on all schools, hospitals, airports, and other public agencies. Finally, the team made visits to every district in the country where they interviewed provincial and district officers, ZESA managers, and the owners and operators of diesel and petrol gensets in the private sector (e.g., commercial farms, industries, hotels, tourism centres, etc.) and in the public sector (e.g., schools, hospitals, other government agencies, etc.).

4. **Solar**

The team focused on two areas of solar that are of interest for the rural energy strategy - solar photovoltaics, and solar water heating.

4.1 **Photovoltaics**

For the solar photovoltaics, the first source consulted was the Customs and Excise Department. As with generating sets, import statistics were of no use to the exercise, as, first, they SITC codes were not broken down for solar panels, modules, BOS and other equipment. Second, statistics covered value of imports and the volume (weight) of such. This proved impossible to interpolate for national sales figures.

The DoE team then held good discussions with the UNDP/GEF project and with the Zimbabwe solar industry. A short questionnaire was prepared by the team and supplied to the Solar Energy Industries Association (SEIA). Unfortunately, only a few firms completed the questionnaire. The team then interviewed a number of the larger solar PV suppliers.

Of far more use, however, was the ZESA survey on urban and rural electricity use. The team worked with ZESA and Quest Research to modify the ZESA survey questionnaire to obtain information on photovoltaics (and other areas of interest, including car batteries, wood, etc.). From the 6001 interviews in the ZESA survey of early 1998, all photovoltaic (123) and genset owners (63) identified during the survey were then followed up with a detailed questionnaire in July-August 1998 to determine:

- the number of units sold, and installed, and when;
- the capacity of the units, allowing the DoE to sum all the capacities to provide a full picture of total installed capacities;
- the distribution of the units (i.e., where).

4.2 **Solar Water Heating**

Solar thermal water heating information was obtained from the producers and installers themselves, and, during field visits, from owners of the sets. The DoE knows the key producers, and was able to obtain good information on solar water heater sales.

5. **Wind**

There are two types of wind power that are of interest for the rural energy strategy; wind for water pumping and wind for electricity generation. Interviews were carried out of the companies engaged, or who have been engaged, in windmill production and distribution over the past decade. Import statistics from the Department of Customs and Excise were also obtained. Information from donors and NGOs active in this field, and from the Ministry of Water.

The information collected included:

1. how many turbines have been produced or imported;
2. who were they sold to;
3. for what purposes are they being used; and,
4. where were they installed.

6. **Coal**

Coal is used in certain rural areas as a source of energy. The major sources of information were the Wankie Colliery, and from key distributors. This was cross-verified by users' interviews in rural areas, and with information supplied by the Ministry of Education, the Ministry of Health, the Prisons Department, and other agencies.

7. **Paraffin**

Paraffin is used extensively in households and in commercial enterprises in rural Zimbabwe. NOCZIM (National Oil Company of Zimbabwe) provided information on distribution.

8. **Other Sources of Energy Information**

Other sources of information included the Zimbabwe Chambers of Commerce, the Zimbabwe Confederation Zimbabwean Industries, The Commercial Farmers Union, the Zimbabwe Farmers Union, numerous Rural Development Councils (RDCs), ARDA, Agritex, the Coffee Board, the

Tea Board, ZESA area offices, BAT, other rural agricultural associations, a number of private firms and suppliers (e.g., Triangle for ethanol and bagasse), and a number of other agencies and institutions cited above.

Annex 2

Questionnaires

A2.1 Follow-Up Questionnaire Rural Solar & GenSet Use (Rural Energy Strategy)

Today's date: ________________ name surveyor: _______________________ Location of respondent: ____________
Name of respondent___________ Original survey ID _______
Type of equipment (tick all appropriate)________ PV system ___________ Genset (diesel) _____________Genset (petrol)

Please complete form for each type of equipment (PV, diesel genset, petrol genset)

Date of purchase of equipment (complete)	MM/YY ________
Price you paid (complete)	Z$_______
Was it on credit? If yes	_______ amount borrowed _____months to pay back loan; who provided it _________
What is general condition of the equipment	good, fair, troublesome, out of order (circle one)
What is the make and model (please complete)	______________________________
Do you share the output with a neighbor	yes/no/sometimes (circle all that apply)
In case of solar, what did you buy at the same time:	module, battery, charge controller, lights, (circle all that apply)
Did you already own a car battery and a few appliances when purchased the PV module (lights, and/or TV, radio)	Y/N; if yes what: battery, radio, TV, lights (circle all that apply)
Power rating for the system (complete)	____ Watt (in case of solar, how many modules ___)
PV/Genset equipment purchased where (circle appropriate)	- Harare private sector - Harare GEF (solar only) - ZESA - South Africa - other: _________________
Are you satisfied with system (circle appropriate, and complete question)	Yes/No/not sure why: _______________________
Who installed it (circle appropriate):	- self - local technician/installer - technician/installer from Harare - GEF technician/installer - ZESA installer - other: __________
What is the main use for the electricity (tick appropriate)	lights/powering radio or TV/backup/other (specify): ________ (please circle all that apply)
Approximate use per day (complete)	Hours used per day: _____________
Number of lights/amps (tick appropriate):	- fluorescent: ____ total Watts: _______ (total watts for all fluorescent lamps combined) - incandescent: _____ total Watts: _______
Does the interviewee have audiovisual equipment that is powered by the genset, the PV equipment, or the car battery (circle appropriate)	- none, radio, cassette, color, BW (circle)
Type of battery: (ask Ah from user, or read on battery; leave blank otherwise; skip if no battery used)	- solar battery _____ Ah ____ Volts - car battery ______ Ah ____ Volts
Battery was purchased when	MM/YY _______
expected total useful life:	_______ months/years
Does battery still need charging/topping up somewhere	Y/N; if yes, how many days ____between charges Where: ______________ (please fill in)
Would like to expand his/her system	Yes/No/Not sure (circle one)
Would recommend to family/friends	Y/N (circle one)
Average diesel/petrol consumption (complete)	Not applicable, Diesel, petrol
Average spare part use (complete)	Z$________/month/week/day
	Z$ __________ per week/month/year (circle one)

- Solar is a good way to electrify Zimbabwe (circle one) — Agree/disagree/ no opinion
- In general, who do you think should use solar systems: ______________________ (please complete)
- What is their main use: ______________________ (please complete)

- Generators are a good way to electrify individual households in Zimbabwe: (circle one) — Agree/disagree/ no opinion
- I prefer it when a business/firm/factory in my village has a large generator and distributes electricity to the villagers (circle one) — Agree/disagree/ no opinion
- I would be willing to pay more for electricity (Zesa quality, but delivered by a business/firm/factory in my village) if I am connected within a year (circle one) — Agree/disagree/ no opinion
- Knowing that you will not be connected to Zesa in the next 5- 10 years, can you indicate how much more you are willing to pay for electricity: (circle one) — not willing/2x/3x/4x/5x

- I prefer to generate my own electricity supply at home (circle one) — Agree/disagree/ no opinion

- The main problem with solar electricity is: ______________________ (please complete)
- The main problem with individual generators is: ______________________ (please complete)
- The main problem with local generation (in your village, by a business, etc.) will be: ______________________ (please complete)
- The main advantage of solar electricity is: ______________________ (please complete)
- The main advantage of individual generators is: ______________________ (please complete)
- The main advantage with local generation (in your village, by a business, etc.) will be: ______________________ (please complete)

A2.2 Questionnaire for Large Farms and Ranches

FARM PROFILE

(Use one form for every farm/ranch visited)

1. Name of Farm/Ranch : ______________________
2. Date of establishment : ______________________
3. Location (district/province): ______________________
4. Farm/Ranch Activity : ______________________
5. Yearly Production : ______________________
6. Level of production : below average/average/above average
9. Any other relevant general details about their operations

Questions for Farm/Ranch Managers:

1. How much electricity do you consume per year/month (kWh)?__________
2. What are the major energy uses on your farm/ranch ?
   ____
3. How do you supply your electricity? ____________________
4. What is the cost of supplying your electricity ? __________________
5. If you supply own electricity, what is the source of energy for generation ? (diesel, fuel, oil, wastes such as bagasse, sawdust etc)
6. If you use heat, how do you generate it ? ______________________
7. Do you supply energy to your employees ? ____________________
8. If yes, what kind of energy ? ____________________
9. What is the cost ? ______________________
10. If you supply own electricity, what is the cost? _____________

11. Do ever experience shortfalls of energy, supply cuts, variable prices etc ________

12. Do you purchase coal, how much per year, at what cost and from whom do you purchase from?____

13. How much diesel, or petroleum do you purchase per annum, and at what cost ?_____________________________

14. Where do you purchase and what are the uses?________________________

15. How much wood do you purchase per annum, the cost, from whom, and the purpose ? ____

16. Any other useful information you feel is important?

A2.3 Survey Questionnaire for Solar Water Heater Producers

(Use one form for every company visited)

1. Name of Company : ____________________
2. Date of establishment : ____________________
3. Location (district/province) : ____________________
4. Area of Production : ____________________
5. How much is the Production : ____________________
6. How many employees : ____________________
7. Address : ____________________

Demand Profile

1. How long has been your company dealing with solar water pumping?____________
2. What type/s of system do you deal with?
3. Where do you source your equipment (locally or imported)?___________
4. If some is locally produced, please list this equipment ? _______________

   What is the cost of the local equipment?__________________
5. What is the cost of importing the material and were do you import from ________
6. What is the taxes, tariff, duties charged when import the raw material? ______________
7. What is the cost of producing a standard solar heater?________________
8. What is/are the energy sources used to produce the solar heater?____________
9. If you produce heat, how do you produce it?__________________________

10. What is your monthly energy bill for the production of solar water heaters ?

11. What is the selling price of this unit ? ____________________

12. Who are your main clients for solar water heaters, give by size?_______________

13. What are the purchasing modes (e.g. cash, credit scheme etc) ?_______________

14. What are your yearly sales (for the past five years if possible)?______________

A2.4 Survey Questionnaire for Solar Water Pump Users

SURVEY QUESTIONNAIRE FOR SOLAR WATER PUMP USERS

Date____________ Name Respondent_______________

Name of Surveyor_____________ Location of Respondent___________

1. When did you purchase your pumping system?________________
2. Where did you purchase your system?_______________
3. What was the cost?_______________
4. What is the power rating of the system?___________________
5. Who installed your system ?________________
6. What is the type of the system (AC or DC)?_______________
   i. type of panels and power rating________________________
   ii. number and type of batteries _________________Ah _________Volts
   iii. type of motor, pump _________________________
7. How much water do you pump per day/week/month?_______________
8. What are the water uses?__________________
9. Are there any other electricity uses besides pumping (e.g. battery charging etc)
10. Do you think your system is adequate?_________________________
11. If not, would you like to expand your system?____________
12. From your experience, would you recommend such a system to friends or anyone else?
13. What other projects would you think can be carried out with such technology?

Annex 3

Summary of Results from ZESA-DOE/ESMAP Energy Use Baseline Survey

The ESMAP Rural Energy and Rural Electrification Strategy exercise was aided considerably by the fact that ZESA was just in the process of carrying out an extensive consumer (and potential consumer) perceptual survey for grid-connected, and near-grid (grid accessible) customers and potential customers starting in late-1997. The ESMAP team, through discussions with ZESA and their consultants, was able to work with them to revise their survey instrument and coverage to include "deep rural" areas (those greater than 10km from ZESA "growth points", and to include questions related to solar photovoltaics, car battery use for households, and other relevant off-grid household questions. The final survey included 6,001 interviews, with nearly 20% or those in "ex-grid" areas, and, overall, approximately 50% of all respondents located in rural areas.

ZESA and their consultant agreed to these additions and a small contract, with detailed methodology and scope of work were drawn up. The ZESA survey began the rural and off-grid surveys in earnest from January to March 1998. The initial results from this survey were very striking. They showed far higher photovoltaic, car battery and diesel/petrol generating set (genset) use in rural areas than was anticipated. They showed higher expenditures on rural energy than were expected.

Therefore, the ESMAP team, working closely with ZESA and their consultants, devised an in-depth follow up questionnaire of 160 interviewees who, during the first round, indicated that they used generating sets and PV systems. A total of 69 genset users and 91 PV users were interviewed during this follow-up survey conducted during July and August 1998. The results from this survey verified the findings of the broad-based survey. They provided further detail on rural energy use patterns, particularly expenditures on PV sets, on batteries, on gensets, both in terms of capital and recurrent costs. They provided perceptual information regarding attitudes towards these rural electricity sources, and how the rural electricity economy is in transformation.

Definitions

The ZESA survey was designed to provide the ZESA marketing and consumer affairs divisions with information on how to expand and deepen the use of electricity amongst primarily low-income customers. ZESA has increased the number of low-income consumers dramatically over the past 15 years, adding nearly 100,000 connections during that period. However, per household electricity use is low, and it is one of ZESA's corporate mandates to improve and deepen the use of electricity by low-income households, primarily to shift those households from using such energy sources wood and kerosene.

Therefore, ZESA's original survey, and the consultant's survey instrument, were designed primarily for qualitative, perceptual and preference observations. That is, they wanted to determine consumers' attitudes towards electricity, its use vis-à-vis other forms of energy, and to define what scope exists for deepening that use. Their questionnaire format reflects that, and although it was easily adapted to the ESMAP requirements, a number of terms need clarification.

Originally the ZESA survey was going to be limited to those consumers either connected to the grid or close to it. They used the term for these groups as "grid accessible". Grid accessible means either a unit is connected to the grid, or is within 10km of the grid or a ZESA "growth point". A ZESA growth point is usually a small town or a resettlement area that will be connected to the grid within the next 10-20 years.

Within the "grid accessible" nomenclature, several categories of interviewees were defined: The first category is "domestic" and the second category is "other". Under the domestic nomenclature, the following definitions apply:

- High density: These are urban areas, generally low-income, in which the population density is very high, generally over 500 persons per km2. There is considerable scope for ZESA expanding its coverage and services in these urban areas.
- Low density: These are urban areas of a medium to large land size (e.g., a tenth of a hectare or more), that are widely dispersed in some of Zimbabwe's major urban areas (Harare, Bulawayo, Mutare, etc.).
- Business/employee: Originally, the consultants used a category of "business" within the domestic sector. Later, after discussions, they classified this as "employee" better to reflect the fact that this group are households living in housing or quarters provided by businesses (e.g., industries, large mines, etc.). This grouping is both urban and rural, unlike both high and low density, who are, by definition, urban.
- Rural: The fourth category of grid accessible is rural. This simply means they are not urban and live within 10km either from the grid or from a ZESA growth point.

The next category in the original ZESA survey was classified as "other". This has a strict definition which is characterized by one unifying fact - they are connected to ZESA. There are two sub-groups within the other classification. They are either "large scale" or "small scale". These apply almost exclusively to rural mines, commercial farms, plantations (e.g., forestry), and other enterprises located outside urban areas. These are very important areas of national economic activity, and ZESA is interested in ways and means to provide better services both to the enterprises as well as their employees.

ESMAP's participation extended the coverage of the survey to include an additional 1,057 households within the "ex-grid accessible" category. This is variously defined as "deep rural" as it was designed to interview respondents in areas that are further than 10km from the grid or from ZESA growth points. This is an area that ZESA do not believe any grid extension can likely occur within the next 10, possibly 20 years. Within this category of ex-grid, the following groups were identified and surveyed:

- Rural domestic: As the name implies, these are deep rural households.
- Rural small-scale: These are enterprises with fewer than 20 employees (the definition of small-scale that the Central Statistics Office applies to business activities). These could be grain mills, small bottle shops and general stores, automobile repair shops, and others.
- Large-scale: These are enterprises with more than 20 employees are not connected to ZESA. They include mines, agricultural and wood processing industries (e.g., sawmills), and a few larger commercial farms and agricultural enterprises not connected to ZESA.

It is important to keep these definitions in mind when reviewing the analysis, as these terms are used to define the strata for the survey, and the target groups for any future actions.

Table A3.1
Nomenclature for ZESA-ESMAP Energy Use Baseline Survey

Grid accessible						**Ex-grid accessible**		
Domestic				**Other**		**Domestic**	**Other**	
H density	L density	Rural	Employees	Lg scale	Sm scale	Rural domestic	Sm scale	Lg scale

Analyses of Results

One of the major objectives of ESMAP's work with ZESA and their consultants on the energy baseline survey was to gauge the extent of off-grid electrification in Zimbabwe. The results of the baseline and the subsequent follow up for PV and gensets prove very insightful. They should provide guidance to ZESA, the Government of Zimbabwe, the World Bank and others interested in rural electrification for preparing and implementing support and development programs in the sector.

Photovoltaics

Three general questions on use of energy were asked of respondents:

- Did they use the energy source for heating?
- Did they use the energy source for lighting?
- Did they use the energy source for powering (e.g., TVs, radios, etc.)?

Each of these questions was specific. Thus far, no analysis has been made for the overlap between respondents who used energy for more than one application (e.g., lighting and powering, as in the case of PV). This analysis is currently underway and will alter the results upwards. That is, as Tables A3.2 and A3.3 show, 105 respondents answered they used PV for powering, while 81 answered they use PV for lighting.

Table A3.2
Respondents Using PV for Powering Appliances

Grid accessible			
Domestic	**No**	**% by category**	**% of total**
H density	8	18.6%	7.6%
L density	2	4.7%	1.9%
Rural	20	46.5%	19.0%
Employees	13	30.2%	12.4%
Sub-total	**43**	**100.0%**	**41.0%**
Other			
Lg scale		0.0%	0.0%
Sm scale		0.0%	0.0%
Sub-total	**0**	**0.0%**	**0.0%**
Ex-grid accessible			
Rural domestic	53	85.5%	50.5%
Sm scale		0.0%	0.0%
Lg scale	9	14.5%	8.6%
Sub-total	**62**	**100.0%**	**59.0%**
Total	**105**		**100.0%**

Table A3.3
Respondents Using PV for Lighting

Grid accessible			
Domestic	**No**	**% by category**	**% of total**
H density	3	0.1%	0.1%
L density	4	0.1%	0.1%
Rural	13	0.3%	0.2%
Employees	16	0.4%	0.3%
Sub-total	**36**	**0.8%**	**0.6%**
Other			
Lg scale		0.0%	0.0%
Sm scale	2	0.6%	0.0%
Sub-total	**2**	**0.6%**	**0.0%**
Ex-grid accessible			
Rural domestic	32	2.5%	0.5%
Sm scale	2	0.2%	0.0%
Lg scale	9	0.7%	0.2%
Sub-total	**43**	**3.3%**	**0.7%**
Total	**81**		**1.4%**

This implies that there were, at a very minimum, 105 respondents, or 1.8% of the entire 6,001 respondents in the survey, who use PV. If, as should be the case, a number of the 85 respondents who said they use their PV for lighting, also use their PV for powering, then, of course, the number of interviewees using PV for both powering and lighting increases. This, then, implies that the extrapolations for general population use of PV based upon those who said they use it for power is an underestimate.

In the survey, and verified in the follow up in July and August, 81 respondents, or 1.4% of the sample stated they used solar electricity for lighting.

Using the higher number of those who use PV for powering (and realizing this is an underestimate, as there are surely respondents who use it for both powering appliances and lighting), and extrapolating this to the national census, we can obtain the following estimates.

Tables A3.4 and A3.5 are taken from the 1992 National Census by the Central Statistics Office. The CSO estimated population in three scenarios to the year 2007, at intervals of 1997, 2002 and 2007. The team has taken the middle estimate, which puts 1997 population at 12.338 million inhabitants. This assumes an overall growth rate of 3.45% until the year 1998 (given contemporary fertility and mortality rates), with an urban growth rate of 5.17% per annum for the period concerned, and a rural growth rate of 2.65% for the same period. Again, it should be noted that these figures are taken from the 1992 Census and the CSO's projections to the year 2007.

Table A3.4
Population Estimates from 1992 Census (1997 estimate from CSO)

1992 Census	1992	1993	1994	1995	1996	1997	1998 (est.)
Rural	7,224,828	7,416,286	7,612,818	7,814,557	8,021,643	8,235,615	8,453,859
Urban	3,187,720	3,352,525	3,525,851	3,708,137	3,899,848	4,102,385	4,314,478
Total	**10,412,548**	**10,768,811**	**11,138,668**	**11,522,694**	**11,921,491**	**12,338,000**	**12,768,337**

Source: CSO

Table A3.4 shows that the urban population in 1998 should be on the order of 4.3 million, and the rural on the order of 8.5 million. Taking CSO figures for urban and rural household sizes, Table A3.5 was prepared.

Table A3.5
Household Estimates from 1992 Census (1997 estimate from CSO)

1992 Census	1992	1993	1994	1995	1996	1997	1998 (est.)
Rural	1,409,106	1,446,447	1,484,778	1,524,124	1,564,514	1,606,246	1,648,812
Urban	777,622	817,825	860,106	904,574	951,340	1,000,748	1,052,486
Total	**2,186,727**	**2,264,272**	**2,344,884**	**2,428,698**	**2,515,854**	**2,606,994**	**2,701,298**

Source: CSO

Taking these census data and applying the ZESA baseline survey and follow up analysis figures, Table A3.6 indicates the minimum level of PV penetration today in Zimbabwe.

Table A3.6
Estimates of PV Penetration for Powering Appliances in Zimbabwe Based upon 1992 Census and !998 ZESA Baseline Survey

Category	No	% solar sample	% sample	% national
Domestic				
Urban	23	21.9%	0.6%	5,993
Rural	73	69.5%	5.2%	85,002
Other	9	8.6%	1.7%	
Total	**105**	**100.0%**	**1.8%**	**90,996**

Source: ZESA, Quest Data and ESMAP

This indicates that, at a minimum, there are over 90,000 PV systems **in use** in Zimbabwe. The emphasis is on **in use**, as the ZESA survey asked interviewees what they used at that point in time for powering appliances. This indicates operational units, not units sold but out of use. It should be noted that, as one would expect, most units are used in rural areas. However, a higher proportion, nearly 22% use PV in urban areas, as defined above (i.e., either high density, low density, or commercial/industrial employees in urban areas). This should be of major interest to ZESA. The "other" category indicates use in rural applications on commercial farms, at mines, and other business establishments in Zimbabwe.

Additionally, as Table A3.7 indicates, a further 81 interviewees stated they used PV systems for lighting. The data are being analyzed to determine the number of users who use their systems for both powering and lighting, as this number will be greater than 105, and will imply a higher national extrapolation for those using PV.

