THE UNIVERSITY OF HULL

Rural Electrification in Ghana: Issues of Photovoltaic Energy Technology Utilisation

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by

Simon Bawakyillenuo

BA (Hons)(University of Ghana), MSc (Hull)

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ABSTRACT

Energy plays a pivotal role in human development. Not only is it sine qua non for national economic development, but it also provides services that enhance social development including, health and sanitation, education, potable water, cooking. In spite of this, at present, there are about two billion people without access to modern sources of energy, most of them in the rural areas of the developing world. Consequentially, the social and economic development of these two billion people hangs in the balance.

In recent times, however, considerable advocacy has taken place in the academic and policy studies, environmental fora, and national agenda about solar PV energy technology serving as a panacea to the energy problems of rural populations in developing countries, especially Sub-Sahara Africa, whilst also helping to reduce greenhouse gas emissions. Notwithstanding this great advocacy, the literature on the dissemination of this technology has been incomplete in fostering understanding on the discourses surrounding its low dissemination rates in rural Ghana compared to countries such as Kenya and Zimbabwe; the sustainability of installed solar PV systems; and the usefulness of solar PV in serving the needs of the rural poor.

In resorting to an interdisciplinary approach (methodology and theoretical foundation), this study has explored the energy perspectives of Ghana, the dynamics of rural electrification and energy needs, and the interplay of processes and forces underpinning the adoption and non-adoption of solar PV in rural Ghana. Results of this study show that, Ghana has abundant renewable energy resources, especially solar radiation. However, the study further reveals that the resource base alone of solar PV technology is not the panacea to its successful dissemination and the energy needs of all in rural Ghana. Significantly, this study has shown that the adoption and non-adoption perspectives of solar PV in rural Ghana and the sustainability of installed solar PV systems, as well as the disparate levels of solar PV dissemination in Ghana, Kenya and Zimbabwe, are contingent on multi-dimensional circumstances. This stands in contrast to the majority of literature that often emphasise cost as the sole determining factor of the non-adoption of solar PV in most developing countries. Results of this study therefore have implications for rural energy supply policy approaches and other institutional arrangements on solar PV issues in Ghana.

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DEDICATION

I dedicate this piece of work to God (for the abundant grace and provisions He showered on me to come this far), and to my late father, James Bawakyillenuo and my late uncle, Leo Nigebolee.

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LIST OF ABBREVIATIONS AND ACRONYMS

AEO	African Economic Outlook
AFC	Agricultural Finance Corporation
AFREPREN/FWD	African Energy Policy Research Network and Foundation for Woodstove Dissemination
AMA	Accra Metropolitan Assembly
ANT	Actor-Network Theory
a-Si	Amorphous Silicon
BCEOM	Bureau Central d'Etudes pour les Equipements d'Outre-Mer.
B.E.S.T	Baba Energy Systems Technology
BOS	Balance of System
BOST	Bulk oil Storage and Transportation
CIA	Central Intelligence Agency
CEPS	Customs Excise and Preventive Service
CIDA	Canadian International Development Agency
CO_2	Carbon Dioxide
DANIDA	Danish International Development Agency
DSC	District Service Centre
EAA	Energy Alternatives Africa Ltd
EC-GH	Energy Commission of Ghana
ECG LTD	Electricity Company of Ghana Limited
EF	Energy Foundation
EFL	Electricity Feed Law
EIC	Energy Information Centre
ERP	Economic Recovery Programme
ESCO	Energy Service Company
ESD	Energy for Sustainable Development
ESDP	Energy Sector Development Programme
ESI-AFRICA	Energy Supply Industry-Africa
ESMAP	Energy Sector Management Assistance Programme
EU	European Union
FAO	Food and Agriculture Organisation
FDI	Foreign Direct Investment
FINNIDA	Finnish International Development Agency
FOE-GH	Friends of the Earth-Ghana
FONDEM	Fondation Energies pour le Monde.
FPIB	Forest Products Inspection Bureau
GCMC	Ghana Cylinder Manufacturing Company
GDP	Gross Domestic Product
GEF	Global Environment Facility
GENI	Global Energy Network Institute
GHC (¢)	Ghana Cedi
GLSS	Ghana Living Standards Survey
GNPC	Ghana National Petroleum Corporation
GOG	Government of Ghana
GOIL	Ghana oil Company Limited
GSS	Ghana Statistical Service
GTZ	German Technical Cooperation
HP	Hire Purchase