Table A3.7
Estimates of PV Penetration for Lighting in Zimbabwe Based upon 1992 Census and !998 ZESA Baseline Survey

Category	No	% solar sample	% sample	% national
Domestic				
Urban	23	28.4%	0.6%	5,993
Rural	45	55.6%	3.2%	52,399
Other	13	16.0%	2.4%	
Total	**81**	**100.0%**	**1.4%**	**58,392**

Source: ZESA, Quest Data and ESMAP

Car Batteries

Another objective of ESMAP in working with and through the ZESA survey was to get a good idea of the number of car batteries in use in the country for providing off-grid electricity. Table A3.8 shows that 540 respondents stated they use car batteries for powering appliances (generally TVs, radios, radio cassettes and similar devices). No respondents stated they used car batteries for lighting.

Table A3.8
Respondents Using Car Batteries for Powering Appliances

Grid accessible			
Domestic	**No**	**% by category**	**% of total**
H density	203	4.6%	3.4%
L density	10	0.2%	0.2%
Rural	45	1.0%	0.8%
Employees	85	1.9%	1.4%
Sub-total	**343**	**7.8%**	**5.7%**
Other			
Lg scale		0.0%	0.0%
Sm scale	6	1.9%	0.1%
Sub-total	**6**	**1.9%**	**0.1%**
Ex-grid accessible			
Rural domestic	152	11.8%	2.5%
Sm scale	20	1.5%	0.3%
Lg scale	19	1.5%	0.3%
Sub-total	**191**	**14.8%**	**3.2%**
Total	**540**		**9.0%**

One of the interesting features of both Table 3.7 and Table A3.8 is the high proportion of "urban" users of car batteries. In fact, a higher number of "urban" respondents state they use car batteries than rural. There are two explanations for this.

First, most of the urban respondents are in high density areas where there are many homes without grid connections. Many employees in the survey in the grid-accessible areas do not have electricity connections, so use batteries for their appliances. Secondly, as ZESA has pointed out, many households have old appliances that are DC-driven, including classic stereo phonographs that are driven by lead acid batteries. This is borne out by market supply surveys that show these types of heavy batteries are widely available in urban retail outlets. ZESA believe that for many of these households, the costs of purchasing a new entertainment unit is prohibitive, relative to continued use of batteries.

Taking the baseline and follow up surveys and extrapolating them to the overall population (Table A3.9), it can be seen that, **at a minimum**, over 314,000 car batteries are in use in Zimbabwe, with at least 230,000 of these in rural areas. The "other" category, which includes small rural and urban businesses, cannot be currently estimated for extrapolation as there is no census or other national data available from which to extrapolate. However, given the importance in the survey group (8.3% of businesses), this probably accounts for thousands of batteries, thereby making the estimates in Table A1.8 underestimates.

Table A3.9
Estimates of Car Battery Penetration for Powering Appliances in Zimbabwe Based upon 1992 Census and 1998 ZESA Baseline Survey

Category	**No**	**% battery sample**	**% sample**	**% national**
Domestic				
Urban	298	55.2%	8.0%	84,722
Rural	197	36.5%	13.9%	229,390
Other	45	8.3%	8.3%	
Total	**540**	**100.0%**	**9.0%**	**314,112**

Source: CSO, ZESA, Quest Data and ESMAP.

Annex 4

Solar Energy Resources in Zimbabwe

Data from the Department of Meteorology and the Civil Aviation Authority

67991 BEITBRIDGE LAT: 22 13 LONG: 30 0 ELEV: 456 M

SOLAR RADIATION (MJ/DAY)

	Jl	Ag	Sp	Oc	Nv	Dc	Ja	Fb	Mr	Ap	My	Ju	Annual
1970-71							24.4	24.7	24.6	20.0	16.7	14.8	20.9
1971-72	16.2	19.4	22.2	22.8	21.9	26.7	21.2	23.6	19.2	19.8	18.1	15.6	20.6
1972-73	16.6	18.7	22.3	23.8	25.5	27.6	26.8	24.9	24.1	19.0	17.0	14.3	21.7
1973-74	15.5	19.5	21.2	23.8	23.2	22.5	23.3	22.7	22.1	18.2	18.2	15.8	20.5
1974-75	15.5	18.1	21.9	23.9	21.9	24.4	25.7	23.1	19.9	17.5			21.2
1975-76	16.6	18.5	21.8	23.5	24.6	22.0	22.6	22.5	18.9	18.7	15.0	14.3	19.9
1976-77	16.1	19.0	20.8	21.6	23.4	26.7	25.7	21.4	18.9	20.4	18.6	15.4	20.7
1977-78	16.6	17.3	20.0	25.3	24.3	21.8	23.1	22.6	21.9	20.5	17.2	14.8	20.4
1978-79	14.8	18.1	20.8	21.1	22.9	24.2	24.9	24.2	22.5	21.3	17.3	14.8	20.6
1979-80	15.7	17.4	19.7	20.8	21.9	24.2	26.2	22.8	22.9	21.1	18.5	16.3	20.6
1980-81	16.5	19.4	19.7	22.7	22.2	26.5	23.2	21.7	21.6	19.8	16.5	16.2	20.5
1981-82	15.4	16.3	19.5	21.8	24.6	27.1	26.2	26.9	23.8	19.7	16.0	15.1	21.0
1982-83	14.9	19.2	22.8	22.3	23.6	26.1	26.6	26.9	24.4	21.1	17.8	14.9	21.7
1983-84	16.3	20.2	23.8	23.7	28.0	27.2	29.1	27.0	22.4	20.8	17.6	14.7	22.6
1984-85	16.1	20.0	22.6	23.2	23.8	27.7	25.0	25.6	23.4	22.5	18.0	16.7	22.1
1985-86	17.9	21.0	22.4	25.0	26.1	24.0	25.7	26.9	26.5	19.0	15.9	14.7	22.1
1986-87	15.0	18.9	19.6	22.4	26.0	24.9	27.0	26.2	23.2	19.8	16.1	13.6	21.0
1987-88	15.4	16.9	20.1	24.2	25.2	21.6	27.5	22.4	20.2	18.1	15.8	13.6	20.1
1988-89	15.8	18.6	21.6	21.1	24.8	24.0	25.6	21.8	24.1	18.2	17.1	14.5	20.6
1989-90	16.0	18.5	22.5	22.9	23.2	23.6	22.3	25.1	22.8	19.2	16.5	15.4	20.7
1990-91	14.9	18.8	22.0	23.4	25.6	23.0	23.4		21.2		13.6		
1991-92		19.5		26.2		23.5	25.6	28.2	25.0	23.3	19.0	15.8	
1992-93	17.5	19.9	22.6	23.8	25.6	28.2	28.8	23.7	23.4	22.9	20.5	16.8	
1993-94	17.0	20.8	24.1	25.1	23.5	26.4	26.8	25.8	26.7	22.4	16.1	14.5	

67755 BINGA LAT: 17 37 LONG: 27 20 ELEV: 617 M

SOLAR RADIATION (MJ/DAY)

	Jl	Ag	Sp	Oc	Nv	Dc	Ja	Fb	Mr	Ap	My	Ju	Annual
1970-71							20.6	25.7	26.6	24.0	20.3	19.0	22.7
1971-72	19.8	21.7	24.5	25.9	23.0	25.0	19.6	26.8	21.8	21.0	20.9	18.1	22.3
1972-73	19.8	21.3	22.4	25.2	27.7	25.7	25.1	21.0	25.8	22.9	20.4	17.4	22.9
1973-74	19.6	21.7	23.1	23.7	22.7	19.3	19.0	18.5	22.3	20.9	19.2	19.3	20.8
1974-75	19.4	21.4	22.4	24.4	20.0	19.4	22.4	22.0	23.2	21.4	20.0	17.6	21.1
1975-76	18.6	21.1	23.7	25.1	27.3	20.8	23.6	22.7	19.7	19.2	18.6	17.0	21.5
1976-77	19.0	22.1	22.4	23.7	24.1	23.0	26.5	22.4	21.0	23.5	20.5	18.8	22.2
1977-78	19.0	20.6	22.5	27.9	24.9	19.8	20.4	21.4	21.0	19.6	19.6	18.1	21.2
1978-79	18.6	21.5	22.7	23.3	26.5	23.4							22.7
1986-87											18.9	19.1	19.0
1987-88	19.4	22.5	24.1	27.1	27.9	23.9	27.9	23.0	23.6	23.3	20.8	18.8	23.5
1988-89	20.2	23.3	25.9	26.6	27.8	24.3	23.8	20.4	25.3	23.8	22.0	18.5	23.5
1989-90	19.8	23.1	24.6	24.9	27.3	27.8	23.4	25.4	27.6	25.6	22.2	19.8	24.3
1990-91	19.3	22.5	24.8	26.3	27.9	26.4	23.8	25.0	25.1	25.6	21.5	18.7	23.9

67977 BUFFALO RANGE LAT: 21 1 LONG: 31 35 ELEV: 429 M

SOLAR RADIATION (MJ/DAY)

	Jl	Ag	Sp	Oc	Nv	Dc	Ja	Fb	Mr	Ap	My	Ju	Annual
1966-67	14.4	16.5	18.3	22.1	21.1	20.6	21.5	20.1	20.5	18.0	15.7	13.0	18.5
1967-68	13.7	15.5	20.2	19.4	23.1	25.3	23.8	20.8	20.0	16.2	14.8	n/a	19.4
1970-71								23.9	26.0	25.0	20.7	16.3	22.4
1971-72	14.4	16.1	19.3	22.2	22.6								
1972-73													
1973-74				20.4	21.2	23.4	19.5	26.9	20.6	21.2	17.1	17.7	24.3
1974-75	16.7	14.9	18.6	22.2	23.1	21.3	23.6	24.8	21.8	19.3	18.8	18.0	20.3
1975-76	14.3	17.1	18.4	23.2	22.6	26.2	22.7	25.1	24.4	20.3	18.9	16.6	20.8
1976-77	15.0	16.1	18.7	22.7	21.8	24.4	25.9	27.4	19.7	18.1	21.2	19.4	20.9
1977-78	15.5	15.5	17.7	18.8	24.8	25.0	22.3	21.6	22.6	21.4	19.5	17.4	20.2
1978-79	14.5	15.8	18.9	21.6	18.7	22.5	21.8	24.5	25.4	21.6	22.9	17.1	20.4
1979-80	14.2	15.3	17.5	18.5	19.3	21.8	24.2	27.4	24.0	23.1	20.7	18.1	20.3
1980-81	15.4	39.0	46.0	44.4	55.1	54.0	61.7	24.0	19.1	22.7	19.7	16.0	34.7
1981-82	15.9	16.9	17.9	19.7	20.2	24.6	26.7	27.5	23.5	25.0	20.1	17.1	21.3
1982-83	16.5	15.3	18.4	21.6	22.1	23.9	27.3	28.9	25.3	24.9	20.9	17.3	21.9
1983-84	14.0	15.0	19.3	22.7	22.0	26.1	26.3	26.5	25.2	20.0	19.7	16.6	21.1
1984-85	13.5	14.9	19.2	20.0	22.0	20.1	25.4	23.5	22.7	22.6	20.8	17.0	20.1
1985-86	14.6	15.7	19.4	18.6	23.9	26.5	24.1	25.5	24.2	24.6	17.5	17.4	21.0

67964 BULAWAYO GOETZ OBSY. LAT: 20 9 LONG: 28 37 ELEV: 1343 M

SOLAR RADIATION (MJ/DAY)

	Jl	Ag	Sp	Oc	Nv	Dc	Ja	Fb	Mr	Ap	My	Ju	Annual
1970-71							22.4	25.8	24.7	20.2	17.0	15.9	21.0
1971-72	17.6	21.7	24.2	25.5	21.5	25.6	20.1	23.8	22.1	20.1	18.9	18.2	21.6
1972-73	18.9	21.5	23.6	25.4	26.3	27.0	25.4	21.7	23.3	20.1	18.9	15.4	22.3
1973-74	18.6	21.1	24.2	22.9	24.1	19.0	21.8	21.2	22.3	17.5	17.2	18.5	20.7
1974-75	17.8	19.1	23.5	25.1	21.2	22.3	24.7	22.7	21.0	21.0	18.9	18.5	21.3
1975-76	19.5	21.3	25.8	26.6	28.0	20.7	26.0	23.8	19.6	19.9	18.0	17.5	22.2
1976-77	19.4	21.2	22.2	20.9	23.5	23.4	25.8	20.0	18.8	22.2	18.7	17.6	21.1
1977-78	17.4	19.0	20.1	26.5	25.0	20.2	18.9	21.5	20.4	19.9	18.3	16.6	20.3
1978-79	17.5	20.8	21.7	20.5	24.9	23.1	23.7	25.1	23.1	22.6	17.3	16.4	21.4
1979-80	18.0	19.4	21.7	21.3	22.5	22.3	26.1	20.7	22.7	22.0	19.8	17.9	21.2
1980-81	18.4	20.3	22.1	26.6	21.0	25.8	22.3	18.4	22.0	19.9	17.1	18.4	21.0
1981-82	18.5	20.0	21.3	22.2	24.1	25.9	26.7	26.4	25.9	19.4	18.9	16.6	22.2
1982-83	16.6	20.7	23.8	22.7	23.1	25.6	25.5	24.9	22.6	20.0	18.1	17.7	21.8
1983-84	17.9	21.8	24.8	23.7	25.3	25.4	27.9	25.9	20.9	20.4	18.9	16.3	22.5
1984-85	17.3	21.8	23.3	22.6	22.8	25.7	20.9	24.4	22.9	21.7	18.0	16.7	21.5
1985-86	16.3	19.7	20.5	23.2	25.6	20.5	24.0	22.0	20.9	15.4	18.0	16.8	20.2
1986-87	17.5	19.3	20.7	21.3	23.0	21.9	24.5	25.4	22.2	21.0	17.2	16.5	20.9
1987-88	17.8	19.0	20.6	24.6	23.9	19.4	26.2	20.1	20.3	18.4	16.9	15.8	20.2
1988-89	17.7	19.9	23.1	21.5	24.1	20.5	22.5	17.6	21.7	17.3	17.4	15.1	19.9
1989-90	16.7	18.3	21.5	22.0	22.8	23.9	20.1	22.3	21.1	18.0	17.1	15.3	19.9
1990-91	16.4	19.4	21.5	23.3	24.9	23.4	12.6	22.0	19.5	22.0	17.4	15.5	19.8
1991-92	16.8	19.2	20.4	23.4	22.9	22.1	23.8	26.3	18.9	20.3	17.9	16.4	
1992-93	16.9	20.2	22.4	21.6	22.7	21.4	23.6	19.7	20.9	19.2	18.1	16.1	
1993-94	14.8	19.0	21.6	24.6	11.7	22.4	11.8	23.0	24.0	21.4	17.8	16.1	

67867 GWERU THORNHILL LAT: 19 27 LONG: 29 51 ELEV: 1428 M

SOLAR RADIATION (MJ/DAY)

	Jl	Ag	Sp	Oc	Nv	Dc	Ja	Fb	Mr	Ap	My	Ju	Annual
1971-72	18.2	22.4	24.6	24.5	20.7	25.0	20.1	22.6	20.7	20.8	18.6	19.2	21.5
1972-73	19.2	22.6	24.8	25.2	25.6	25.0	25.5	23.2	24.9	21.1	20.1	16.2	22.8
1973-74	20.3	22.1	24.9	23.5	23.7	17.4	22.2	19.7	22.3	19.2	18.7	20.4	21.2
1974-75	17.9	20.0	23.4	25.8	20.1	19.0	21.8	21.0	20.7	20.3	18.5	17.5	20.5
1975-76	18.9	21.1	25.0	26.4	25.8	19.1	23.1	21.3	18.1	18.7	17.3	16.8	21.0
1976-77	18.8	22.9	22.8	21.7	23.0	21.0	24.5	17.8	18.4	23.6	19.7	19.5	21.1
1977-78	18.2	20.4	21.5	27.0	24.1	20.1	19.4	21.9	20.6	19.0	19.0	16.8	20.7
1978-79	18.8	22.2	22.7	20.7	25.0	19.9	23.7	25.6	22.3	24.4	18.4	17.5	21.8
1979-80	19.2	21.2	24.3	22.3	21.4	20.7	25.4	21.5	22.6	22.0	20.9	18.4	21.6
1980-81	19.4	22.4	22.3	25.7	20.0	23.4	21.6	17.8	22.0	20.3	17.5	19.4	21.0
1981-82	19.8	22.0	22.2	22.6	23.0	25.3	25.5	26.8	25.4	20.7	20.3	18.6	22.7
1982-83	17.4	21.8	26.0	22.5	23.7	25.7	23.9	25.0	22.6	21.2	19.7	18.1	22.3
1983-84	18.1	23.0	25.7	23.5	24.5	23.6	26.5	25.2	21.3	21.6	18.4	17.2	22.4
1984-85	17.0	22.9	24.2	22.9	21.1	23.3	21.7	24.4	22.9	21.9	18.9	18.1	21.6
1985-86	17.6	22.8	22.2	25.0	26.2	19.7	22.4	23.5	23.8	18.2	21.1	19.7	21.9
1986-87	20.1	22.9	24.7	22.0	25.6	22.6	26.5	27.2	24.9	24.5	20.5	20.0	23.5
1987-88	21.6	22.1	23.3	26.4	25.9	22.8	27.5	21.5	22.8	20.6	18.7	17.9	22.6
1988-89	19.6	22.8	26.5	24.4	25.4	22.5	24.5	17.0	23.2	19.8	20.8	17.0	22.0
1989-90	20.3	21.0	24.5	23.9	24.7	25.2	20.3	23.8	23.9	20.8	20.5	17.4	22.2
1990-91	20.3	23.3	25.4	26.7	28.5	25.7	23.6	22.1	21.2	24.5	19.8	18.3	23.3
1991-92	19.6	22.5	23.6	23.8	22.1	23.2	24.4	28.3	21.3	22.0	19.9	19.0	
1992-93	20.0	23.2	25.9	27.1	25.6	24.7	24.6	21.7	23.6	21.9	22.4	20.0	
1993-94	17.9	23.1	25.5	28.1	21.4	24.2	24.6	27.6	29.1	25.9	22.8	19.9	
1994-95	21.3	22.9	27.4	24.3	27.1	27.3	29.2	28.5	27.1				
1995-96	21.0	22.4	25.6	25.1	26.3	22.8	22.1				19.4		

67774 HARARE BELVEDERE LAT: 17 50 LONG: 31 1 ELEV: 1471 M

SOLAR RADIATION (MJ/DAY)

	Jl	Ag	Sp	Oc	Nv	Dc	Ja	Fb	Mr	Ap	My	Ju	Annual
1970-71	n/a	n/a	n/a	n/a	n/a	n/a	19.8	20.9	24.7	21.8	19.4	17.9	20.8
1971-72	18.1	21.0	24.7	26.7	20.9	23.1	20.9	21.5	20.7	18.7	17.7	18.9	21.1
1972-73	18.8	21.6	23.1	24.1	25.4	25.2	24.1	22.2	23.8	19.1	19.2	16.3	21.9
1973-74	19.1	21.2	25.1	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	21.8
1974-75	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
1975-76	n/a	n/a	25.7	27.7	27.3	20.8	23.4	21.9	19.4	19.4	17.4	17.8	22.1
1976-77	20.3	23.3	24.9	24.2	25.6	20.9	25.3	18.0	19.7	22.0	19.3	18.8	21.9
1977-78	17.9	20.4	22.0	27.8	25.3	20.7	19.6	21.6	19.7	18.8	19.0	17.6	20.9
1978-79	18.3	22.7	23.6	23.5	25.8	21.2	24.3	23.9	20.1	22.6	19.4	17.3	21.9
1979-80	18.1	21.6	24.8	23.5	22.3	20.6	24.4	22.8	21.0	19.6	21.3	19.2	21.6
1980-81	19.8	22.3	24.1	25.8	23.5	22.2	20.6	16.7	19.1	19.2	17.5	18.6	20.8
1981-82	18.4	20.9	22.5	22.4	22.9	23.9	20.3	20.7	22.2	19.4	18.0	16.8	20.7
1982-83	17.0	20.5	22.8	22.3	22.8	23.0	20.9	23.0	22.3	21.1	17.6	16.1	20.8
1983-84	17.0	20.5	22.8	22.9	22.1	19.2	24.6	21.7	20.0	19.6	17.7	15.8	20.3
1984-85	15.4	21.1	22.8	22.6	19.7	20.2	22.4	24.2	22.5	23.1	n/a	14.3	20.8
1985-86	17.1	20.1	20.7	23.8	24.8	n/a	n/a	n/a	19.3	17.0	17.9	16.4	19.7
1986-87	17.4	20.3	21.7	21.7	23.2	20.4	22.0	21.8	20.8	21.8	17.2	17.4	20.5
1987-88	18.0	17.7	21.4	24.1	25.1	18.6	22.5	20.2	17.4	18.7	16.3	16.3	19.7
1988-89	17.0	20.1	23.7	22.4	24.4	19.7	19.2	14.4	18.6	18.5	18.7	n/a	19.7
1989-90	15.6	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	15.6
1990-91	15.7	18.7	21.6	23.1	23.1	20.4	21.1	17.6	20.1	19.6	16.4	16.5	19.5
1991-92	16.8	19.3	20.8	22.9	21.3	20.9	22.9	24.3	18.7	17.0	17.4	15.7	
1992-93	17.3	18.2	23.1	23.5	22.6		19.4	19.0	19.2	17.7	18.3		
1993-94	14.6	17.9	21.5	24.0	19.9	21.7	28.6	19.5	22.1	19.0	17.8	16.1	

67791 HARARE KUTSAGA T.R.S. LAT: 17 55 LONG: 31 8 ELEV: 1479 M

SOLAR RADIATION (MJ/DAY)

	Jl	Ag	Sp	Oc	Nv	Dc	Ja	Fb	Mr	Ap	My	Ju	Annual
1979-80	17.8	20.9	22.8	21.2	20.7	19.5	23.6	21.8	19.6	19.7	20.8	18.3	20.6
1980-81	19.5	20.3	22.2	23.7	22.3	20.6	20.6	17.1	19.8	19.0	16.5	17.8	19.9
1981-82	18.3	21.0	22.0	22.0	22.2	23.8	20.9	20.4	22.4	20.0	18.3	17.5	20.7
1982-83	18.4	21.3	22.1	22.3	22.8	22.5	21.0	22.6	22.5	20.2	18.6	16.5	20.9
1983-84	17.5	20.2	22.9	20.7	22.6	18.9	23.8	21.5	19.4	19.4	17.7	15.9	20.0
1984-85	15.0	20.7	21.9	21.8	19.6	19.5	19.2	20.7	19.8	20.3	17.4	17.7	19.5
1985-86	18.7	19.9	20.5	22.1	21.0	18.3	19.9	19.7	21.0	18.2	19.0	17.7	19.7
1986-87	18.3	21.2	21.6	20.7	22.2	20.2	22.4	22.0	21.9	22.3	18.9	18.6	20.9
1987-88	20.5	19.9	21.5	24.3	24.8	19.1	24.1	20.9	19.6	19.9	16.9	17.2	20.7
1988-89	19.0	21.3	23.1	22.3	22.7	19.8	19.2	14.2	18.9	19.7	20.3	17.5	19.8
1989-90	19.5	20.1	20.8	21.5	21.8	21.6	18.6	19.3	21.3	18.8	18.9	15.8	19.8
1990-91	18.6	20.0	21.7	22.6	22.4	20.1	22.0	19.7	19.8	20.0	17.8	17.6	20.2
1991-92	17.4	20.6	21.4	22.6	20.4	21.2	22.0	23.8	18.7	19.7	18.5	16.6	
1992-93	18.4	19.5	22.2	22.1	22.6	16.9	19.6	18.2	19.2	18.2	18.5	16.8	
1993-94		18.2	20.3	22.1	18.2	21.8	18.1	19.0	21.1	18.4	18.2	15.8	
1994-95	16.5	17.6	20.4	18.8	21.7		19.7	19.0	19.9	17.9			
1995-96	16.2	16.5	19.4	18.8	18.4	15.7	15.1	16.5	17.7	16.6	13.1	14.9	14.9
1996-97	15.0	17.4	18.7	19.4	17.7	16.4		16.0					

67795 HARARE RES. STATION LAT: 17 48 LONG: 31 3 ELEV: 1506 M

SOLAR RADIATION (MJ/DAY)

	Jl	Ag	Sp	Oc	Nv	Dc	Ja	Fb	Mr	Ap	My	Ju	Annual
1982-83	19.7	23.4	25.0	24.2	25.3	25.1	23.2	25.6	24.7	22.9	21.0	19.8	23.3
1983-84	20.1	23.3	26.8	24.2	25.8	21.7	27.1	24.7	23.0	23.1	21.2	18.8	23.3
1984-85	18.9	23.6	24.8	24.8	21.9	23.2	22.1	24.0	23.3	24.2	19.7	19.4	22.5
1985-86	20.4	23.1	24.3	25.6	24.0	20.5	23.1	22.4	22.9	20.4	22.7	21.1	22.5
1986-87	22.2	24.2	24.2	22.8	24.2	21.4	22.4	23.5	23.1	24.1	21.5	21.7	22.9
1987-88	23.1	21.9	24.3	24.8	26.5	21.0	24.3	22.9	22.2	23.4	20.4	18.7	22.8
1988-89	20.5	23.7	26.4	24.9	26.8	22.6	22.1	17.1	22.1	22.9	22.6	18.9	22.6
1989-90	21.1	22.0	25.7	24.8	25.9	25.7	22.8	22.9	26.6	24.2	21.8	18.5	23.5
1990-91	22.0	23.5	26.6	27.9	27.9	24.8	26.0	23.2	25.0	24.9	21.9	21.1	24.6

67869 KADOMA COTTON RES. INST. LAT: 18 19 LONG: 29 53 ELEV: 1149 M

SOLAR RADIATION (MJ/DAY)

	Jl	Ag	Sp	Oc	Nv	Dc	Ja	Fb	Mr	Ap	My	Ju	Annual
1970-71	n/a	n/a	n/a	n/a	n/a	n/a	20.2	23.9	24.2	21.6	19.1	17.9	21.1
1971-72	18.5	22.0	23.8	24.6	22.6	24.9	19.5	23.8	22.3	20.9	20.2	18.8	21.8
1972-73	18.5	21.8	24.2	24.0	25.5	24.7	23.9	23.0	25.0	20.8	19.1	16.5	22.3
1973-74	19.6	21.6	24.2	23.9	22.2	19.3	21.4	21.3	22.6	19.5	18.1	18.7	21.0
1974-75	17.9	20.1	24.0	25.5	20.4	21.6	22.5	21.8	23.2	20.4	20.8	18.4	21.4
1975-76	18.8	22.0	26.3	27.1	27.8	21.2	25.0	24.1	20.3	20.5	19.8	19.3	22.7
1976-77	20.8	23.8	24.0	23.4	25.3	23.2	28.0	20.9	21.5	24.7	20.3	20.2	23.0
1977-78	19.2	21.9	22.3	26.9	24.8	22.6	21.6	23.6	21.6	20.9	18.3	19.2	21.9
1978-79	19.2	22.6	23.3	23.3	26.4	20.8	26.6	26.6	22.5	25.0	20.6	19.1	23.0
1979-80	20.4	21.4	23.7	22.9	22.6	15.2	n/a	n/a	n/a	n/a	n/a	n/a	21.0

67761 KARIBA AIRPORT LAT: 16 31 LONG: 28 53 ELEV: 518 M

SOLAR RADIATION (MJ/DAY)

	Jl	Ag	Sp	Oc	Nv	Dc	Ja	Fb	Mr	Ap	My	Ju	Annual
1970-71	n/a	n/a	n/a	n/a	n/a	n/a	19.5	21.5	23.9	23.5	20.9	17.2	21.1
1971-72	19.3	21.6	24.3	26.0	22.6	24.6	19.2	24.7	21.4	20.9	20.8	19.6	22.8
1972-73	19.7	22.4	24.3	26.1	26.8	25.5	24.4	21.2	25.6	20.9	20.7	16.3	18.1
1973-74	20.1	22.7	24.2	24.8	22.0	17.8	19.9	19.1	19.2	21.4	17.6	19.3	20.7
1974-75	18.9	20.8	23.3	26.1	21.4	19.2	22.6	21.5	20.2	21.0	21.1	16.8	21.1
1975-76	19.0	21.4	24.1	25.3	26.9	21.6	22.9	22.5	17.3	17.6	18.7	18.3	21.3
1976-77	19.9	22.5	23.2	23.7	25.1	23.4	25.0	21.1	21.1	24.8	21.6	19.0	22.5
1977-78	18.1	21.1	22.9	27.0	27.5	19.2	17.1	21.2	17.8	18.5	20.2	18.0	20.7
1978-79	19.0	21.9	22.5	24.1	27.1	23.6	24.3	25.5	18.9	24.5	22.3	18.3	22.7
1979-80	19.5	22.2	22.9	24.0	23.9	20.4	28.1	21.3	22.1	22.1	22.2	18.9	22.3
1980-81	20.0	22.5	25.2	26.0	25.0	22.8	23.7	18.2	22.4	22.1	18.9	20.2	22.2
1981-82	18.9	23.3	23.8	25.3	28.0	28.1	23.8	22.7	25.7	22.9	20.8	19.0	23.5
1982-83	19.1	23.1	24.7	25.9	27.2	25.7	24.1	26.6	24.0	23.6	21.7	19.8	23.8
1983-84	20.4	23.4	25.3	26.5	27.4	23.1	28.4	23.9	21.7	23.2	21.3	18.8	23.6
1984-85	18.9	23.0	24.7	26.3	24.1	21.4	20.9	20.8	22.1	23.3	19.3	19.0	22.0
1985-86	19.0	21.0	24.0	24.2	25.0	20.7	20.5	23.3	23.3	19.6	21.6	19.2	21.8
1986-87	19.2	23.0	23.7	24.7	26.9	25.3	24.5	27.7	26.4	24.2	19.6	17.6	23.6
1987-88	20.7	21.1	24.6	27.3	28.4	23.0	25.8	22.3	21.7	22.4	19.0	18.9	22.9
1988-89	20.1	21.8	25.0	25.0	28.1	23.8	19.8	19.0	24.2	21.3	20.3	18.8	22.3
1989-90	20.1	22.3	23.9	25.1	26.4	24.9	22.1	22.4	25.3	21.9	20.9	17.1	22.7
1990-91	19.9	21.1	23.8	25.7	28.4	24.8	21.5	24.8	23.9	22.5	20.6	19.7	23.1
1991-92	19.1	22.7	23.8	25.6	24.9	25.7	27.2	28.5	22.7	22.7	20.1		
1992-93	19.8	23.2	25.9	27.9	26.1	22.2	25.3	21.5	22.1	21.7	21.7	18.7	
1993-94	18.2	22.6	24.0	26.4	23.3	26.4	22.8	24.8	27.3	24.1	21.6	19.0	24.1
1994-95	19.3	22.3		25.5	28.3	25.4	17.9	23.8	25.9	24.7	20.6	20.8	
1995-96	20.0	22.7				24.2	21.8	23.2	23.5	19.7	20.2		
1996-97	20.6	23.3	25.4	28.1	23.8	25.1	21.8		22.8				

67765 KAROI LAT: 16 50 LONG: 29 37 ELEV: 1343 M

SOLAR RADIATION (MJ/DAY)

	Jl	Ag	Sp	Oc	Nv	Dc	Ja	Fb	Mr	Ap	My	Ju	Annual
1970-71	n/a	n/a	n/a	n/a	n/a	n/a	19.8	20.8	23.5	23.1	20.1	17.7	20.8
1971-72	19.3	22.5	23.7	25.3	19.8	22.8	19.0	21.7	20.9	20.3	19.0	19.0	21.1
1972-73	19.1	22.8	24.5	25.3	26.2	24.4	23.9	22.6	23.6	20.8	21.3	17.4	22.7
1973-74	20.3	22.3	25.1	24.9	20.3	19.0	20.4	20.1	20.4	19.8	17.1	19.9	20.8
1974-75	19.2	21.7	25.0	26.3	21.1	19.1	22.0	20.7	21.2	21.8	20.8	17.5	21.4
1975-76	20.3	21.7	24.9	25.5	26.1	20.3	22.0	22.9	19.2	19.8	18.1	17.9	21.6
1976-77	20.0	23.5	24.2	23.1	24.4	21.2	23.4	20.6	21.6	22.4	19.5	19.9	22.0
1977-78	19.8	21.6	23.3	27.7	26.4	19.6	20.7	21.1	20.2	18.3	19.9	18.8	21.5
1978-79	19.3	23.3	23.4	24.4	25.6	19.8	23.3	22.4	20.7	23.9	21.9	19.9	22.3
1979-80	20.8	22.5	24.7	23.7	22.1	20.4	25.8	22.2	22.3	20.8	22.5	20.3	22.3
1980-81	21.0	23.6	24.5	25.4	23.6	22.4	23.5	18.0	21.1	21.3	18.9	20.3	22.0
1981-82	19.8	23.8	24.1	25.1	24.5	24.8	21.1	20.9	25.2	21.7	20.0	19.2	22.5
1982-83	19.6	23.1	24.3	24.0	25.6	24.1	23.6	25.8	24.9	22.8	20.8	18.9	23.1
1983-84	20.0	22.7	25.4	23.9	24.3	20.0	24.2	23.2	21.9	21.9	20.8	17.7	22.2
1984-85	18.5	23.3	24.5	25.7	22.6	21.6	20.2	19.6	22.0	23.7	19.0	18.7	21.6
1985-86	19.5	23.1	24.8	24.5	25.1	18.5	21.0	21.3	23.2	20.0	21.8	20.1	21.9
1986-87	21.1	24.0	24.5	23.8	26.3	24.6	24.1	26.0	25.5	25.6	21.2	19.7	23.9
1987-88	21.4	21.7	24.7	27.5	26.7	21.8	25.8	21.4	22.3	23.0	20.2	19.2	23.0
1988-89	20.2	24.3	26.3	25.1	26.9	23.6	22.2	18.1	23.0	23.1	22.1	18.6	22.8
1989-90	19.8	21.4	23.3	25.4	25.0	23.5	20.4	19.5	25.7	22.6	20.6	18.0	22.1
1990-91	21.6	22.5	25.5	26.5	27.0	25.2	24.0	24.7	24.9	23.6	20.8	20.4	23.9
1991-92	20.4	24.0	25.1	25.4	24.4	24.8	27.4	30.0	22.4	23.8	21.9	18.9	
1992-93	21.5	24.0	27.1	28.6	26.6	21.2	24.2	20.9	22.8	23.1	23.4	20.7	
1993-94	19.4	23.9	25.4	28.3	24.9	26.3	24.5	22.7	25.6		23.4		
1994-95	21.1		26.9	28.4		25.6	24.5						
1995-96		23.2	26.7	26.5	25.0	20.7	22.8						
1996-97							23.8						

67879 MAKOHOLI LAT: 19 50 LONG: 30 47 ELEV: 1204 M

SOLAR RADIATION (MJ/DAY)

	Jl	Ag	Sp	Oc	Nv	Dc	Ja	Fb	Mr	Ap	My	Ju	Annual
1970-71	n/a	n/a	n/a	n/a	n/a	n/a	22.0	25.5	25.4	22.1	18.6	17.6	21.9
1971-72	17.7	21.0	23.1	24.0	22.2	24.4	20.2	22.3	20.4	20.6	19.0	17.6	21.0
1972-73	18.8	21.3	22.5	23.7	24.2	26.1	25.2	22.2	25.0	19.1	19.4	15.6	21.9
1973-74	18.3	21.6	24.1	23.1	23.9	19.2	23.4	20.2	21.8	18.0	18.8	19.5	21.0
1974-75	17.2	19.8	23.6	24.6	22.0	21.2	24.5	22.1	21.2	20.9	19.1	17.5	21.1
1975-76	19.5	20.6	25.1	24.6	26.6	22.4	24.1	23.0	19.8	19.6	17.2	16.5	21.6
1976-77	19.3	21.4	23.6	21.4	24.2	23.2	26.7	18.4	18.6	23.3	19.3	18.1	21.5
1977-78	17.5	19.3	20.7	27.0	24.0	20.7	22.1	22.3	20.4	19.4	19.2	16.3	20.7
1978-79	19.0	22.2	21.5	20.8	23.7	20.9	24.8	24.9	22.0	23.8	18.7	18.4	21.7
1979-80	18.5	21.5	22.7	21.9	22.0	22.4	27.1	23.0	22.0	21.9	20.7	18.1	21.8
1980-81	18.5	20.9	20.9	24.9	21.2	23.4	20.6	18.4	22.7	20.8	18.4	19.0	20.8
1981-82	19.1	20.5	22.2	21.5	24.3	25.7	25.7	24.6	25.0	21.2	19.9	18.7	22.4
1982-83	17.4	21.8	23.6	21.7	24.0	28.2	26.5	25.3	22.9	21.3	19.6	18.8	22.6
1983-84	18.1	22.2	25.7	23.7	26.8	24.8	28.0	25.4	21.9	21.6	19.2	16.9	22.9
1984-85	17.3	22.6	22.9	23.1	21.7	25.4	21.4	23.9	23.3	21.4	18.8	17.5	21.6
1985-86	17.7	22.2	21.5	24.8	23.7	19.8	23.1	23.1	23.6	18.3	20.6	18.3	21.4
1986-87	19.4	22.0	22.8	22.6	25.3	21.6	26.6	27.1	23.7	22.4	19.1	18.0	22.5

67877 MARONDERA RES. STN. IRRIG. LAT: 18 11 LONG: 31 28 ELEV: 1631 M

SOLAR RADIATION (MJ/DAY)

	Jl	Ag	Sp	Oc	Nv	Dc	Ja	Fb	Mr	Ap	My	Ju	Annual
1971-72	20.9	24.7	26.4	26.9	22.4	25.2	21.6	24.6	23.1	21.7	21.1	21.2	
1972-73	21.3	24.7	25.7	25.5	27.3	28.8	26.5	24.7	26.2	21.5	21.3	17.3	
1973-74	21.5	23.6	26.9	24.2	22.6	19.2	22.4	19.2	22.0	21.5	18.9	21.5	
1974-75	19.5	23.1	27.0	27.5	23.7	23.9	24.5	23.2	24.2	21.6	21.8	19.4	
1975-76	20.9	23.1	27.0	27.1	28.3	22.8	24.3	23.3	21.4	22.0	19.9	19.2	
1976-77	22.7	25.9	26.3	26.5	26.3	22.0	27.6	20.0	22.0	25.7	22.5	21.3	
1977-78	18.8	23.1	23.1	28.4	25.5	22.3	22.6	23.3	21.7	20.4	20.4	19.4	
1978-79	20.5	25.0	24.5	23.1	26.9	21.5	25.7	26.1	22.9	25.2	20.5	19.4	
1979-80	20.1	23.6	25.6	24.9	22.6	23.1	27.6	23.6	23.6	23.1	23.1	20.1	
1980-81	21.2	23.5	25.2	26.4	26.2	23.5	24.9	20.4	24.2	22.9	21.7	21.8	
1981-82	19.4	22.0	22.8	23.8	23.3	24.8	22.0	22.9	24.5	20.0	19.5	18.1	
1982-83	18.4	22.0	23.4	22.8	23.1	24.5	22.9	25.5	24.0	22.8	20.3	19.1	
1983-84	19.2	21.9	25.3	23.5	23.4	21.2	25.1	22.9	20.3	21.4	18.9	17.2	
1984-85	16.3	22.6	24.2	23.1	22.0	20.8	21.3	22.8	20.4	22.3	18.6	18.2	
1985-86	18.3	21.5	22.4	23.6	22.9	19.9	20.1	22.3	23.0	19.4	20.4	19.0	
1986-87	20.0	23.0	24.3	22.3	24.4	22.7	24.7	25.9	23.6	23.7	20.1	19.3	
1987-88	20.4	20.2	22.9	25.2	25.4	20.0	23.8	20.2	20.2	19.4	17.3	16.3	
1988-89	18.2	21.4	24.6	22.3	25.4	20.9	21.4	15.7	20.7	21.0	19.7	16.4	
1989-90	18.1	19.8	22.6	22.4	23.1	21.9	19.6	20.4	22.2	19.7	18.5	15.4	
1990-91	18.9	20.1	21.9	23.8	23.4	21.0	22.4	20.5	20.9	22.2	18.2	18.7	
1991-92	18.7	20.8	22.4	22.6	21.6	22.2	24.0	26.5	19.4	20.4	18.5	16.8	
1992-93	19.0	20.9	23.9	24.1	22.7	22.5	21.3	20.1	21.2	18.6	21.1	18.3	

67975 MASVINGO LAT: 20 4 LONG: 30 52 ELEV: 1094 M

SOLAR RADIATION (MJ/DAY)

	Jl	Ag	Sp	Oc	Nv	Dc	Ja	Fb	Mr	Ap	My	Ju	Annual
1970-71	n/a	n/a	n/a	n/a	n/a	n/a	23.1	25.9	25.0	22.2	17.5	16.8	21.7
1971-72	16.7	21.3	23.1	23.3	21.4	25.5	20.3	22.6	21.3	20.2	17.8	16.2	20.8
1972-73	17.9	20.9	22.7	23.4	24.7	26.2	25.9	22.5	24.4	18.5	18.5	14.4	21.7
1973-74	17.1	20.7	23.7	22.4	23.7	19.7	24.9	20.9	20.9	17.4	17.3	17.9	20.5
1974-75	15.8	19.1	22.8	23.9	21.0	20.6	25.0	21.9	20.0	20.1	17.9	16.3	20.4
1975-76	17.7	19.6	23.9	23.8	25.7	22.3	24.1	23.4	18.4	19.4	15.8	15.5	20.8
1976-77	17.6	20.3	23.5	21.5	23.6	24.2	26.6	18.0	18.5	22.4	20.2	16.9	21.1
1977-78	16.2	18.3	20.6	26.4	23.7	21.2	21.3	21.3	20.0	19.2	18.0	14.7	20.1
1978-79	16.5	20.9	20.9	20.0	22.5	19.3	23.6	23.7	21.4	22.6	17.7	15.2	20.4
1979-80	16.3	19.3	21.0	20.2	21.1	22.0	26.1	22.2	21.8	21.1	18.9	16.1	20.5
1980-81	16.4	19.1	19.1	23.4	20.9	23.2	21.3	18.7	21.8	19.3	16.5	16.6	19.7
1981-82	17.3	18.8	20.3	20.2	23.9	24.1	24.6	23.7	23.9	19.9	18.5	16.3	21.0
1982-83	14.8	19.4	22.5	21.0	22.0	25.4	25.7	24.7	21.9	19.4	18.0	16.7	21.0
1983-84	16.3	20.3	24.0	22.3	25.6	23.4	27.0	24.0	21.2	20.1	18.1	15.5	21.5
1984-85	15.6	21.0	21.4	21.7	21.2	24.0	21.2	23.7	22.5	20.1	17.4	16.1	20.5
1985-86	16.6	20.8	20.0	24.6	24.8	20.3	22.5	23.0	23.5	18.2	18.9	17.1	20.9
1986-87	17.9	21.1	22.0	22.2	23.9	20.6	25.1	25.8	23.7	22.0	18.5	17.1	21.7
1987-88	18.3	18.9	21.6	23.5	24.8	18.9	26.1	23.5	22.5	20.5	19.0	16.4	21.2
1988-89	18.1	21.9	24.1	21.5	24.4	22.7	25.8	18.4	23.1	17.8	20.2	15.5	21.1
1989-90	17.3	19.0	22.3	23.2	23.5	24.2	20.2	23.1	24.5	20.2	18.7	16.7	21.1
1990-91	17.9	20.4	22.2	24.1	25.3	24.3	24.8	23.0	20.7	22.9	19.1	17.0	21.8
1991-92	17.8	21.2	21.7	25.4	24.6	23.9	25.8	28.1	22.0	21.9	19.7	16.9	
1992-93		20.3	24.5	24.0	23.3	23.6	26.0	22.7	22.5	20.9	20.2	16.8	
1993-94	16.3	19.5	24.2	25.9	20.2	24.9	23.9	24.3	25.0	22.5	19.1	16.3	
1994-95	16.8	20.9	23.8	22.6	26.3	24.1	25.9						
1995-96									16.1				
1996-97							21.0						

67963 MATOPOS SANDVELD LAT: 20 24 LONG: 28 28 ELEV: 1338 M

SOLAR RADIATION (MJ/DAY)