HS	Harmonized System
IAEA	International Atomic Energy Agency
IEA	International Energy Agency
IEA-PVPS	International Energy Agency Photovoltaic Power Systems Programme
IFC	International Finance Corporation
ILRI	International Livestock Research Institute
ISS	Institute for Security Studies
ISSER-Ghana	Institute of Statistical, Social and Economic Research-Ghana
JICA	Japan International Cooperation Agency
KENPREP	Kenya Photovoltaic Rural Energy Project
KES	Kenyan Shilling
KITE	Kumasi Institute of Technology and Environment
KNUST	Kwame Nkrumah university of Science and Technology
kgoe	Kilogram of Oil Equivalent
KPLC	Kenya Power and Lighting Company
KW	Kilowatt
LPG	Liquified petroleum gas
MARA/ARMA	Mapping Malaria Risk in Africa / Atlas du Risque de la Malaria en Afrique
MDG	Millennium Development Goals
MME-GH	Ministry of Mines and Energy-Ghana
MOE-GH	Ministry of Energy - Ghana
MOE-KENYA	Ministry of Energy - Kenya
MOFA-GH	Ministry of Food and Agriculture-Ghana
MOFEP-GH	Ministry of Finance and Economic Planning-Ghana
MOH	Ministry of Health
MW	Megawatt
NASEP	National Solar Energy Programme
NDC	National Democratic Congress
NEB	National Energy Board
NES	National Electrification Scheme
NFFO	Non-Fossil Fuel Obligation
NGO	Non-Governmental Organisation
NPA	National Petroleum Authority
NREL	National Renewable Energy Laboratory
PNDC	Provisional National Defence Council
PV	Photovoltaic
PVMTI	Photovoltaic Market Transformation Initiative
PWD	Public Works Department
RCEER	Resource Centre for Energy Economics and Regulation
REDP	Renewable Energy Development Project
REF	Rural Electrification Fund
REP	Rural Electrification Programme
RESPRO	Renewable Energy Development Project
RET	Renewable Energy Technology
RO	Renewables Obligation
RPS	Renewable Portfolio Standard
RSC	Rural Service Centre
SCOT	Social Construction of Technology
SCEE	Southern Centre for Energy and Environment

SHEP	Self-Help Electrification Project
SHP	Small Hydro Power
SHS	Solar Home System
SIDA	Swedish International Development Agency
SPSS	Statistical Package for Social Sciences
SST	Social Shaping of Technology
S.U.N	Solar Utilisation Network
TMA	Tema Metropolitan Assembly
toe	Tonne of Oil Equivalent
TOR	Tema Oil Refinery
TU-Berlin	Technical University of Berlin
UN	United Nations
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific
UNFCCC	United Nations Framework Convention on Climate Change
UOR	University of Regina
VALCO	Volta Alumimium Company
VAT	Value Added Tax
VRA	Volta River Authority
W	Watt
WCRE	World Council for Renewable Energy
WEC	World Energy Council
WHO	World Health Organisation
WP	Peak Watt
ZWD	Zimbabwean Dollar
ZESA	Zimbabwe Electricity Supply Authority

CHAPTER ONE

BACKGROUND TO THE STUDY

1.1 GENERAL INTRODUCTION

Energy resources have always played an important role in the development of human society. Since the industrial revolution, energy has been a driving force for the development of modern civilization. Technological development and the consumption of energy, along with the increase in population, are interdependent. The industrial revolution, especially the momentum created by the change from reciprocal engines to the great horsepower of steam engines in the late nineteenth century, brought about a revolution in dynamics and began a drastic increase in energy consumption and the population of the world (Marchetti, 1979).