	Jl	Ag	Sp	Oc	Nv	Dc	Ja	Fb	Mr	Ap	My	Ju	Annual
1981-82	18.1	20.2	22.6	21.8	23.3	25.0	26.0	25.9	26.3	19.9	19.2	17.0	22.1
1982-83	16.2	20.7	23.9	22.2	24.2	24.1	24.1	25.4	22.7	20.5	18.9	17.3	21.7
1983-84	17.3	21.5	25.7	23.5	24.9	24.2	27.4	24.6	20.4	19.9	18.6	15.0	21.9
1984-85	16.1	21.4	23.0	21.4	22.0	24.9	19.7	23.2	22.0	22.9	17.0	14.7	20.7
1985-86	14.8	20.3	22.6	24.0	27.2	20.5	24.1	23.2	24.3	20.9	17.6	21.4	21.7
1986-87	20.9	20.8	22.9	22.7	26.0	25.2	26.6	27.8	27.6	21.5	17.7	18.6	23.2
1987-88	19.2	20.7	23.1	26.2	24.8	21.2	27.3	20.1	22.7	20.7	17.6	17.1	21.7
1988-89	17.9	20.4	24.8	21.8	24.8	22.4	25.4	19.1	23.0	17.6	18.0	15.4	20.9
1989-90	17.3	19.4	22.9	23.6	23.3	24.0	18.4	22.5	21.5	17.7	16.1	14.5	20.1
1990-91	15.6	19.8	21.8	24.4	25.9	24.1	21.5	22.6	19.7	22.9	18.7	16.2	21.1

67975 MASVINGO LAT: 20 4 LONG: 30 52 ELEV: 1094 M

SOLAR RADIATION (MJ/DAY)

	Jl	Ag	Sp	Oc	Nv	Dc	Ja	Fb	Mr	Ap	My	Ju	Annual
1970-71	n/a	n/a	n/a	n/a	n/a	n/a	23.1	25.9	25.0	22.2	17.5	16.8	21.7
1971-72	16.7	21.3	23.1	23.3	21.4	25.5	20.3	22.6	21.3	20.2	17.8	16.2	20.8
1972-73	17.9	20.9	22.7	23.4	24.7	26.2	25.9	22.5	24.4	18.5	18.5	14.4	21.7
1973-74	17.1	20.7	23.7	22.4	23.7	19.7	24.9	20.9	20.9	17.4	17.3	17.9	20.5
1974-75	15.8	19.1	22.8	23.9	21.0	20.6	25.0	21.9	20.0	20.1	17.9	16.3	20.4
1975-76	17.7	19.6	23.9	23.8	25.7	22.3	24.1	23.4	18.4	19.4	15.8	15.5	20.8
1976-77	17.6	20.3	23.5	21.5	23.6	24.2	26.6	18.0	18.5	22.4	20.2	16.9	21.1
1977-78	16.2	18.3	20.6	26.4	23.7	21.2	21.3	21.3	20.0	19.2	18.0	14.7	20.1
1978-79	16.5	20.9	20.9	20.0	22.5	19.3	23.6	23.7	21.4	22.6	17.7	15.2	20.4
1979-80	16.3	19.3	21.0	20.2	21.1	22.0	26.1	22.2	21.8	21.1	18.9	16.1	20.5
1980-81	16.4	19.1	19.1	23.4	20.9	23.2	21.3	18.7	21.8	19.3	16.5	16.6	19.7
1981-82	17.3	18.8	20.3	20.2	23.9	24.1	24.6	23.7	23.9	19.9	18.5	16.3	21.0
1982-83	14.8	19.4	22.5	21.0	22.0	25.4	25.7	24.7	21.9	19.4	18.0	16.7	21.0
1983-84	16.3	20.3	24.0	22.3	25.6	23.4	27.0	24.0	21.2	20.1	18.1	15.5	21.5
1984-85	15.6	21.0	21.4	21.7	21.2	24.0	21.2	23.7	22.5	20.1	17.4	16.1	20.5
1985-86	16.6	20.8	20.0	24.6	24.8	20.3	22.5	23.0	23.5	18.2	18.9	17.1	20.9
1986-87	17.9	21.1	22.0	22.2	23.9	20.6	25.1	25.8	23.7	22.0	18.5	17.1	21.7
1987-88	18.3	18.9	21.6	23.5	24.8	18.9	26.1	23.5	22.5	20.5	19.0	16.4	21.2
1988-89	18.1	21.9	24.1	21.5	24.4	22.7	25.8	18.4	23.1	17.8	20.2	15.5	21.1
1989-90	17.3	19.0	22.3	23.2	23.5	24.2	20.2	23.1	24.5	20.2	18.7	16.7	21.1
1990-91	17.9	20.4	22.2	24.1	25.3	24.3	24.8	23.0	20.7	22.9	19.1	17.0	21.8
1991-92	17.8	21.2	21.7	25.4	24.6	23.9	25.8	28.1	22.0	21.9	19.7	16.9	
1992-93		20.3	24.5	24.0	23.3	23.6	26.0	22.7	22.5	20.9	20.2	16.8	
1993-94	16.3	19.5	24.2	25.9	20.2	24.9	23.9	24.3	25.0	22.5	19.1	16.3	
1994-95	16.8	20.9	23.8	22.6	26.3	24.1	25.9						
1995-96									16.1				
1996-97							21.0						

67779 MOUNT DARWIN LAT: 16 47 LONG: 31 35 ELEV: 965 M

SOLAR RADIATION (MJ/DAY)

	Jl	Ag	Sp	Oc	Nv	Dc	Ja	Fb	Mr	Ap	My	Ju	Annual
1970-71	n/a	n/a	n/a	n/a	n/a	n/a	20.0	22.7	23.5	22.4	19.9	17.4	21.0
1971-72	19.0	21.1	23.1	23.3	21.2	22.8	19.1	21.8	21.0	19.6	18.7	18.7	20.8
1972-73	17.9	21.5	22.4	23.9	24.9	25.0	22.1	23.2	24.1	20.0	19.9	16.8	21.8
1973-74	19.6	21.6	23.2	23.1	19.8	19.9	21.4	17.9	21.0	19.7	18.2	19.3	20.4
1974-75	17.6	20.1	22.7	24.3	20.9	21.3	22.9	20.2	21.5	20.9	20.4	17.5	20.9
1975-76	18.6	19.7	23.8	24.1	26.4	22.0	22.8	22.1	19.1	20.5	17.8	17.1	21.2
1976-77	18.7	21.9	22.4	22.2	25.6	20.2	24.0	21.9	19.3	21.8	19.7	17.9	21.3
1977-78	17.8	20.4	21.6	24.9	23.4	20.3	20.2	20.5	19.4	18.1	19.0	17.1	20.2
1978-79	18.0	21.4	22.3	22.6	25.0	21.8	23.2	24.6	20.7	22.9	20.7	17.7	21.7
1979-80	18.4	20.1	23.0	22.6	22.4	22.2	25.7	22.6	22.5	20.4	21.0	17.2	21.5
1980-81	18.2	20.5	21.7	23.2	24.4	21.6	23.5	19.1	21.8	21.5	20.2	19.6	21.3
1981-82	18.6	22.1	23.2	23.7	24.6	24.3	23.2	21.4	24.7	21.1	19.3	18.6	22.1
1982-83	18.9	22.1	23.6	22.4	25.1	27.0	25.9	25.9	25.4	22.0	19.5	18.8	23.1
1983-84	18.7	21.9	24.1	24.9	26.8	21.5	26.3	24.1	23.2	22.1	20.6	18.5	22.7
1984-85	18.6	22.6	24.2	25.7	22.6	21.6	21.0	23.4	22.8	22.8	20.0	18.5	22.0
1985-86	18.4	21.4	22.1	24.4	24.4	19.6	21.5	22.3	24.2	19.0	21.2	18.5	21.4
1986-87	17.6	21.9	23.7	23.5	26.7	23.9	23.4	26.1	25.6	24.5	20.0	19.0	23.0
1987-88	20.2	20.0	23.0	26.7	27.2	21.9	26.2	21.1	21.7	21.2	19.0	17.7	22.1
1988-89	18.0	22.3	23.6	22.3	26.4	23.0	21.4	17.0	23.2	21.7	19.7	17.7	21.4
1989-90	18.7	19.9	22.8	23.9	24.5	23.1	21.0	n/a	25.3	21.2	19.2	17.2	21.5
1990-91	19.5	21.5	22.9	25.5	26.0	26.8	23.8	24.2	23.9	22.9	20.7	18.6	23.0
1991-92	19.6	21.6	23.2	26.3	24.7	25.0	28.2	27.1	22.8	22.4	20.4	18.7	
1992-93	19.4	21.9	25.2	27.5	26.5	21.5	23.4	22.4	22.7	21.9	21.4	18.2	
1993-94	18.7	20.3	24.2	25.8	22.0	24.5	23.0	23.2	25.1	23.4	20.8	17.6	
1994-95													

67889 NYANGA EXP. STN. LAT: 18 17 LONG: 32 45 ELEV: 1878 M

SOLAR RADIATION (MJ/DAY)

	Jl	Ag	Sp	Oc	Nv	Dc	Ja	Fb	Mr	Ap	My	Ju	Annual
1970-71	n/a	n/a	n/a	n/a	n/a	n/a	19.0	23.5	23.4	21.5	19.6	17.9	20.8
1971-72	17.0	21.3	24.3	24.5	20.0	20.5	18.3	19.5	20.4	19.2	18.3	19.2	20.2
1972-73	18.1	22.2	23.5	24.3	23.6	23.7	21.7	22.3	23.8	19.2	18.7	15.7	21.4
1973-74	18.1	21.9	24.5	22.8	19.5	15.8	19.8	16.6	20.2	20.4	16.9	19.3	19.7
1974-75	17.3	20.7	24.9	24.0	18.6	19.2	22.0	19.0	21.9	20.7	19.3	18.2	20.5
1975-76	19.4	21.6	25.2	25.3	25.8	21.3	20.3	19.2	18.8	19.8	18.8	18.4	21.2
1976-77	20.3	23.3	24.0	22.0	23.0	17.9	23.2	17.7	18.7	22.0	19.1	20.0	20.9
1977-78	18.7	22.0	21.4	25.9	22.2	18.5	19.8	19.8	20.8	19.5	18.5	17.9	20.4
1978-79	18.9	22.9	23.2	21.4	25.4	17.8	24.0	21.7	21.2	22.8	19.5	n/a	21.7
1979-80	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
1980-81	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
1981-82	19.3	22.3	23.6	21.9	22.0	22.9	21.0	21.3	23.7	20.7	19.5	18.5	21.4
1982-83	18.2	22.4	23.8	21.4	24.8	25.7	25.1	24.9	23.0	22.8	16.6	18.8	22.3
1983-84	17.4	21.4	23.9	22.9	24.2	21.1	25.1	21.6	20.9	22.4	19.1	17.1	21.4
1984-85	16.8	22.3	24.6	23.4	21.0	20.1	18.3	22.9	20.5	21.7	20.1	18.6	20.8
1985-86	19.5	22.5	21.0	23.2	22.8	17.6	21.1	20.7	22.8	19.3	19.2	19.3	20.7
1986-87	19.0	22.8	24.1	22.3	24.2	22.4	23.5	25.7	23.4	23.4	21.4	19.4	22.6
1987-88	21.4	19.5	22.0	24.3	26.0	17.7	23.0	20.7	20.3	20.4	17.5	18.0	20.9
1988-89	18.4	21.8	26.0	22.2	24.2	20.7	21.6	15.3	22.8	21.5	20.0	16.5	20.9
1989-90	18.6	19.9	24.0	22.1	22.3	21.4	19.6	21.5	23.2	19.5	20.3	16.6	20.8
1990-91	20.7	21.2	22.5	24.4	24.0	22.7	23.1	21.6	22.0	23.8	19.5	20.4	22.1
1991-92	19.6	24.0	24.2	25.7	23.5	24.5	23.2	27.1	20.4	22.6	20.3	18.1	
1992-93	20.6	21.6	26.4	27.2	24.6	17.5	20.7	18.8	20.6	19.5	21.0	17.5	
1993-94	18.8	20.5	23.7	24.3	20.2	22.4	20.8	23.5	25.1	21.8	20.7	18.1	
1994-95													

67857 TSHOLOTSHO LAT: 0 0 LONG: 0 0 ELEV: 0 M

SOLAR RADIATION (MJ/DAY)

	Jl	Ag	Sp	Oc	Nv	Dc	Ja	Fb	Mr	Ap	My	Ju	Annual
1970-71	n/a	n/a	n/a	n/a	n/a	n/a	22.7	25.9	25.4	22.3	19.7	17.8	22.3
1971-72	18.9	21.7	24.4	23.9	22.0	25.9	19.9	25.2	20.4	20.2	19.0	17.9	21.6
1972-73	18.2	21.5	23.9	23.7	25.6	26.1	24.3	21.4	23.3	19.9	18.7	15.3	21.8
1973-74	18.3	20.4	23.3	21.1	23.1	18.3	20.7	20.3	21.6	18.4	18.5	18.3	20.2
1974-75	17.8	19.7	22.8	24.4	19.9	21.0	23.4	22.6	21.0	21.9	18.8	18.5	21.0
1975-76	19.1	21.5	23.9	24.9	25.3	28.2	37.1	21.1	19.5	19.7	17.8	16.1	22.9
1976-77	18.6	21.6	21.2	22.1	22.8	22.6	25.0	20.7	19.3	21.5	19.3	17.6	21.0
1977-78	18.2	19.9	20.2	25.6	23.4	19.8	20.1	20.1	20.7	20.4	18.4	16.7	20.3
1978-79	16.9	20.6	21.9	20.7	24.0	21.5	23.8	23.0	22.3	22.7	17.6	16.8	21.0
1979-80	17.5	18.9	21.8	21.1	20.2	20.5	24.0	19.9	22.8	22.7	19.3	16.9	20.5
1980-81	17.0	19.4	22.6	24.5	21.4	24.2	21.1	17.8	20.3	21.5	17.6	17.9	20.4

67843 VICTORIA FALLS AIRPORT LAT: 18 6 LONG: 25 51 ELEV: 1061 M

SOLAR RADIATION (MJ/DAY)

	Jl	Ag	Sp	Oc	Nv	Dc	Ja	Fb	Mr	Ap	My	Ju	Annual
1970-71	n/a	n/a	n/a	n/a	n/a	n/a	19.6	25.3	25.2	21.8	20.3	18.8	21.8
1971-72	18.9	22.4	24.8	24.8	22.7	23.4	18.8	26.3	21.6	20.1	20.5	18.7	21.9
1972-73	18.9	22.2	23.9	24.4	27.5	24.4	24.9	22.7	26.8	22.7	20.0	17.2	23.0
1973-74	20.5	22.8	25.1	22.9	24.2	18.4	20.2	19.1	23.0	20.7	20.1	19.2	21.3
1974-75	19.9	21.6	23.5	25.7	21.2	20.0	23.4	23.0	22.3	21.8	19.8	18.1	21.7
1975-76	19.2	21.7	24.7	26.6	26.5	22.1	22.1	22.8	19.5	20.0	18.6	17.8	21.8
1976-77	20.2	23.5	22.8	22.6	22.5	23.4	26.5	23.2	21.0	23.4	21.1	19.8	22.5
1977-78	20.3	21.7	23.3	27.6	24.6	20.6	21.3	21.6	21.9	20.9	20.7	19.4	22.0
1978-79	19.1	23.2	23.8	22.7	24.2	24.2	24.8	26.6	24.3	24.9	21.6	19.7	23.3
1979-80	20.5	22.0	24.7	22.4	22.0	22.6	26.5	21.0	24.6	24.2	22.8	19.6	22.7
1980-81	20.3	22.8	25.9	27.2	23.6	25.0	22.5	18.9	22.0	24.1	21.2	20.2	22.8
1981-82	19.8	22.2	25.4	26.4	24.1	27.4	25.7	23.0	24.6	21.5	20.9	18.3	23.3
1982-83	19.3	24.6	24.6	23.5	23.7	26.6	22.9	26.6	24.3	23.6	21.4	19.3	23.4
1983-84	20.4	23.8	25.7	25.3	24.9	23.3	27.6	25.7	21.9	23.9	21.6	19.9	23.7
1984-85	20.8	24.8	26.7	26.0	24.9	26.2	22.8	25.3	26.2	26.3	22.0	21.0	24.4
1985-86	20.7	24.2	27.4	28.0	30.0	24.7	26.1	26.5	25.4	23.1	24.1	22.4	25.2
1986-87	21.7	25.3	25.9	25.4	27.5	26.8	29.1	30.2	27.2	26.7	22.3	22.0	25.8
1987-88	22.7	25.0	26.7	29.2	28.1	23.0	29.5	22.5	24.0	24.1	22.3	20.7	24.8
1988-89	22.5	25.1	27.4	27.7	29.1	25.5	23.3	20.9	27.2	23.4	23.7	20.2	24.7
1989-90	22.1	24.6	27.1	26.3	27.1	28.1	22.4	26.8	25.3	24.5	22.6	20.3	24.8
1990-91	21.8	24.8	26.9	26.4	28.0	26.8	23.8	27.2	25.0	26.4	22.8	20.4	25.0

67969 WEST NICHOLSON LAT: 21 3 LONG: 29 22 ELEV: 860 M

SOLAR RADIATION (MJ/DAY)

	Jl	Ag	Sp	Oc	Nv	Dc	Ja	Fb	Mr	Ap	My	Ju	Annual
1970-71	n/a	n/a	n/a	n/a	n/a	n/a	23.0	26.6	25.5	22.5	17.8	16.9	22.1
1971-72	17.6	22.2	23.3	23.2	21.7	27.3	21.2	25.4	20.7	21.1	17.9	16.0	21.5
1972-73	18.7	20.3	23.9	26.1	26.0	27.6	26.0	24.5	24.3	18.9	18.6	15.1	22.5
1973-74	17.7	21.4	24.4	23.3	24.9	19.9	25.8	21.6	21.7	18.6	19.2	18.7	21.4
1974-75	16.9	19.8	23.9	25.2	22.0	24.3	28.4	24.3	21.4	20.7	20.0	18.3	22.1
1975-76	19.9	21.2	26.8	25.0	27.9	23.3	26.4	25.8	21.3	20.6	17.5	16.3	22.7
1976-77	18.7	21.9	25.0	22.3	25.0	26.1	26.8	21.3	19.5	24.3	21.5	18.2	22.6
1977-78	17.5	19.2	21.8	28.6	27.7	23.3	21.7	23.7	20.6	21.1	23.4	14.6	21.9
1978-79	15.2	18.7	19.6	20.0	21.9	19.4	22.7	22.1	20.8	20.8	16.1	14.1	19.3
1979-80	15.3	17.1	19.3	19.3	20.7	21.9	24.4	20.6	20.3	20.5	18.2	16.1	19.5
1980-81	16.1	17.8	18.0	22.3	20.3	24.1	22.0	17.4	21.4	18.9	15.6	16.6	19.2
1981-82	16.1	17.7	19.3	20.3	24.0	25.2	23.9	23.6	23.5	19.2	15.9	15.0	20.3
1982-83	14.1	18.5	21.2	20.1	21.7	24.5	25.0	23.8	23.0	19.6	17.1	15.8	20.4
1983-84	15.3	19.3	22.8	22.4	25.6	24.3	25.5	24.2	20.2	18.9	17.5	13.3	20.8
1984-85	15.8	19.4	20.6	21.3	21.8	24.4	20.9	22.1	21.5	20.7	16.9	15.4	20.1
1985-86	16.6	19.2	19.1	22.5	25.5	21.1	24.3	23.0	23.8	16.2	18.6	17.0	20.6
1986-87	17.8	20.6	21.0	20.2	22.7	22.9	25.4	24.7	22.8	20.3	17.8	16.0	21.0
1987-88	16.4	17.7	19.3	22.8	23.4	20.4	26.7	20.9	20.3	20.0	16.6	15.6	20.0
1988-89	17.3	19.8	22.2	20.6	22.9	21.9	24.8	19.7	22.8	17.1	17.6	15.1	20.2
1989-90	16.8	19.1	21.3	21.3	23.2	24.4	21.0	23.3	n/a	n/a	n/a	n/a	21.3
1990-91	16.4	19.7	20.8	23.5	23.8	24.9	24.9	24.4	20.4	21.1	16.7	15.8	
1991-92	17.2	19.8	19.3	24.8	24.7	24.0		27.2	21.6	20.7	18.3	16.4	
1992-93		19.3	22.8	21.7		23.5	20.4						

Annex 5

Companies in Zimbabwe Active in Solar Energy

Solar Water Heaters

The solar water heating industry in Zimbabwe has a long history. Solar water heaters were first produced in country in the late-1970s. The industry catered primarily to urban high-income groups and to the tourism industry. It is not known how many solar water heaters have been produced in Zimbabwe over the past twenty years, but estimates put it as high as ten thousand, including all industrial, tourism and service sector units. The industry ran into difficulties in the late-1980s. Consumers lost confidence in the quality of most units, and even good producers and assemblers received a bad reputation as a result.

The industry has been slowly turning around over the past five years. This seems likely to accelerate as the price of electricity goes up, and the reliability of electricity goes down. There is currently one big company, Sol Monarch in Bulawayo. It has been in business for seven years. There have been spin-off effects from the growing photovoltaic industry. Now, at least a dozen firms import solar water heaters, primarily on demand. These are generally small firms, with not more than 5 employees. They are engaged in solar photovoltaics, and will order and install solar heaters upon request.

Most of the companies at the moment import solar water heaters from Europe, America and Asia. They operate as agents. However, some assemble sets in Zimbabwe. They provide some local input, such as coating with black paint, to suit local conditions. A few other companies are producing complete solar water heaters. They import some components, but the bulk of the value-added is in Zimbabwe.

The DOE team visited Sol-Monarch and obtained the following profile:

Name of Company	**Sol-Monarch**	
Date of Establishment	1992	
Type of Products	Ball and Pressure Solar Water heaters	
Sizes and prices	250 litres	Z$ 25 941 , 24
	150 litres	Z$ 17 866 , 86

	100 litres Z$ 14 030 , 46
Sales per month (on average)	250 litres - 1
	150 litres - 4
	100 litres - 2
Main rural customers	Boarding schools
Mode of payment	Cash
All geysers have electric back up	
Foreign market	Botswana regularly purchases
Most recent order	20 x 150 litres
Material	
Most material locally available	90 % of required material is local
	10 % imported from South Arica
Imports	Inner tank and outer casing of the storage tank
Taxes	VAT
Any type of energy use during production	Welding was quoted but they could not separate the bill from the general uses like lighting

The other major solar water heater manufacturer and installer is Solarmatics. This company markets low and medium income urban households. As with Sol-Monarch, all Solarmatics' solar water heater have electric backup.

Solar Photovoltaics

The following lists all companies, as at September 1998, active in the solar energy field in Zimbabwe. Approximately ten of these companies either produce and install, or import and install, solar water heaters. All are involved, to some extent, with solar photovoltaics.

1 Adam Telkoms Systems
2 Battery World
3 Caletaf Engineering
4 Candle Power Elec. Engineers
5 Caresolar Systems
6 C. G. Solar
7 Competent Marketing
8 Configuration Project
9 Cosine Energy Systems
10 Eclipse
11 Ecological Designs
12 Enercare Electrical Consultants
13 Energy Glow Elect. Engineers
14 Extensive Range Engineering
15 Fairbridge Solar Company
16 Gistex
17 Gokwe Electronics
18 Guch & Philms Agric. Eng.
19 Harava Co-operative Society
20 Hupertz Solargate
21 I & O Magnet Electronics
22 Impact Solar Systems
23 Infinity Electrical Engineering
24 Jettateck
25 Joamac
26 Jotpav Distributors
27 Kalisolar
28 Kilowatt
29 Mega Solar Systems
30 Modern Buildings
31 Munyati Solar Distributors
32 Nani
33 Netombo
34 Nyamatsa Associates
35 Nyika Distributors
36 Partson & Allen Solar & Photo
37 Pazuva
38 Prister

39	Rallantier	57	Solar Surgeon
40	S.A. Solar	58	Sollatek
41	Sebsolar	59	Sunburn Electrical System
42	Sirial Electronic	60	SunFamily
43	Solamatics	61	Sunplug
44	Solanergy Systems	62	Sun Power Systems
45	Solar Ace	63	Sunpower
46	Solarama Systems	64	Sun Rays
47	Solarcon	65	Sunrise
48	Solarcomm	66	Sunsytems
49	Solar Elect	67	Suntech
50	Solar Electrical Engineering	68	Tendo Electronics and Power Engineering
51	Solar Equip Technologies		
52	Solar Master	69	Tido Systems
53	Solarmwenje	70	Up to Date
54	Solar Power Systems	71	Zidecote
55	Solar Products	72	Zim Torch
56	Solar Rays	73	Zverengo Solar Professionals

List and Contacts of GEF-Approved Solar Companies in Zimbabwe

1 Battery World
P.O. Box CY 793, Causeway
Harare Tel:757575/8 Fax:790286

2 Candle Power Electrical Engineers
P.O. Box 1823
Mutare. Tel 61951

3 Caresolar Systems
P.O.Box CY 2493 Causeway
Harare. Tel : 708399

4 Chivu Electrical Contractors
31 Biddulph Rd. Cranbourne Pk.
Harare

5 Competent Marketing
P.O. Box 1204, Masvingo
Tel : 64589 (After Hrs.)

6 Configuration Project
P.O.Box CY 2556 Causeway
Harare

7 Cosine Energy Systems
P.O. Box CY 2271
Causeway Harare

8 Ecological Designs
P.O. Box 6084
Harare Tel: 6084; Fax: 756924

9 Enercare Electrical Consultants
P. O. Box CY2804 Causeway
Harare

10 Energy Glow Elect. Engineers
P.O. Box 559
Masvingo

11 Extensive Range Engineering
90 Robert Mugabe
Harare

12 Gistex
14 Carrington Road; Darlington
Mutare

13 Guch & Philms Agric. Eng.
P. O. BW 330; Borrowdale
Harare. Tel: 860019/55

14 Harava Co-operative Society
P.O. Box AY96Amby Masasa
Harare

15 Hupertz Solargate
P.O. Box 1649
Mutare

16 I & O Magnet Electronics
P. O. Box 7109
Harare. Tel: 752073/4

17 Impact Solar Systems
1 Conald/Boshoff Dve. Graniteside

Harare. Tel: 752245 Fax: 752202
18 Infinity Electrical Engineering
P.O. Box CY 3121, Causeway
Harare
19 Joamac
P.O. Box 1393
Bulawayo. Tel : 62450
20 Jotpav Distributors
P.O. Box RM 100: Rimuka
Kadoma
21 Rallantier
P.Box CY 395 Causeway
Harare, Tel: 752073/4
22 Nyamatsa Associates
RE81 Malvern Rd.
Waterfalls; Harare
23 Own Electrical Sales & Repairs
P.O. Box CY2493 Causeway
Harare
24 Pazuva
8 Debyshire Road, Waterfalls
Harare
25 Prister Solar Systems
P.O. Box 70
Murewa Tel: (178) 2445
26 Rallantier
P.O. Box CY 395, Causeway
Harare. Tel:752073/4
27 Up To Date Engineering
P.O. Box CY 3383, Causeway
Harare
28 S.A. Solar
P.O. Box 1896
Mutare
29 Sebsolar
21 Chalfont Road, Avonlea
Harare; Tel:333089
30 Solamatics
P.O. Box 2851
Harare; Tel: 749930
31 Solar Ace
P.O. Box BE 665 Belvedere
Harare Tel: 759887
32 Solar Electrical Engineering
P.O. Box 744
Mutare. Tel: 60891; Fax 64238
33 Solar Equip Technologies
P.O. Box 435 Causeway
Harare
34 Solar Master
P.O. Box 1595
Mutare
35 Solar Power Systems
P.O. Box CY 281 Causeway
Harare. Tel; 706477/8
36 Solar Products
P.O. Box ST 628
Harare
37 Solar Rays
P.O. Box 5976
Harare
38 Solar Surgeon
P.O. Box ST 775 Southerton
Harare Tel: 661912
39 Solarama Systems
P. O. Box HD 113, Highfields
Harare
40 Solarcomm
P.O. Box ST 319 Southerton
Harare, Tel:669211/4 Fax 669113
41 Solarit
P.O. Box 1031
Masvingo
42 Sollatek
P.O. Box 66479, Kopje
Harare; Tel: 758680
43 SunFamily
6 Tweed Avenue, Eastlea
Harare
44 Sun Power Solar Systems
2 Fern Road, Hatfield
Harare; Tel: 573923
45 Sunrise Environmental Technologies
P.O. Box MP 455 Mt. Pleasant
Harare
46 Suntech
P.O. Box ST 100
Harare. Tel: 665677
47 Zidecot
P.O. Box 1468
Mutare
48 Zim Torch

P. O. Box MR 16, Marlborough
Harare. Tel : 739441
49 Zverengo Solar Professionals
P.O. Box 4424
Harare
50 Jettatech
P.O. Box 302
Chiredzi

Annex 6

Small Hydropower Resources in Zimbabwe

Summary

Zimbabwe is not particularly well-endowed with small hydropower resources. While the country has significant large hydropower resources, it does not have the hydrological profile for more than a limited number of hydropower schemes. Eight hydro-electric schemes have been developed over the past sixty years. Surveys have been carried out for a number of other possible sites, based on existing dams and weirs. However, these studies show only limited potential for hydro-electricity or hydropower (e.g., mechanical or shaft power) to be developed to meet rural energy needs.

Existing Schemes

Two types of hydropower schemes have been developed in Zimbabwe over the past sixty years. The first are schemes developed either by ZESA or on farms and ranches using existing dams. These provide power to meet local demand. The second have been more recently developed, some by private individuals, the rest by NGOs. Table A6.1 shows the total of eight hydropower schemes developed in Zimbabwe (seven of which are currently operational). Only four of the eight generate electricity, while the other three operational units are used for pumping and motive power.

Table A6.1
Existing Small Hydro Schemes

Location	Capacity (kW)	Year Installed	Produces Electricity
Claremont	250	1963	Yes
Aberfoyle	25	1966	Yes
Nyafaru	30	1995	Yes
Rusitu	700	1997	Yes
Mutsikira (pump scheme)	3	1995 (rehab)	no
Svinurai (hydro-mill)	10	1995 (rehab)	no
Sithole-Chikane (hydro-mill)	25	1965	no
Kuenda	75		not operational

Zimbabwe has a number of dams built for supplying drinking water, water for irrigation and water for livestock. The most thorough study of these dams was conducted in 1990 and 1991 with support from GTZ to the then Ministry of Energy and Water Resources. Table A.6.2 lists all sites studied during this survey, their power and energy potential, and estimated development costs (sites are listed from least cost of development to highest anticipated cost of development).

Table A.6.2
Energy Potential on Small Hydropower Sites on Existing Sites

Dam	kW	GWh	Total Cost ('000 $)	Cost/kW
Mukorsi	4,616	40.46	4,893	1,060.0
Mutirikwi (Kyle)	4,215	36.95	4,951	1,174.6
Mazwikadei	972	8.52	1,730	1,779.8
Bangala	1,037	9.09	1,939	1,869.8
Manjirenji	914	8.01	1,785	1,953.0
Chivero (Hunyani Poort)	549	4.82	1,195	2,176.7
Sebakwe	469	4.11	1,083	2,309.2
Manyame	484	4.24	1,181	2,440.1
Mzingwane (Umzingwane)	76	0.67	211	2,776.3
Ngezi (Palawan)	267	2.34	811	3,037.5
Rusape	308	2.7	970	3,149.4
Glassblcok	181	1.58	591	3,265.2
Smallbridge	85	0.75	278	3,270.6
Mazowe	106	0.093	369	3,481.1
Seke pr.	158	1.39	571	3,613.9
Gwenoro	80	0.7	293	3,662.5
Ncema	41	0.36	157	3,829.3
UpperNcema	83	0.73	325	3,915.7
Inyankuni	93	0.81	389	4,182.8
Mwenji II	170	1.49	714	4,200.0
Insiza	166	1.46	719	4,331.3
Sobi	147	1.29	652	4,435.4
Jumbo	53	0.46	236	4,452.8
Bumururu	131	1.15	680	5,190.8
Odzani	48	0.42	256	5,333.3
Ruti	283	4.24	1,521	5,374.6
Mwanakuridza	65	0.57	384	5,907.7
Amapongokwe	27	0.24	171	6,333.3
Ngondoma	15	0.13	96	6,400.0
Siya	526	4.61	3,555	6,758.6
Ingwesi	63	0.56	452	7,174.6
Nyajena	19	0.17	141	7,421.1
Upper Insiza	10	0.09	76	7,600.0
Silalbuhwa	35	0.31	274	7,828.6
Mwarazi	25	0.22	200	8,000.0
Claremount	7	0.06	60	8,571.4
Tuli Makwe	11	0.09	102	9,272.7
Mushandike (Umshandige)	44	0.39	414	9,409.1
Mirror	41	0.36	401	9,780.5
Lower Zivagwe	7	0.07	70	10,000.0
Total	**16,627**	**147**		**4,918**

Source: Ministry of Energy & Water Resources & Development, GTZ, Sir Alexander Gibb & Partners, "Final Report, Stages 1 & 2: Study on Hydro Power from Existing Dams in Zimbabwe", July 1991.

A total of 40 sites were identified at the first stage of this study. From these, 20 sites were then chosen for further investigation. A number of these were eliminated for further study due to a variety of factors. From the remaining sites, relatively thorough economic and technical investigations were conducted, primarily from the perspective of developing the hydropower capabilities of these dams for sales of electricity to ZESA. After these investigations, only six sites were deemed to be economically feasible, as shown in Table A6.3, below.

Table A6.3
Most Promising Hydro Sites on Existing Dams

Dam	kW	GWh	Total Cost ('000 $)	Cost/kW
Mutirikwi (Kyle)	4215	36.95	4,951	1,175
Bangala	1037	9.09	1,939	1,870
Ngezi (Palawan)	267	2.34	811	3,037
Ruti	283	4.24	1,521	5,375
Siya	526	4.61	3,555	6,759
Manyuchi II	170	n/a	n/a	n/a
Total	**6,498**	**57.23**	**12,777**	**3,643**

Source: MoE&WR&D, GTZ, Alexander Gibb & Partners, 1991.

However, there is good reason for revisiting this 1991 study in light of both sales to the grid, and in light of off-grid electricity generation. Indeed, the 1991 study pointed out that several sites could be developed for local electricity demand, and that, were local economic factors considered, rather than grid supply factors, a number of other sites would be economically viable for development.

Considering the price paid by rural dwellers for diesel-generated electricity, for batteries and battery charging, and for photovoltaics, the assumption that several more of these sites could be economically developed to meet off-grid rural demand should prove valid. It is recommended to revisit this study in light of increasing electricity costs.

Annex 7

Wind Energy in Rural Zimbabwe

Summary

Zimbabwe has relatively good wind resources. Wind has provided rural energy for water pumping for one hundred years. Wind use reached its peak in the 1930s, and wind for water pumping fell steadily with the availability of cheap petroleum products and electricity grid extension to ranches and commercial farms during the 1950s. Today, wind is making something of a comeback, with increasing interest on the part of government, schools, hospitals, NGOs and others in windpumping, and increasingly in electricity generation for isolated, non-grid connected areas. There is considerable potential for wind energy to be harnessed for applications in isolated areas. The economics for this are improving steadily.

Resource

Zimbabwe has an evenly distributed meteorological station network. About 20 stations record wind speeds using anemometers at heights of 10 meters above ground level. Wind data from all these stations recorded, as hourly means is readily available for periods of up to 30 years. Unfortunately no detailed wind map exists for the country and hence only regions of poor, moderate, to good winds can be identified.

The annual wind speed averages range from 2.0 m/s (poor stations) to 4.4 m/s (good stations) throughout the country. An analysis of the day and night wind speeds data has indicated that average wind speeds of about 5 m/s do exist on some of the good stations for periods of up to 12 hours per day during the good wind seasons. Table A.7.2 provides information from these stations to give a good idea of the overall wind regime in the country.

History

The history of the windmill technology in Zimbabwe dates back to the beginning of the century. The principal application of windmills has been for water pumping on farms for livestock and humans. Use of windmills to generate electricity was not common in Zimbabwe due to the weak wind regimes, although small-scale "dyanmos" were used extensively in conjunction with car batteries on many commercial farms and ranches for operating radios until the mid-1950s.

Wind pumps

Presently, there are two companies that manufacture wind pumps, namely Stewart and Lloyds Ltd. and Sheet Metal Craft. Studies carried out by Stewart and Lloyds Ltd. and B. Byabura-Kirya of the Institute of Agricultural Engineering indicate that there are up to 650 wind pumps currently in use countrywide. The manufacturing capacity that exists in the country is more than adequate to make high class wind pumps at about 85% local content. The total number of windmills installed by Stewarts and Lloyds over the past 5 years (1992 to 1997) is set out in Table A.7.1.

Table A7.1
Stewart & Lloyd's Wind pump Sales: 1992-1997

Quantity	Customer	Area	Year
3	World Vision	Matebeleland North/South	1994/98
11	ORAP	Matebeleland North/South	1994/98
20	District Dev. Fund(DDF)	Matebeleland South	1994/98
1	Wankie National Park	Matebeleland North	1994/98
1	Dr. Maposa	Kezi	1994/98
1	Mr. Tshuma	Bulawayo	1994/98
1	Malalakwe Lodge	Matebeleland South	1994/98
3	Plan International	Midlands	1994/98
1	Farmer	Midlands	1994/98
1	B. S. Hein	Gweru	1994
1	Vungu Secondary School	Midlands	1994
1	G. W. Lourens	Midlands	1995
1	CADEC Manzvire	Chipinge	1994/98
1	Inyati Mine School	Rusape	1994/98
1	Zongoro Clinic	Mutasa	1994/98
1	Mudanda Clinic	Buhera	1994/98
1	Dope Secondary School	Makoni	1994/98
1	Mbuya Emma Co-op	Makoni	1994/98
1	Gwasira Secondary School	Makoni	1994/98
1	Mr. Medzai	Rusape	1994/98
1	Tsindi Secondary School	Rusape	1994/98
1	Dr. Makoni	Rusape	1994/98
1	Mr. Mastow	Rusape	1994/98
1	M. Wiggins	Chipinge	1994/98
1	Mutukwa Primary School	Mutare	1994/98
1	Mr. Kwinje	Mutare	1994/98
1	G. M. S.	Mutare	1994/98
1	Umzila Estates	Chipinge	1994/98
1	Christian Care	Chiredzi	1995
1	Nyanetsi Ranch	Matebeleland South	1997
1	Josh Farm	Karoi	1994
1	Rufaro Farm	Karoi	1994
1	Coldomo Estates	Karoi	1994
1	Mr. Graig	Karoi	1995
1	Karoi Methodist Church	Karoi	1996
1	Name N/A	Masvingo	1994
1	Mr. Madondo	Gutu	1995
1	Kushinga Secondary School	Masvingo	1995

28	Records not immediately available	Mashonaland	1994/95
39	Veterinary Department	National	1994/95
138	**Total**		

The Stewart and Lloyd's wind pump is an ITDG wind pump which is manufactured locally and marketed under license from the Intermediate Technology Group Limited of UK. The most common size is the 9m tower with 6m rotor diameter. The average cost (selling price for supply, delivery and installation) over the 5 years has been approximately Z$45 000 per unit (average US$2000 per unit).

Wind Electricity

A local NGO, ZERO, carried out a three year wind monitoring program that has established that there is potential for wind electricity generation in a number of parts of Zimbabwe. In 1997, a local company, Powertronics/Powervision, manufactured three wind turbine prototypes for electricity production, rated at 1 kW and 4 kW each respectively. The prototypes are currently under test and the preliminary results have been positive. The company is now installing a series of four wind turbines for a pilot community-based isolated electricity project. It is also supplying ZERO with a number of wind turbines for the former's wind program, supported by the Dutch Embassy in Zimbabwe.

Table A7.2
Mean Annual Wind Speeds at Selected Meteorological Stations (1971-1997)

Station/Location	Elevation/Altitude	Avg wind speed (m/s)
Binga	617	2.4
Buffalo Range	429	2.3
Bulawayo Airport	1326	4.4
Bulawayo-Goetz Observatory	1351	2.9
Chipinge	1131	3.7
Chirundu	395	2.1
Gweru	1428	3.7
Harare Airport	1497	3.2
Harare-Belvedere	1471	2.2
Harare-Kutsage	1478	3.4
Kadoma	1149	3.6
Kariba Airport	518	2
Karoi	1343	2.9
KweKwe	1213	2.4
Marondera	1631	2.8
Masvingo	1087	2.7
Mt Darwin	965	2.3
Nyanga	1878	3.1
Victoria Falls Airport	1061	2.3

Detailed Background

Zimbabwe has an evenly distributed Meteorological station network. About 20 stations record wind speeds using Dines pressure anemographs or Munro electrical cup anemometers at heights of 10 meters above ground level. However, some stations still record wind data using totalizing cup anemometers mounted 1.8m above ground level. Wind data from all these stations recorded as hourly means is readily available for periods of up to 30 years. Unfortunately no wind map exists for the country and hence only regions of poor, moderate, to good winds can be identified.

The windmills that were first installed in Zimbabwe came from South Africa and were of the "Climax" type. Presently, there are two companies, which manufacture wind pumps, and there are up to 650 wind pumps that are currently in use countrywide.

Wind pumps have great potential for meeting rural water demand. Ground water offers the biggest potential as the major source of water for the rural population. It is estimated that up to 2 000 x 106 m3 per annum could be economically abstracted from groundwater resources. The water quality is generally good and safe for domestic use for humans and livestock.

It is estimated that in 1995 there were about 1 000 rural clinics which were equipped with motorized pumping systems. Many more clinics were at this time equipped with hand pumps. There are more than 4 000 rural schools, most of which are fitted with hand pumps. However, there still exist some rural schools that do not have any safe water at all. Because of financial constraints the change over from manual to motorized pumping systems proceeds slowly.

ZESA currently supplies electricity to approximately 20% of Zimbabwe's households, and far fewer of its rural households, institutions and enterprises. The remainder of the overall population of nearly 10.5 million is without electricity. All liquid fuels are imported, and for a landlocked country, the procurement of these fuels is a major drain on foreign currency reserves and is susceptible to disruption as it has to pass through neighboring countries. Diesel represents 57% of all liquid fuels amounting to 8% of total energy consumed.

Past and Present Activities

There is no known ongoing government program to promote use of wind pumps and wind electricity generation in the country. The Institute of Agricultural Engineering has been running a program on monitoring windmill performance. The program has covered both locally manufactured wind pumps.

In 1987, the World Bank and UNDP supported the Global Wind Pump Evaluation Programme (GWEP), which included Zimbabwe. The Institute of Agricultural Engineering, a Government research organization, carried out the country study which included compilation and analysis of existing data and literature, a wind pump evaluation survey and round the country visits and discussions. The study recommended as a follow up to the next phase of GWEP, inter alia, an intensive wind data and water resources study to clearly identify the future potential of wind pumps with respect to water use and geographic distribution of the viable areas.

The Department of Water Development (DWD) and the District Development Fund (DDF) do provision of potable drinking water in communal lands and resettlement areas, both in the Ministry of Rural Resources and Water Development, as well as local authorities and a number of NGOs.

The largest capacity in rural water supply is the Department of Water Development, which operates and maintains the bulk of rural water supply stations. The number of pumping stations is estimated to be approximately 600. All consumers are billed every month for the water they use. The cost of the water per m^3 covers operations and maintenance only, and is a fixed rate for every consumer in the country.

Some rural borehole drilling, installation and maintenance of hand pumps and some water supply stations is done by the District Development Fund (DDF). The consumers get free water from all DDF owned stations. In some cases, they contribute towards repair in the form of labor and money for spares.

The Institute of Agricultural Engineering (IAE), a branch of the Department of Agricultural, Technical and Extension Services (Agritex), in the Ministry of Agriculture, has as its major activities research, machinery development and agricultural engineering knowledge to the farming community in the country.

There are about two major local companies involved in the manufacture and installation of wind pumps and one company has recently designed and manufactured a wind turbine for electricity generation.

Wind and Water Pumping in Rural Zimbabwe

Over 70% of Zimbabwe's population live in rural areas without access to electricity. Women in Zimbabwe spend considerable time collecting water, in addition to their other activities. In 1992 there were approximately 30 000 primary water supplies, of which 13 000 were boreholes, 8 200 were deep wells and 8 500 were shallow wells. These water supplies were at this time serving 4.9 million people, out of an estimated 6.4 million in the rural areas. Some 33 % of the rural people were still without access to safe water supplies. The demand in this field has increased due to population growth. The present estimate is that 50 000 extra water points are needed up to the year 2005. There is, therefore, an urgent need to ensure that rural communities have access to safe drinking water.

The above figures do not include institutions such as schools and clinics. It is estimated that in 1995 there were about 1 000 rural clinics which were equipped with motorised pumping systems. Many other clinics were at this time equipped with hand pumps. There are more than 4 000 rural schools, most of which are fitted with hand pumps. However, there still exist some rural schools that do not have any safe water at all. Because of financial constraints the change over from manual to motorised pumping systems proceeds slowly.

Hand pumps are used extensively in rural areas, mainly for pumping of smaller quantities of drinking water from boreholes. They are known as bush-pumps, are locally made and regarded robust and reliable. Hand pumps are usually supplied and installed free of charge by the District Development Fund. The water is carried manually from the borehole for direct consumption in households. Water is not stored in tanks and piped to end-user points such as with electric or diesel pumping systems. Consequently, hand pumps are not regarded as suitable for schools and clinics with a reticulation and water storage system and a larger demand than normally can be supplied via hand pumps.

The Department of Water Development commonly use diesel pumps in rural water supply. They are mono-pumps with a v-belt connection to diesel engine. The lifetime of the diesel engines is normally 5 years, or 12,000 hours of operation. Some diesel engines are however reported to be in operation after 30 years. The main problems related to diesel pumps are fuel, maintenance and theft. Fuel is supplied in 200 liter drums over long distances, up to 250km, involving high transportation costs and possible spillage. Contamination of the boreholes from diesel fuel and engine oil is likely to be widespread, but is not fully investigated.

Maintenance of pumps and engines has to be done from the workshop of the Provincial Water Engineer. The wear of pump parts, shafts and bearings is significant, and the engines require regular maintenance. Service is often difficult because of limited resources for transportation. Diesel fuel and diesel engines can be used for many purposes in rural areas, such as for transportation, power generation and grinding. Consequently the risk of theft is high. The installation is normally protected with a security fence and a brick house for the engine.

The grid-connected pumps are mono-pumps of the same type as those used for diesel pumps, but operated via an electric motor. This involves some level of maintenance, particularly when the water source contains suspended materials. If the power grid is available nearby, it is often necessary to install a transformer with substantial excess capacity. As with the diesel engines, the electric motors are useful for many purposes and are subject to theft and are protected by a fence and a pump house.

Experiences with PVP in Zimbabwe dates back to the early 1980's, where different configurations were installed for end-uses such as clinics, cattle and game watering, irrigation, community water supply and co-operatives. The different system configurations were tried out with mixed experiences. The system that proved most successful was a system with PV array, DC/AC inverter and submersible pump. This system is now commercially available in Zimbabwe, and an estimated number of 100 units are in operation. Even though operational and maintenance problems are significantly less than with diesel or electrically powered monopumps, PVP-systems face similar security problems. PV panels are highly visible and there is an increasing awareness among rural people on the potential benefits from PVs. Consequently they have a high value on the black market. Vandalism from throwing rocks on the PV arrays is another problem. A fence normally protects PVPs, as with the conventional pumping systems.

From the above indications, the search for a pumping solution that is technically reliable and economically viable is a priority for improving the availability of rural water supplies. From the studies carried out so far, there are indications that there is an attractive business and technological potential in the country for wind energy. Wind pumps used in the country are on average about 20 to 30 years old and are still working proving that the technology is durable and reliable. Moreover, experience has shown that wind machines are not susceptible to theft as compared to the other pumping equipment, save for one or two parts that may be removed by vandals.

The study by B. Byabura Kirya (1987) confirmed the viability of wind pumps in the country technically and economically for some specified applications, e.g. cattle watering, game ranching, small domestic water supplies as on farms, and primary water supplies at institutions where labor is not freely available. The later case is particularly relevant to primary and secondary schools were water is required five days a week (leaving two days for recharging) and in relatively small quantities for drinking, ablutions, and laboratories or small flower/vegetable gardens for teaching demonstrations.

According to the same study, the constraints limiting popular utilization of wind pumps in the viable areas have been: lack of awareness of the benefits to be reaped by utilization of a wind pump, lack of capital or support credit institutions to enable the would be users afford wind pumps available on the market and to a less extent, the conservativeness of some water authorities with regard to implementation of the technology. This fact is supported by the success of the wind pump application for cattle water supply on commercial farms in areas where wind pumps have at times been thought to be non-viable.

With the current major increase in prices of engine pumps and appreciating the high reliability of wind pumps, the number of wind pumps in use would be seen to grow by large numbers if the benefits of the technology were made known to all he farmers. Other added advantages would be no worries about the fuel bill, minimum maintenance costs, automatic start-up/stop functions and saving of foreign currency in imported diesel.

Annex 8

Rural Energy Pilot Project: Temaruru Community Power Trust

A Community-Run Wind Power Scheme

Duncan Kerridge, Powervisions, Harare

Introduction

This paper provides an outline of a novel renewable energy project currently taking place in the Eastern Highlands of Zimbabwe, in the rural community of Temaruru. In Zimbabwe, the main emphasis in the promotion of renewable energy has been focussed on grid extension, credit-based home small domestic systems and grant funded institutional systems. These have been largely government and donor initiated, and have stimulated a significant growth in small PV service companies, mainly supplying domestic 'lights and TV' systems of 20 to 100 Wp.

Meanwhile, most rural electricity users have chosen a do-it-yourself path, finding their own solutions without institutional assistance. A new World Bank/ZESA survey suggests that over 15% of rural households use automotive batteries, primarily for TV and music. The batteries are carried 30 to 100 kilometers, once or twice per month, for charging in local towns with utility supply. In addition, it appears that there may be as many as 100 000 PV systems are operating in rural Zimbabwe, over 80% of which have been purchased, often from South Africa, without assistance from formal renewable energy credit schemes. It appears that the ingenuity and determination of rural people to obtain electrical power may have been considerably underestimated by institutions involved in rural energy supply.

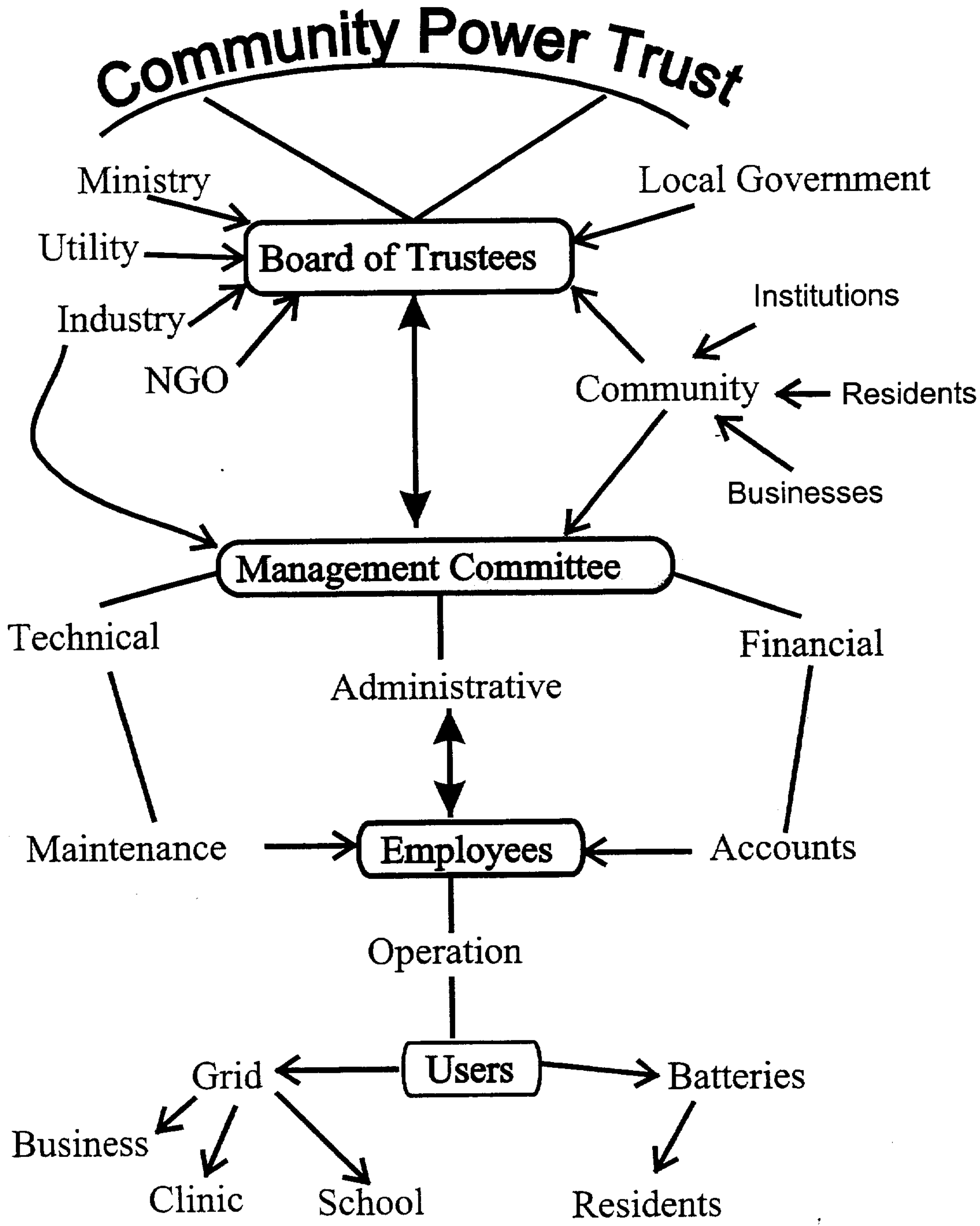
The main focus of rural electrification initiatives have been on grid extension and individual PV systems. In large areas of the country, the former is a distant prospect. However, for most rural people, a domestic PV system is not affordable even with soft credit schemes. Instead, battery users carry their batteries long distances for charging. Although many rural businesses use PV systems for lighting and entertainment, the cost of a system scaled to operate refrigerators or workshop tools is prohibitive.

Temaruru Community Power Trust seeks to tap a fraction of this vast, neglected market. The scheme incorporates:

- a 220 V AC mini-grid supplying about 10 businesses with power for lights, entertainment, refrigeration and power tools
- a battery charging station for local battery users

as shown in Figure A.13.1. The Trust brings together stakeholders from all sectors with the aim of providing a sustainable energy supply to the local community. The organizational setup used in this pilot project is depicted in Figure A-1. Responsibility and ownership of the system will lie with the local community, who will operate, administer and manage the system along commercial lines.

Figure A-1. Organizational Structure: Temaruru Community Power Trust



Before addressing this project in detail, some mention should be made of the power source. This Workshop addresses financing schemes for *solar* systems. However, this project is a wind power scheme. There is a prevailing attitude that solar PV is the only viable renewable energy source in southern Africa. Certainly, the solar resource is universal and predictable, and the technology relatively simple and modular at least as regards design and installation. However, larger scale PV arrays are very expensive. PV module manufacture is dominated by (largely petrochemical) global corporations and over 50% of a typical system's cost is for the imported modules.

There is undoubtedly a useful wind resource in many parts of southern Africa. However, mean windspeeds are much lower than those found in Europe and America and wind turbines from these countries have given poor performance in previous projects. Our company, with assistance from British wind power experts, has developed a wind turbine optimized for low windspeeds with a combination of rugged reliability and sophisticated design. The use of windpower is highly site specific, but following the initial results of a resource monitoring programme conducted with local NGO, ZERO, it appears that as much as one third of Zimbabwe has sufficient wind for viable use of this wind turbine. On reasonable sites with mean windspeeds of 3 ms^{-1} (4 ms^{-1} being the typical minimum viable speed for European machines) our turbine can produce power at between half and third of the cost of a comparable PV array.

Roughly 90% of the turbine's cost is for local components, and when combined with our own 3 kilowatt sine-wave inverter and local deep-cycle traction batteries, creates a sophisticated system comparable to any Northern installation without the need for high import costs. Keeping expenditure local stimulates the local industry. In contrast, a new bilateral initiative to provide 500 wholly imported PV systems for schools and clinics is about to remove much of the local market, with a predictably negative effect on the hitherto expanding Zimbabwean solar industry. Renewable energy development strategies should take full cognizance of the fact that the only path to sustainable renewable use is to encourage a vibrant local industry capable of manufacture as well as installation. Dependence on imported PV systems is no different to dependence on imported oil from an economic point of view.

Demand assessment

Temaruru Business Centre is situated in Makoni District near Rusape, and lies at the foot of a dombo (rounded rock hill) that has been identified as an ideal site for wind turbines. There are about 10 active businesses in the centre, and two new premises are being constructed. The business centre draws custom from a 10km radius, covering a resettlement area and a large village 7km south, as well as at least 400 households within the Madziwa ward which extends up to 4 km from the centre.

The original prototype of the PT3600 wind turbine was tested at the local clinic for nine months and the windspeed data logged over this period proved that the site was highly viable for a wind power system. On initiation of the project, two Powervision engineers conducted a detailed survey of local energy use and interest in the proposed scheme.

Businesses

Eight businesses were surveyed; the other two are diesel grinding mills which would be far too powerful for the proposed system, and only operate during the day. The bulk of the energy demand is for refrigeration; lighting and entertainment are the other commonly desired loads.

Current power sources include candles, dry cells (radios), automotive batteries and paraffin and LPG for refrigeration. Two businesses have small PV systems running lights and stereos, allowing them to remain open later and attract more custom.

Expected peak loads vary from 500 W to 1000 W in most cases, whilst daily consumption varies between approximately 4 to 11 kW-hours. Since the heavy loads are all refrigerators, daily loading will tend to increase over the warmer, summer months and will peak at weekends and holidays. The estimated desired daily load is 24 kW-hours. In the first phase of the project, it is expected that supply can be limited to about 16 kW-hours through the use of load limited connections and tariff structures.

Secondary school

Dumbamwe Secondary School is situated roughly 1 km from the business centre. Over 500 pupils attend, and 24 teachers live on site in 8 government-provided houses. At present, the school has no power supply of any form. One teacher's house has a small PV system for lights, music and TV, and several others use automotive batteries, charged in Rusape (35 km away) for TV and music. Candles and paraffin are the main light sources.

Given that teachers do a lot of their work outside the classroom, preparing lessons and marking, there was universal enthusiasm for the prospect of improved power supply, either in the form of 240 V AC supply (preferred) or a local battery charging facility. The main need is for electric lighting and entertainment; refrigeration (AC supply only) would also be very popular. Typical expected daily loads for an AC supply are about 700 Watt-hours per house with a 200 W peak load. Fridges would roughly double these loads. Average daily loads would be about 6 kW-hours without refrigerators.

Clinic

Dumbamwe Clinic draws patients from a 10 to 15km radius, treating between 20 and 50 per day. There are four three-bed wards for patients awaiting transfer to the district hospital and for maternity and labour purposes. The main energy requirements are for two small vaccine refrigerators and a small autoclave, currently running on LPG, and for lighting for night time deliveries and emergency operations. A UHF radio linking the clinic to the District Council in Rusape is powered by a 40W PV panel. Water is supplied from a borehole via a diesel pump.

Three houses on the site provide accommodation for the clinic staff, several of whom already use automotive batteries for TV and music. Although they would prefer a 240V AC supply, they would also welcome a local battery charging facility.

The clinic is administered by the district council and the officer in charge, and the District Administrator, expressed considerable interest in the project as the regular supply of gas to the clinic often creates logistical difficulties. Estimated daily load for the clinic and staff houses is 5 kW-hours.

Battery users

There are roughly 50 households situated within 800 metres of the business centre, and a further 300 to 400 within Madziwa ward that extends to a radius of 4 km. Many households in the area, possibly as much as 30%, use automotive batteries for music and TV. With the exception of several PV systems, no one currently uses 12 volt lighting, relying instead on candles and paraffin lamps. At present, batteries are recharged 35km away in Rusape, incurring significant transport costs. Users typically charge their batteries once or twice per month. A local battery charging facility could be expected to increase local demand and spread the benefits of the system far beyond the range of the mini-grid system. A similar off-grid battery charging station set up in the same region proved very popular.

With 100 battery users charging twice per month, the daily load would be about 4 kW-hours.

Table A-2 summarises the survey data on current costs and acceptable fees for the scheme. In most cases, users are prepared to more for the improvement in service from the scheme. Energy costs account for 10 to 20% of household expenditure.

Table A-2. Demand Survey Results: Existing Energy Costs and Acceptable Tariffs

		Existing monthly expenditure					Acceptable fees			Daily load kW-hrs
	No.	Lights	Music & TV	Fridge	Other	Total	Join (once)	Fixed fees	Month Total	
Business	8	$ 50	$ 60	$ 180		$ 290	$3,000	$ 500	$ 4000	16
Clinic	1	$ 100		$ 500	$ 150	$ 750	$3,000	$ 750	$750	4
Staff houses	3	$ 50	$ 80			$ 130	$1,500	$ 200	$ 600	1
School	1						$3,000	$ 500	$ 500	3
Staff houses	8	$ 50	$ 50			$ 100	$1,500	$ 200	$ 1600	3
Battery users	100	$ 50	$ 80			$ 130	$ 200	$ 20	$ 400	4

Source: Powervisions

Conclusions

Neglected market requires larger scale system than supported by current approaches. Potential users already spend lots on energy – willingness to pay for the service depends on its cost and convenience relative to alternatives. Grant funded and externally controlled systems will inevitably be abused or neglected – full participation in planning, policy and management of the system is critical to long term success. Combination of different stakeholders brings a valuable range of strengths and outlooks. Use of locally manufactured equipment and skills provides valuable experience and showcases potential of locally initiated solutions.

Annex 9

List of Contacts

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Chidanguro, H., Maungwa Secondary School (Gulu District), Headmaster
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Chidovori, M., Masvingo Rural District Council, Executive Officer Administration
Chigwada, Johannes, DoE, Deputy Director
Chikukwa, H.B., Bondolfi Catholic Mission (Masvingo), Principal
Chikukwa, M., Sipambi Grinding Mill (Masvingo), Owner, operator
Chikurira, A., Masvingo Provincial Administration, Provincial Administrator
Chikwanda, Fungai, ENDA-Zimbabwe, ME Technician
Chinengundu, T. R., Chaka, Mashonaland West, Genset owner
Chingosho, A., Mashonaland Central Provincial Administration, Dep. Provinicial Administrator
Chingosho, M., Mashonaland West Provincial Administration, Provincial Administrator
Chiwa, S., Nemamwa Soap Making (Masvingo), Soap maker, owner
Chogo, S., Chinyika Rural Hospital, Gutu RDC, Sister-in-charge
Chombo, Chiminya, Citomborwizi Wind Pump, Lomagundi, Mashonaland W., Owner
Daly, A., C. Gauche (Pvt) Ltd., Bulawayo, MD
Denga, S., Nemamwa Welding Shop (Masvingo), Welder, owner
Dhile, M., Mberengwa Rural District Council (Mataga), Supervisor
Dube, A., Matabeleland South Province, Provincial Administrator
Dube, S., Mberengwa Rural District Council (Mataga), Executive Officer Health
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Madzivise, T.V., Zaka Rural District Council (Masvingo Province), Project Officer
Makomva, Alex. C. B., Zimbabwe Electricity Supply Authority (ZESA), Marketing Mgr
Makomva, Regis, Quest Research Services, MD
Mamukwa, E.N., ZESA, Customer Service
Mandizha, L., Midlands Province - Gweru, Mining Commissioner
Manomano, M., Mazoe Rural District Council (Mashonaland C.), Projects Officer
Maseko, B., Ntabazinduna Communal Area (Matabeleland N.), Windmill owner
Mashiri, M., Chivakanenyama, Magunje, Mashonaland W., Windmill owner
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Matekaire, Kuda B., Zimbabwe Farmers Union, Director
Matirekwe, Desire U., ZERO, Assistant
Maugara, M., Morgenstern Mission (Zim.Reformed Church) Masvingo, Administrator
Mbetsi, F., Tongwe Secondary School (Beit Bridge), Head Master
Mboyi, Bhekumusa, Maboyi, ZERO, Policy Analyst
Mbulawa, P., Zaka Rural District Council (Masvingo Province), Education & Social Services Officer
Midzi, Emmanual, ZESA, Rural Electrification Engineer
Mishi, E. W., Comperdown Farm (Guruve, Mashonaland C.), Owner
Mortensen, Erik, Royal Danish Embassy, Counsellor
Moyo, A., Kwalu Irrigation Scheme, TA, DWR
Moyo, M., Musume Hospital, Mberengwa RDC, Mataga, Administrator
Mpande, Rodger L., DANIDA, Environment Consultant
Mpila, A., Matabeleland North Province, Senior Administration Officer, Acting Provincial Administrator and Governor
Mtetwa, Daniel, ENDA-Zimbabwe, MD
Muchenje, Charm, Impact Solar Systems, MD
Mukaro, M., Gutu Rural District Council, Senior Executive Officer
Munemo, M.D., Ministry of Environment & Tourism, Director, MNR
Munemo, S., Chematamba Grazing Scheme, Mubayira, Mashonaland W., Operator
Musiiwa, A., Chomuchena Secondary School, Mashonaland W., Headmaster
Mukaro, M., Gutu Rural District Council, Senior Executive Officer
Mutambara, L., Mutero Mission Hospital, Gutu RDC, Sister-in-Charge
Mutengambiri, M., Magunje Rural District Council (Mashonaland W.), Projects Officer
Mzezewa, Mr, Department of Energy, Director
N'anda, R.C., Chaminuka Rural District Council, Administrator
Ndebele, R., Stewarts & Lloyds Bulawayo Branch, Branch Manager
Ndovu, Mr, Association of RDCs (ARDC), Representative
Nkala, D., David Livingstone Secondary School, Deputy Headmaster
Nyabeze, Washington, ITDG-Zimbabwe, Systems Specialist
Park, A., Sheet Metal Kraft (Bulawayo), MD

Rafemoyo, Ben R., ZESA, Customer Service
Samborera, M., Rushinga Rural District Council (Mashonaland C.), Officer
Shava, M., Musume Mission, Mberengwa RD, Mataga, Deputy Headmaster
Shoko, A., Chirumanzu Rural District Council (Midlands), Chief Executive Officer
Shoko, E., Hunyani Pulp and Paper, Pulp Mill Manager
Sibanda, Alice, Quest Research Services, Economist
Sibanda, D., Beit Bridge Rural District Council, District Planning Officer
Sithole, S., Mitchell & Johnston (Pvt) Ltd., Bulawayo, Coal stoves, sales
Smyth, Oloff, Powertronics, MD
Spence, Stuart, Border Timber, Mutare, Manicaland, Chief Engineer
Stalls, Nick, Bindura Hauliage Coal Suppliers, Mashonaland C., Transport Manager
Taylor, Rob, Ministry of Natural Resources, Environment, CIDA
Thompson, A.M., C. Gauche (Pvt) Ltd., Bulawayo, Coal stoves
Tshuma, S., Ntabazinduna Communal Area, Windmill owner
Wafawanaka, W., Bhasera Business Centre Welding Shop, Gutu RDC, Owner
Wenman, Clive M., Triangle Sugar, Technical Director

In addition, the team interviewed a number of people at the following institutions and locations:

1, Connie Farm, Chegutu, Mashonaland West,
2, Farm 385, Mt Darwin/Chesa, Mashonaland Central,
3, Chimwe Farm, Chesa, Mt Darwin, Mashonaland C.,
4, Nyamatikiti High School, Rushinga District, Mashonaland C.,
5, St Phillips Manyenya High School, Gruve, Mashonaland C.,
6, St Mary's School, Chegutu, Mashonaland West,
7, Mhondoro Rural Hospital, Mubayira, Chegutu, Mashonaland W.,
8, Rosa Rural Hospital, Chiweshe, Mashonaland C.,
9, Big Value Soap Making, Guruve, Mashonaland C.,
10, Mazoe Brick Making, Mazoe, Mashonaland C.,
11, New Magunje Bakery, Hurungwe DC, Mashonaland W.,
12, Geo Elcombes Coal Suppliers, Banket, Mashonaland W.,
13, Cotton Company of Zimbabwe, Zvipani, Hurungwe, Mashonaland W., Genset
14, Cotton Company of Zimbabwe, Muzarabani, Mashonaland C., Cotton ginnery
15, Pasi Panopa Co-operative, Zvipani, Hurungwe, Mashonaland W., Genset
16, Jati Millers Milling Co-operative, Hurungwe DC, Mashonaland W., Maize milling
17, Nyashanu Sec. School, Buhera RDC, Manicaland,
18, Dinidza Vermiculite Mine, Buhera, Manicaland,
19, Mudanda Rural Health Centre, Buhera, Manicaland,
20, March Trading Supermarket, Mashonaland East, Genset
21, Total Zimbabwe, Nyamapanda, Mashonaland E., Genset
22, BP & Shell, Nyamapanda, Mashonaland East, Genset
23, Nyadire Secondary School, Mutoko RDC, Mashonaland E.,
24, Nyadire Teachers Training College, Mutoko RDC, Mashonaland E.,
25, Tenjo Investments, Mutoko, Mashonaland East, Quarrying
26, Aroma Bakeries, Mutoko, Mashonaland East, Baking
27, Chemhanza Sec. School, Wedza District, Mashonaland E.,

28, Teera Bakery, Sadza, Chikomba District, Mashonaland E., Baking
29, Matsine Secondary School, Mashonaland E., Wind pump
30, St Francis of Assisi Sec. School, Chikomba District, Mashonaland E.,
31, Mahusekwa Bakery, Mahusekwa, Mashonaland E.,
32, Tsindi Secondary School, Rusape DC, Manicaland, Wind pump
33, The Wattle Company

Annex 10

Further Information and Sources

The following companies and organizations provided information on generating sets for this survey. Follow-up meetings were also arranged with Honda, Hawker Siddeley, Stewart and Lloyds, ZESA and the Department of Water Resources.

Organization

1. Honda Center (Pvt.) Ltd.
2. Hawker Siddeley Electric
3. G. Wilson Power
4. Hunton Engineering
5. Stewart & Lloyds
6. Ministry of Public Construction
7. Confederation of Zimbabwe Industries
8. ZESA
9. Department of Water Resources

Coal Merchants in Zimbabwe

Interviews were held with a number of coal merchants in Zimbabwe. There are currently 13 dedicated coal distributors including:

Bindura Haulage (Pvt.) Ltd., Bindura
C. Gauche (Pvt.) Ltd., Bulawayo
Carters Transport (Pvt.) Ltd, Kadoma
Colbro Transport (Pvt.) Ltd., Masvingo
Dunstan Transport
Elcombe Coal Distributors (Pvt.) Ltd., Harare
ENKAY Coal and Trucking, Chinhoyi
Johnston Motor Transport (Pvt.) Ltd., Kwekwe
Lakas Products (Pvt.) Ltd., Harare

Midlands Hauliers (Pvt.) Ltd.
Tremolite Hauliers
The Wattle Company Limited, Mutare

Annex 11

Rural Energy Equipment Producers and Suppliers

1. Alternative Technologies (Pvt) Ltd Zimbabwe
2. Aquajets Zimbabwe
3. Battery World - Solar World Zimbabwe
4. Brake & Clutch (PVT) Ltd Zimbabwe
5. Des & R (Pvt) Limited Zimbabwe
6. Development Technology Centre - DTC Zimbabwe
7. Ecological Designs Zimbabwe
8. Electro Technologies Zimbabwe
9. Impact Solar Systems Zimbabwe
10. JEC Trading (Pvt) Ltd Zimbabwe
11. Joamac (Pvt) Limited Zimbabwe
12. Kariba Battery Manufacturers (Pvt) Ltd Zimbabwe
13. Kiel Electronics Zimbabwe
14. Kufakurinani Enterprises Zimbabwe
15. Lewsey, Paul (Pvt) Ltd Zimbabwe
16. Magden Electric Pvt Ltd Zimbabwe
17. Midland Distributors Zimbabwe
18. Mobile Electrical Engineering Zimbabwe
19. Non-Ferrous Metals Zimbabwe
20. Payen Zimbabwe (Pvt.) Ltd Zimbabwe
21. Powervision Zimbabwe
22. Quinlan Trade Associates (Pvt) Ltd Zimbabwe
23. Radiator & Tinning Zimbabwe
24. Ref-Air Zimbabwe
25. Samansco (Pvt) Ltd Zimbabwe
26. Sol-Monarch/Treggers Zimbabwe
27. Solamatics (Pvt) Ltd Zimbabwe
28. Solar Energy Distributors (Pvt) Ltd Zimbabwe
29. Solar Powered Systems Zimbabwe
30. Solar Products (Pvt) Ltd Zimbabwe
31. Solar Systems Zimbabwe
32. Solar Tech Zimbabwe

33. Solarcomm Zimbabwe
34. Sollatek Electronics Zimbabwe
35. Solmonarch (Pvt) Limited Zimbabwe
36. Sun-Tech Systems Zimbabwe
37. Sunlite Products Zimbabwe
38. Teletronix Zimbabwe

Annex 12

ESMAP Mission Terms of Reference

ESMAP

Joint UNDP / World Bank **Energy Sector Management Assistance Programme**

c/o The World Bank • 1818 H Street, N.W. • Washington, D.C. 20433 • U.S.A.

ZIMBABWE

Rural Energy and Rural Electrification Study

Strategic Framework and Policy Alternatives

Activity Initiation Brief

October, 97

Power Development, Efficiency and Household Fuels Division
Industry and Energy Department
The World Bank
Washington DC 20433

Introduction

The Government of Zimbabwe has requested ESMAP support for the development of a comprehensive strategy to address the energy and electricity needs of the rural and peri-urban households of Zimbabwe within the overall national energy policy framework. The purpose of this Activity Initiation Brief (AIB) is to outline the objective and scope of the proposed study.

Objectives

The objectives of the proposed activity are to assist the Government of Zimbabwe to devise a strategic framework and formulate and implement energy policies, plans and projects with a view to:

[a] to minimize the cost to the economy and the environment of the supply of energy;

[b] to reduce the financial cost of energy to rural and peri-urban households and industries; and

[c] to strengthen the capability of the Government of Zimbabwe to evaluate the parameters affecting the cost-effectiveness of decentralized electricity distribution systems and their impact on low-income peri-urban as well as rural households and socio-economic development, and to design, revise, and execute effective rural and urban electrification energy strategies, including decentralized power production.

Background

Zimbabwe's energy resource base is considerable. Although there are no proven domestic oil resources, Zimbabwe has large coal reserves that have been estimated at 10.6 billion tons (2 billion tons mineable) located in 21 fields. It has substantial natural and plantation woodland with a total accessible growing stock of fuelwood estimated at 320 million air-dried tons with an annual sustainable yield of about 13 million air-dried tons. Large-scale hydropower resources are concentrated on the Zambezi river with an annual average estimated potential 39 TWh. About fifty major dams have been built in Zimbabwe for irrigation and water supply purposes, some of which could be equipped with small generating units to produce an estimated total of 2 GWh of annual electricity. Solar radiation of 3000 hours per annum with an estimated daily radiation of 2KJ/cm2; although relatively high, it is being used at negligible levels.

The household residential sector is the largest energy consuming subsector in Zimbabwe. Of a total final energy consumption of 261,000 TJ, the residential sector consumes about 48% of this total. Industry consumes about 24%, followed by agriculture (13%), transport (8%), mining (3 %) and commerce by (4%) ('93 data).

As in most African countries, fuelwood is the primary energy source for most of the population where about 90% of the energy consumed by households and in rural areas, particularly small rural industries. Consumption of fuelwood is growing with an estimated increase of demand at about the same rate as population growth; about 3 % per annum. In some of the more densely populated and arid communal areas, woodland resources have been severely depleted by agriculture and land clearing and wood curing for fuel and poles.

In Zimbabwe as a whole, the urban low-income population is predominantly located in the high-density areas (HDA). It has been estimated that about 80% of the total number of urban houses of all types, are located in these HDAs. Since firewood is a predominant fuel used by households living in urban HDAs, one important consequence of continued urban population growth (estimated at about 5% per annum) is a persistence demand for fuelwood. This increases the pressure on fuelwood supply from peri-urban woodland catchment areas. Wood supply in the urban HDAs comes from nearby rural areas, commercial farms and communal areas, where live trees are cut to supply wood.

Electricity is supplied form a mix of hydroelectric and coal-fired thermal power plant in Zimbabwe and neighboring countries (interconnections exits to Zaire, Botswana, Mozambique and South Africa). The 1266 MW Kariba hydroelectric complex (666MW for Zimbabwe) on the Zambia/ Zimbabwe border supplies the bulk of the hydropower and the 920 MW Hwange Power Station the bulk of the thermal. Three small old thermal stations at Harare, Bulawayo and Munyati are used mainly for peaking and reserve duty. Total installed capacity is 1961 MW but needs to be expanded substantially, both by the proposed Batoka project, an expansion of Hwange, and larger imports from South Africa and Mozambique. A key element in its strategy is the development of a regional grid. The recent establishment of a Southern African Power Pool (SAPP) is a first step in regional integrated and coordinated development.

Electricity is presently supplied to over 320,000 consumers in Zimbabwe. Approximately 20 % of households are connected to the grid. HDAs are given priority for new connections, followed by schools, commercial buildings and rural growth points. The rural population currently served with electricity is approximately 155,000, out of a total of 10.5 million. Grid extensions are very costly. It is estimated that it costs approximately US 17,000/km to extend a 11kV line. The traditional non-grid options available to the rural population are a combination of batteries, candles, paraffin, wood and gas, or renewable energy technologies. Hence exploring the potential of decentralized power production by means of renewable energy technologies, particularly photovoltaics will also be part of this technical assistance activity.

The dispersion and low incomes of the rural populations renders rural electrification an expensive, often non-viable process. Consistent with it policy of commercializing ZESA and to avoid the risk that future rural electrification projects will weaken ZESA's financial performance, the Government is subsidizing any financially non-viable grid extension. To promote rural electrification, ZESA is channeling at present 1% of it revenue into a rural electrification fund.

Scope of Work

The study will focus on both rural energy and on decentralized, off-grid, electricity supply systems such as small diesel, solar PV, wind and micro/pico-hydro systems. Present policies and practices shall be investigated and a technical inventory made of facilities already executed, evaluating their adequacy with respect to the objectives stated above.

The proposed activity aims to review and analyze the existing problems of peri-urban and rural energy use, needs and expectations. In particular, the proposed study aims to examine the technical, financial, economical and institutional feasibility of a program to provide sustainable energy to targeted peri-urban and rural areas throughout the country in the next 20 years, taking into account the projects now under execution and the forecast requirements for energy services in the cities and villages to be served. It will also focus on the enhanced use of modern energy, including the use of decentralized renewable forms of energy, for productive purposes in the rural areas. To the greatest extent possible use will be made of local expertise.

Collate and review results of all renewable energy projects carried out by DOE as well as all other known energy projects in Zimbabwe. Focus should be made on areas of success or failure and the reasons for the success or failure. Comparison of the Zimbabwean experience in renewable energy technologies should be made with experiences in other countries. On the job training to DOE officers will be provided in such areas as cost - benefit analysis, environmental impact assessment, project formulation and evaluation etc, to ensure maximum technological transfer.

A detailed strategy will be prepared by specifically focusing on:

- assessment of energy needs / requirements for household and productive purposes by geographical area or ecological zones, and assessment of income levels with the view of establishing the rural people's ability to pay for rural development projects which empower them financially;

- assessment of the local resource base to satisfy the above demand e.g. availability of dams, perennial rivers, biomass, wind speeds etc in each region or zone; and identify the available technologies, establishing their performance extend of use and identifying possible supply options on the basis of cost/benefit analysis and availability of resources in a given area or zone;

- identify the appropriate institutional framework for implementation of the strategy, investigate the environmental and gender effects of the proposed strategy with particular reference to the socio-economic issues, and recommend mitigating measures and support activities, e.g. training, publicity; equipment maintenance etc;

In addition, sites for possible pilot energy projects for productive use will be identified. Several technological options that are economically viable are not being pursued at the moment, such as small wind generators, pico-hydro generation. Provision is made to launch a number of small demonstration projects, using donor and community funds to leverage this. Such projects will be carried out in those villages where the population, a business, or individual has demonstrated an ability and willingness for co-financing.

Duration of the Study

The study will be carried out by DOE with assistance from a consultant. The consultant will visit Harare in November/December to plot a work program and agree on responsibilities for carrying out the work. Although the consultant will be responsible for overall coordination of the work, DOE staff will assist by analyzing & writing components/chapters of the final report. The consultant shall complete and submit in ten copies the strategy document within a period not exceeding three months from the date of contract signature. Reports shall be submitted as follows after date of signature of the contract:

Expected Output
A successful review and analysis of the existing supply-demand situation and of the relevant issues and options would result in:

[i] a least-cost approach in the supply of rural energy;

[ii] the most effective of the economically and financially viable low-cost technical options for (rural) electrification;

[iii] the required policy framework for the implementation of a rural energy strategy and a decentralized rural electrification strategy;

[iv] an investment program matching the least-cost solution, including credit packages to improve access electricity for low-income consumers; and

[v] the required program to strengthen institutional capability and attitudes within the Government and power company to implement and monitor (rural) electrification programs and policies and to support private sector participation and initiatives.

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Joint UNDP/World Bank

ENERGY SECTOR MANAGEMENT ASSISTANCE PROGRAMME (ESMAP)

LIST OF REPORTS ON COMPLETED ACTIVITIES

Region/Country	*Activity/Report Title*	*Date*	*Number*
	SUB-SAHARAN AFRICA (AFR)		
Africa Regional	Anglophone Africa Household Energy Workshop (English)	07/88	085/88
	Regional Power Seminar on Reducing Electric Power System Losses in Africa (English)	08/88	087/88
	Institutional Evaluation of EGL (English)	02/89	098/89
	Biomass Mapping Regional Workshops (English)	05/89	--
	Francophone Household Energy Workshop (French)	08/89	--
	Interafrican Electrical Engineering College: Proposals for Short- and Long-Term Development (English)	03/90	112/90
	Biomass Assessment and Mapping (English)	03/90	--
	Symposium on Power Sector Reform and Efficiency Improvement in Sub-Saharan Africa (English)	06/96	182/96
	Commercialization of Marginal Gas Fields (English)	12/97	201/97
	Commercilizing Natural Gas: Lessons from the Seminar in Nairobi for Sub-Saharan Africa and Beyond	01/00	225/00
Angola	Energy Assessment (English and Portuguese)	05/89	4708-ANG
	Power Rehabilitation and Technical Assistance (English)	10/91	142/91
Benin	Energy Assessment (English and French)	06/85	5222-BEN
Botswana	Energy Assessment (English)	09/84	4998-BT
	Pump Electrification Prefeasibility Study (English)	01/86	047/86
	Review of Electricity Service Connection Policy (English)	07/87	071/87
	Tuli Block Farms Electrification Study (English)	07/87	072/87
	Household Energy Issues Study (English)	02/88	--
	Urban Household Energy Strategy Study (English)	05/91	132/91
Burkina Faso	Energy Assessment (English and French)	01/86	5730-BUR
	Technical Assistance Program (English)	03/86	052/86
	Urban Household Energy Strategy Study (English and French)	06/91	134/91
Burundi	Energy Assessment (English)	06/82	3778-BU
	Petroleum Supply Management (English)	01/84	012/84
	Status Report (English and French)	02/84	011/84
	Presentation of Energy Projects for the Fourth Five-Year Plan (1983-1987) (English and French)	05/85	036/85
	Improved Charcoal Cookstove Strategy (English and French)	09/85	042/85
	Peat Utilization Project (English)	11/85	046/85
	Energy Assessment (English and French)	01/92	9215-BU
Cape Verde	Energy Assessment (English and Portuguese)	08/84	5073-CV
	Household Energy Strategy Study (English)	02/90	110/90
Central African Republic	Energy Assessement (French)	08/92	9898-CAR
Chad	Elements of Strategy for Urban Household Energy The Case of N'djamena (French)	12/93	160/94
Comoros	Energy Assessment (English and French)	01/88	7104-COM
Congo	Energy Assessment (English)	01/88	6420-COB
	Power Development Plan (English and French)	03/90	106/90
Côte d'Ivoire	Energy Assessment (English and French)	04/85	5250-IVC
	Improved Biomass Utilization (English and French)	04/87	069/87
	Power System Efficiency Study (English)	12/87	--
	Power Sector Efficiency Study (French)	02/92	140/91

Region/Country	***Activity/Report Title***	***Date***	***Number***
Côte d'Ivoire	Project of Energy Efficiency in Buildings (English)	09/95	175/95
Ethiopia	Energy Assessment (English)	07/84	4741-ET
	Power System Efficiency Study (English)	10/85	045/85
	Agricultural Residue Briquetting Pilot Project (English)	12/86	062/86
	Bagasse Study (English)	12/86	063/86
	Cooking Efficiency Project (English)	12/87	--
	Energy Assessment (English)	02/96	179/96
Gabon	Energy Assessment (English)	07/88	6915-GA
The Gambia	Energy Assessment (English)	11/83	4743-GM
	Solar Water Heating Retrofit Project (English)	02/85	030/85
	Solar Photovoltaic Applications (English)	03/85	032/85
	Petroleum Supply Management Assistance (English)	04/85	035/85
Ghana	Energy Assessment (English)	11/86	6234-GH
	Energy Rationalization in the Industrial Sector (English)	06/88	084/88
	Sawmill Residues Utilization Study (English)	11/88	074/87
	Industrial Energy Efficiency (English)	11/92	148/92
Guinea	Energy Assessment (English)	11/86	6137-GUI
	Household Energy Strategy (English and French)	01/94	163/94
Guinea-Bissau	Energy Assessment (English and Portuguese)	08/84	5083-GUB
	Recommended Technical Assistance Projects (English & Portuguese)	04/85	033/85
	Management Options for the Electric Power and Water Supply Subsectors (English)	02/90	100/90
	Power and Water Institutional Restructuring (French)	04/91	118/91
Kenya	Energy Assessment (English)	05/82	3800-KE
	Power System Efficiency Study (English)	03/84	014/84
	Status Report (English)	05/84	016/84
	Coal Conversion Action Plan (English)	02/87	--
	Solar Water Heating Study (English)	02/87	066/87
	Peri-Urban Woodfuel Development (English)	10/87	076/87
	Power Master Plan (English)	11/87	--
	Power Loss Reduction Study (English)	09/96	186/96
Lesotho	Energy Assessment (English)	01/84	4676-LSO
Liberia	Energy Assessment (English)	12/84	5279-LBR
	Recommended Technical Assistance Projects (English)	06/85	038/85
	Power System Efficiency Study (English)	12/87	081/87
Madagascar	Energy Assessment (English)	01/87	5700-MAG
	Power System Efficiency Study (English and French)	12/87	075/87
	Environmental Impact of Woodfuels (French)	10/95	176/95
Malawi	Energy Assessment (English)	08/82	3903-MAL
	Technical Assistance to Improve the Efficiency of Fuelwood Use in the Tobacco Industry (English)	11/83	009/83
	Status Report (English)	01/84	013/84
Mali	Energy Assessment (English and French)	11/91	8423-MLI
	Household Energy Strategy (English and French)	03/92	147/92
Islamic Republic of Mauritania	Energy Assessment (English and French)	04/85	5224-MAU
	Household Energy Strategy Study (English and French)	07/90	123/90
Mauritius	Energy Assessment (English)	12/81	3510-MAS
	Status Report (English)	10/83	008/83
	Power System Efficiency Audit (English)	05/87	070/87
Mauritius	Bagasse Power Potential (English)	10/87	077/87

Region/Country	***Activity/Report Title***	***Date***	***Number***
Mauritius	Energy Sector Review (English)	12/94	3643-MAS
Mozambique	Energy Assessment (English)	01/87	6128-MOZ
	Household Electricity Utilization Study (English)	03/90	113/90
	Electricity Tariffs Study (English)	06/96	181/96
	Sample Survey of Low Voltage Electricity Customers	06/97	195/97
Namibia	Energy Assessment (English)	03/93	11320-NAM
Niger	Energy Assessment (French)	05/84	4642-NIR
	Status Report (English and French)	02/86	051/86
	Improved Stoves Project (English and French)	12/87	080/87
	Household Energy Conservation and Substitution (English and French)	01/88	082/88
Nigeria	Energy Assessment (English)	08/83	4440-UNI
	Energy Assessment (English)	07/93	11672-UNI
Rwanda	Energy Assessment (English)	06/82	3779-RW
	Status Report (English and French)	05/84	017/84
	Improved Charcoal Cookstove Strategy (English and French)	08/86	059/86
	Improved Charcoal Production Techniques (English and French)	02/87	065/87
	Energy Assessment (English and French)	07/91	8017-RW
	Commercialization of Improved Charcoal Stoves and Carbonization Techniques Mid-Term Progress Report (English and French)	12/91	141/91
SADC	SADC Regional Power Interconnection Study, Vols. I-IV (English)	12/93	--
SADCC	SADCC Regional Sector: Regional Capacity-Building Program for Energy Surveys and Policy Analysis (English)	11/91	--
Sao Tome and Principe	Energy Assessment (English)	10/85	5803-STP
Senegal	Energy Assessment (English)	07/83	4182-SE
	Status Report (English and French)	10/84	025/84
	Industrial Energy Conservation Study (English)	05/85	037/85
	Preparatory Assistance for Donor Meeting (English and French)	04/86	056/86
	Urban Household Energy Strategy (English)	02/89	096/89
	Industrial Energy Conservation Program (English)	05/94	165/94
Seychelles	Energy Assessment (English)	01/84	4693-SEY
	Electric Power System Efficiency Study (English)	08/84	021/84
Sierra Leone	Energy Assessment (English)	10/87	6597-SL
Somalia	Energy Assessment (English)	12/85	5796-SO
South Africa Republic of	Options for the Structure and Regulation of Natural Gas Industry (English)	05/95	172/95
Sudan	Management Assistance to the Ministry of Energy and Mining	05/83	003/83
	Energy Assessment (English)	07/83	4511-SU
	Power System Efficiency Study (English)	06/84	018/84
	Status Report (English)	11/84	026/84
	Wood Energy/Forestry Feasibility (English)	07/87	073/87
Swaziland	Energy Assessment (English)	02/87	6262-SW
	Household Energy Strategy Study	10/97	198/97
Tanzania	Energy Assessment (English)	11/84	4969-TA
	Peri-Urban Woodfuels Feasibility Study (English)	08/88	086/88
	Tobacco Curing Efficiency Study (English)	05/89	102/89
	Remote Sensing and Mapping of Woodlands (English)	06/90	--
	Industrial Energy Efficiency Technical Assistance (English)	08/90	122/90
Tanzania	Power Loss Reduction Volume 1: Transmission and Distribution SystemTechnical Loss Reduction and Network Development (English)	06/98	204A/98

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Tanzania	Power Loss Reduction Volume 2: Reduction of Non-Technical Losses (English)	06/98	204B/98
Togo	Energy Assessment (English)	06/85	5221-TO
	Wood Recovery in the Nangbeto Lake (English and French)	04/86	055/86
	Power Efficiency Improvement (English and French)	12/87	078/87
Uganda	Energy Assessment (English)	07/83	4453-UG
	Status Report (English)	08/84	020/84
	Institutional Review of the Energy Sector (English)	01/85	029/85
	Energy Efficiency in Tobacco Curing Industry (English)	02/86	049/86
	Fuelwood/Forestry Feasibility Study (English)	03/86	053/86
	Power System Efficiency Study (English)	12/88	092/88
	Energy Efficiency Improvement in the Brick and Tile Industry (English)	02/89	097/89
	Tobacco Curing Pilot Project (English)	03/89	UNDP Terminal Report
	Energy Assessment (English)	12/96	193/96
	Rural Electrification Strategy Study	09/99	221/99
Zaire	Energy Assessment (English)	05/86	5837-ZR
Zambia	Energy Assessment (English)	01/83	4110-ZA
	Status Report (English)	08/85	039/85
	Energy Sector Institutional Review (English)	11/86	060/86
	Power Subsector Efficiency Study (English)	02/89	093/88
	Energy Strategy Study (English)	02/89	094/88
	Urban Household Energy Strategy Study (English)	08/90	121/90
Zimbabwe	Energy Assessment (English)	06/82	3765-ZIM
	Power System Efficiency Study (English)	06/83	005/83
	Status Report (English)	08/84	019/84
	Power Sector Management Assistance Project (English)	04/85	034/85
	Power Sector Management Institution Building (English)	09/89	--
	Petroleum Management Assistance (English)	12/89	109/89
	Charcoal Utilization Prefeasibility Study (English)	06/90	119/90
	Integrated Energy Strategy Evaluation (English)	01/92	8768-ZIM
	Energy Efficiency Technical Assistance Project: Strategic Framework for a National Energy Efficiency Improvement Program (English)	04/94	--
	Capacity Building for the National Energy Efficiency Improvement Programme (NEEIP) (English)	12/94	--
	Rural Electrification Study	03/00	228/00

EAST ASIA AND PACIFIC (EAP)

Asia Regional	Pacific Household and Rural Energy Seminar (English)	11/90	--
China	County-Level Rural Energy Assessments (English)	05/89	101/89
	Fuelwood Forestry Preinvestment Study (English)	12/89	105/89
	Strategic Options for Power Sector Reform in China (English)	07/93	156/93
	Energy Efficiency and Pollution Control in Township and Village Enterprises (TVE) Industry (English)	11/94	168/94
	Energy for Rural Development in China: An Assessment Based on a Joint Chinese/ESMAP Study in Six Counties (English)	06/96	183/96
	Improving the Technical Efficiency of Decentralized Power Companies	09/99	222/999

Region/Country	*Activity/Report Title*	*Date*	*Number*
Fiji	Energy Assessment (English)	06/83	4462-FIJ
Indonesia	Energy Assessment (English)	11/81	3543-IND
	Status Report (English)	09/84	022/84
	Power Generation Efficiency Study (English)	02/86	050/86
	Energy Efficiency in the Brick, Tile and Lime Industries (English)	04/87	067/87
	Diesel Generating Plant Efficiency Study (English)	12/88	095/88
	Urban Household Energy Strategy Study (English)	02/90	107/90
	Biomass Gasifier Preinvestment Study Vols. I & II (English)	12/90	124/90
	Prospects for Biomass Power Generation with Emphasis on Palm Oil, Sugar, Rubberwood and Plywood Residues (English)	11/94	167/94
Lao PDR	Urban Electricity Demand Assessment Study (English)	03/93	154/93
	Institutional Development for Off-Grid Electrification	06/99	215/99
Malaysia	Sabah Power System Efficiency Study (English)	03/87	068/87
	Gas Utilization Study (English)	09/91	9645-MA
Myanmar	Energy Assessment (English)	06/85	5416-BA
Papua New Guinea	Energy Assessment (English)	06/82	3882-PNG
	Status Report (English)	07/83	006/83
	Energy Strategy Paper (English)	--	--
	Institutional Review in the Energy Sector (English)	10/84	023/84
	Power Tariff Study (English)	10/84	024/84
Philippines	Commercial Potential for Power Production from Agricultural Residues (English)	12/93	157/93
	Energy Conservation Study (English)	08/94	--
Solomon Islands	Energy Assessment (English)	06/83	4404-SOL
	Energy Assessment (English)	01/92	979-SOL
South Pacific	Petroleum Transport in the South Pacific (English)	05/86	--
Thailand	Energy Assessment (English)	09/85	5793-TH
	Rural Energy Issues and Options (English)	09/85	044/85
	Accelerated Dissemination of Improved Stoves and Charcoal Kilns (English)	09/87	079/87
	Northeast Region Village Forestry and Woodfuels Preinvestment Study (English)	02/88	083/88
	Impact of Lower Oil Prices (English)	08/88	--
	Coal Development and Utilization Study (English)	10/89	--
Tonga	Energy Assessment (English)	06/85	5498-TON
Vanuatu	Energy Assessment (English)	06/85	5577-VA
Vietnam	Rural and Household Energy-Issues and Options (English)	01/94	161/94
	Power Sector Reform and Restructuring in Vietnam: Final Report to the Steering Committee (English and Vietnamese)	09/95	174/95
	Household Energy Technical Assistance: Improved Coal Briquetting and Commercialized Dissemination of Higher Efficiency Biomass and Coal Stoves (English)	01/96	178/96
Western Samoa	Energy Assessment (English)	06/85	5497-WSO

SOUTH ASIA (SAS)

Bangladesh	Energy Assessment (English)	10/82	3873-BD
	Priority Investment Program (English)	05/83	002/83
	Status Report (English)	04/84	015/84

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Bangladesh	Power System Efficiency Study (English)	02/85	031/85
	Small Scale Uses of Gas Prefeasibility Study (English)	12/88	--
India	Opportunities for Commercialization of Nonconventional Energy Systems (English)	11/88	091/88
	Maharashtra Bagasse Energy Efficiency Project (English)	07/90	120/90
	Mini-Hydro Development on Irrigation Dams and Canal Drops Vols. I, II and III (English)	07/91	139/91
	WindFarm Pre-Investment Study (English)	12/92	150/92
	Power Sector Reform Seminar (English)	04/94	166/94
	Environmental Issues in the Power Sector (English)	06/98	205/98
	Environmental Issues in the Power Sector: Manual for Environmental Decision Making (English)	06/99	213/99
	Household Energy Strategies for Urban India: The Case of Hyderabad	06/99	214/99
Nepal	Energy Assessment (English)	08/83	4474-NEP
	Status Report (English)	01/85	028/84
	Energy Efficiency & Fuel Substitution in Industries (English)	06/93	158/93
Pakistan	Household Energy Assessment (English)	05/88	--
	Assessment of Photovoltaic Programs, Applications, and Markets (English)	10/89	103/89
	National Household Energy Survey and Strategy Formulation Study: Project Terminal Report (English)	03/94	--
	Managing the Energy Transition (English)	10/94	--
	Lighting Efficiency Improvement Program Phase 1: Commercial Buildings Five Year Plan (English)	10/94	--
Sri Lanka	Energy Assessment (English)	05/82	3792-CE
	Power System Loss Reduction Study (English)	07/83	007/83
	Status Report (English)	01/84	010/84
	Industrial Energy Conservation Study (English)	03/86	054/86

EUROPE AND CENTRAL ASIA (ECA)

Bulgaria	Natural Gas Policies and Issues (English)	10/96	188/96
Central and Eastern Europe	Power Sector Reform in Selected Countries	07/97	196/97
Eastern Europe	The Future of Natural Gas in Eastern Europe (English)	08/92	149/92
Kazakhstan	Natural Gas Investment Study, Volumes 1, 2 & 3	12/97	199/97
Kazakhstan & Kyrgyzstan	Opportunities for Renewable Energy Development	11/97	16855-KAZ
Poland	Energy Sector Restructuring Program Vols. I-V (English)	01/93	153/93
	Natural Gas Upstream Policy (English and Polish)	08/98	206/98
	Energy Sector Restructuring Program: Establishing the Energy Regulation Authority	10/98	208/98
Portugal	Energy Assessment (English)	04/84	4824-PO
Romania	Natural Gas Development Strategy (English)	12/96	192/96
Slovenia	Workshop on Private Participation in the Power Sector (English)	02/99	211/99
Turkey	Energy Assessment (English)	03/83	3877-TU

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	MIDDLE EAST AND NORTH AFRICA (MNA)		
Arab Republic of Egypt	Energy Assessment (English)	10/96	189/96
Arab Republic of Egypt	Energy Assessment (English and French)	03/84	4157-MOR
	Status Report (English and French)	01/86	048/86
Morocco	Energy Sector Institutional Development Study (English and French)	07/95	173/95
	Natural Gas Pricing Study (French)	10/98	209/98
	Gas Development Plan Phase II (French)	02/99	210/99
Syria	Energy Assessment (English)	05/86	5822-SYR
	Electric Power Efficiency Study (English)	09/88	089/88
	Energy Efficiency Improvement in the Cement Sector (English)	04/89	099/89
Syria	Energy Efficiency Improvement in the Fertilizer Sector (English)	06/90	115/90
Tunisia	Fuel Substitution (English and French)	03/90	--
	Power Efficiency Study (English and French)	02/92	136/91
	Energy Management Strategy in the Residential and Tertiary Sectors (English)	04/92	146/92
	Renewable Energy Strategy Study, Volume I (French)	11/96	190A/96
	Renewable Energy Strategy Study, Volume II (French)	11/96	190B/96
Yemen	Energy Assessment (English)	12/84	4892-YAR
	Energy Investment Priorities (English)	02/87	6376-YAR
	Household Energy Strategy Study Phase I (English)	03/91	126/91
	LATIN AMERICA AND THE CARIBBEAN (LAC)		
LAC Regional	Regional Seminar on Electric Power System Loss Reduction in the Caribbean (English)	07/89	--
	Elimination of Lead in Gasoline in Latin America and the Caribbean (English and Spanish)	04/97	194/97
	Elimination of Lead in Gasoline in Latin America and the Caribbean - Status Report (English and Spanish)	12/97	200/97
	Harmonization of Fuels Specifications in Latin America and the Caribbean (English and Spanish)	06/98	203/98
Bolivia	Energy Assessment (English)	04/83	4213-BO
	National Energy Plan (English)	12/87	--
	La Paz Private Power Technical Assistance (English)	11/90	111/90
	Prefeasibility Evaluation Rural Electrification and Demand Assessment (English and Spanish)	04/91	129/91
	National Energy Plan (Spanish)	08/91	131/91
	Private Power Generation and Transmission (English)	01/92	137/91
	Natural Gas Distribution: Economics and Regulation (English)	03/92	125/92
	Natural Gas Sector Policies and Issues (English and Spanish)	12/93	164/93
	Household Rural Energy Strategy (English and Spanish)	01/94	162/94
	Preparation of Capitalization of the Hydrocarbon Sector	12/96	191/96
Brazil	Energy Efficiency & Conservation: Strategic Partnership for Energy Efficiency in Brazil (English)	01/95	170/95
	Hydro and Thermal Power Sector Study	09/97	197/97
Chile	Energy Sector Review (English)	08/88	7129-CH
Colombia	Energy Strategy Paper (English)	12/86	--
	Power Sector Restructuring (English)	11/94	169/94

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Colombia	Energy Efficiency Report for the Commercial and Public Sector (English)	06/96	184/96
Costa Rica	Energy Assessment (English and Spanish)	01/84	4655-CR
	Recommended Technical Assistance Projects (English)	11/84	027/84
	Forest Residues Utilization Study (English and Spanish)	02/90	108/90
Dominican Republic	Energy Assessment (English)	05/91	8234-DO
Ecuador	Energy Assessment (Spanish)	12/85	5865-EC
	Energy Strategy Phase I (Spanish)	07/88	--
	Energy Strategy (English)	04/91	--
	Private Minihydropower Development Study (English)	11/92	--
	Energy Pricing Subsidies and Interfuel Substitution (English)	08/94	11798-EC
	Energy Pricing, Poverty and Social Mitigation (English)	08/94	12831-EC
Guatemala	Issues and Options in the Energy Sector (English)	09/93	12160-GU
Haiti	Energy Assessment (English and French)	06/82	3672-HA
	Status Report (English and French)	08/85	041/85
	Household Energy Strategy (English and French)	12/91	143/91
Honduras	Energy Assessment (English)	08/87	6476-HO
	Petroleum Supply Management (English)	03/91	128/91
Jamaica	Energy Assessment (English)	04/85	5466-JM
	Petroleum Procurement, Refining, and Distribution Study (English)	11/86	061/86
	Energy Efficiency Building Code Phase I (English)	03/88	--
	Energy Efficiency Standards and Labels Phase I (English)	03/88	--
	Management Information System Phase I (English)	03/88	--
	Charcoal Production Project (English)	09/88	090/88
	FIDCO Sawmill Residues Utilization Study (English)	09/88	088/88
	Energy Sector Strategy and Investment Planning Study (English)	07/92	135/92
Mexico	Improved Charcoal Production Within Forest Management for the State of Veracruz (English and Spanish)	08/91	138/91
	Energy Efficiency Management Technical Assistance to the Comision Nacional para el Ahorro de Energia (CONAE) (English)	04/96	180/96
Panama	Power System Efficiency Study (English)	06/83	004/83
Paraguay	Energy Assessment (English)	10/84	5145-PA
	Recommended Technical Assistance Projects (English)	09/85	--
	Status Report (English and Spanish)	09/85	043/85
Peru	Energy Assessment (English)	01/84	4677-PE
	Status Report (English)	08/85	040/85
	Proposal for a Stove Dissemination Program in the Sierra (English and Spanish)	02/87	064/87
	Energy Strategy (English and Spanish)	12/90	--
	Study of Energy Taxation and Liberalization of the Hydrocarbons Sector (English and Spanish)	120/93	159/93
	Reform and Privatization in the Hydrocarbon Sector (English and Spanish)	07/99	216/99
Saint Lucia	Energy Assessment (English)	09/84	5111-SLU
St. Vincent and the Grenadines	Energy Assessment (English)	09/84	5103-STV
Sub Andean	Environmental and Social Regulation of Oil and Gas Operations in Sensitive Areas of the Sub-Andean Basin (English and Spanish)	07/99	217/99

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Trinidad and Tobago	Energy Assessment (English)	12/85	5930-TR

GLOBAL

	Energy End Use Efficiency: Research and Strategy (English)	11/89	--
	Women and Energy--A Resource Guide The International Network: Policies and Experience (English)	04/90	--
	Guidelines for Utility Customer Management and Metering (English and Spanish)	07/91	--
	Assessment of Personal Computer Models for Energy Planning in Developing Countries (English)	10/91	--
	Long-Term Gas Contracts Principles and Applications (English)	02/93	152/93
	Comparative Behavior of Firms Under Public and Private Ownership (English)	05/93	155/93
	Development of Regional Electric Power Networks (English)	10/94	--
	Roundtable on Energy Efficiency (English)	02/95	171/95
	Assessing Pollution Abatement Policies with a Case Study of Ankara (English)	11/95	177/95
	A Synopsis of the Third Annual Roundtable on Independent Power Projects: Rhetoric and Reality (English)	08/96	187/96
	Rural Energy and Development Roundtable (English)	05/98	202/98
	A Synopsis of the Second Roundtable on Energy Efficiency: Institutional and Financial Delivery Mechanisms (English)	09/98	207/98
	The Effect of a Shadow Price on Carbon Emission in the Energy Portfolio of the World Bank: A Carbon Backcasting Exercise (English)	02/99	212/99
	Increasing the Efficiency of Gas Distribution Phase 1: Case Studies and Thematic Data Sheets	07/99	218/99
	Global Energy Sector Reform in Developing Countries: A Scorecard	07/99	219/99
	Global Lighting Services for the Poor Phase II: Text Marketing of Small "Solar" Batteries for Rural Electrification Purposes	08/99	220/99
	A Review of the Renewable Energy Activities of the UNDP/ World Bank Energy Sector Management Assistance Programme 1993 to 1998	11/99	223/99
	Energy, Transportation and Environment: Policy Options for Environmental Improvement	12/99	224/99
	Privatization, Competition and Regulation in the British Electricity Industry, With Implications for Developing Countries	02/00	226/00
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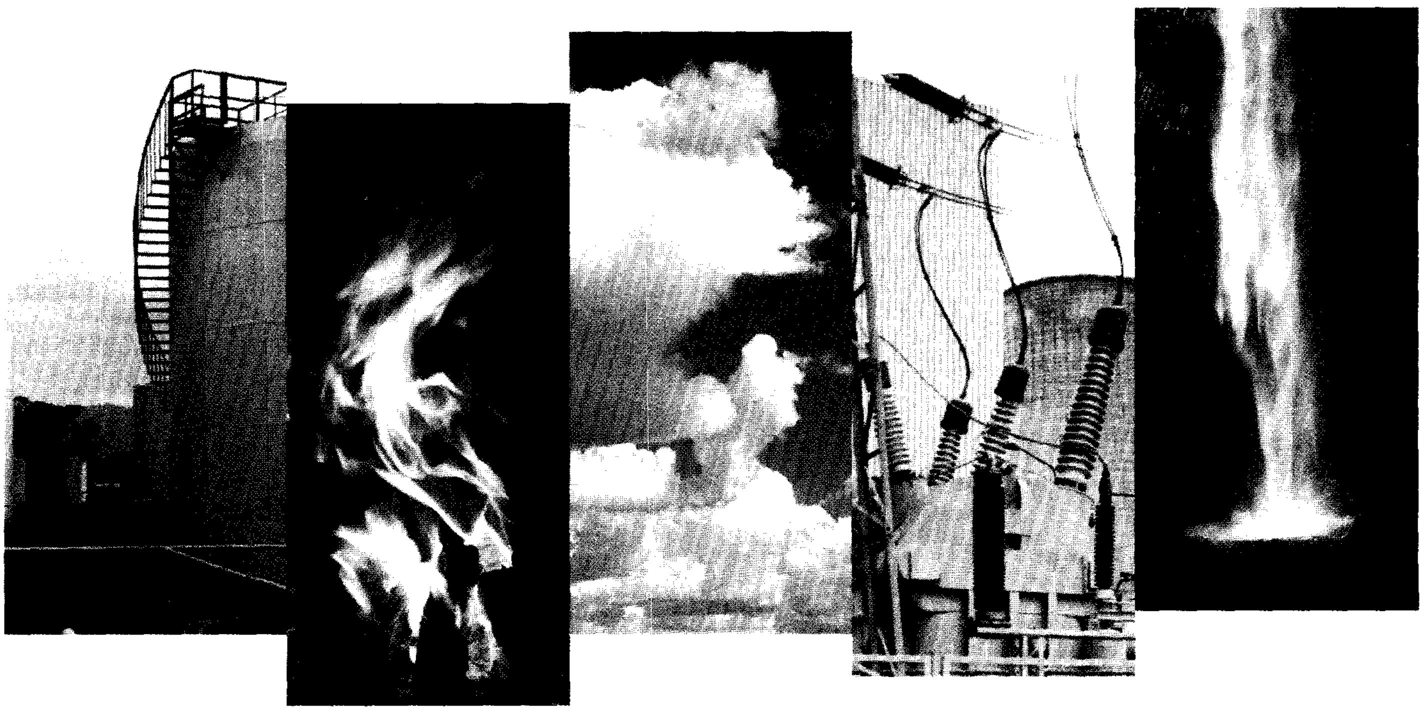

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