Deliberations at the World Summit on Sustainable Development in Johannesburg, 2002 and the Millennium Development Goals (MDG) have recognised at a global level that the provision of a modern energy source such as electricity has been a *sine qua non* for many of the advancements made in economic growth, employment opportunities, healthcare provision, education as well as improvements in living standards, especially the rural communities. Stemming from these deliberations is the notion that rural communities will stand a better chance of achieving both social and economic prosperity, once they have access to a modern source of electricity. While the World Bank (1996) considered that the lack of access to energy in rural areas is above all a manifestation of poverty, the International Energy Agency (IEA) (2002) also pointed out that the “lack of electricity exacerbates poverty and contributes to its perpetuation, as it precludes most industrial activities and the jobs they create” (p.33).

Thus, the lack of access to a reliable energy source in rural communities in the developing world is a major impediment to sustainable development.

However, at present, there are about two billion people without access to electricity, and most of them live in the rural areas of the developing world, especially Africa (Ciscar, 1997; Duke et al; 2002; WEC, 2003). It is estimated that only 43 percent of the population of Ghana, have access to electricity (Ghana Population Census, 2000). The imbalance in economic and other social development between the 43 percent with access to electricity and the 57 percent without access to electricity demands policy attention. Further estimates by the World Bank (1992) indicate that, in the last twenty-five years, developing countries have provided electricity to only 800 million people in rural areas (40 percent of the two billion people without access to modern electricity). Driven by the need to solve this rural electrification problem, many governments in the developing world have tried different energy programmes, projects and models over recent decades.

Energy for rural development in developing countries has been an issue of national interest for some time (see Chapter Two), receiving significant attention in most developing countries during the last three decades of the twentieth century (Abdalla, 1994; Byrnes, 1998; Lew, 2000). Three main options have been considered to steer the electrification drive for rural areas. The first is centralized electrification, consisting of an extension of the domestic electricity network. Another is the decentralized local grid, powered for instance, by diesel or small hydro plants. The third is electrification without grids, which includes stand alone systems such as photovoltaic (PV) Solar Home Systems (SHSs).

The implementation measures for these initiatives and the question of whether they are having the desired effects on the rural populations in the developing world (especially solar PV) are issues worthy of detailed critical scrutiny. Zomers (2001) for example, notes that "…the assessment of rural electrification projects revealed that many of the existing rural electrification systems in the developing countries fell short of expectations and did not meet their objectives" (p. 21). African countries such as Kenya and Zambia have experienced failures in their rural electrification programmes (Karekezi and Kithyoma, 2002). This means the developments that these programmes were envisaged to bring, were never achieved.

It can be argued that electricity can stimulate development that is already taking place but cannot by itself ensure economic development. For example, communities which are very poor, with very little economic activity, are unlikely to derive much economic benefit from an electricity supply, although they may derive some benefits from better lighting and communication. According to Amulya *et al* (2000) "electrification works best when overall conditions are right for rural income growth and when it is complemented by social and economic infrastructure development—such as rural water supplies, health programmes, primary and secondary school education, and regional and feeder roads" (p.375). The implication here is that the positive correlation between rural electrification and development does not always work out. Thus, even though energy plays an important role in modern society, it should be noted that its usefulness could be relative to each community's development trajectory.

The background and needs of every society dictate the kind of energy system that is required. The energy needs of the poor in society will contrast with those of the rich in the urban or rural areas. In consequence, there is the need to assess the various rural electrification initiatives vis-à-vis the energy needs of the rural poor. Particular attention will be paid to PV Solar Home Systems (SHSs).

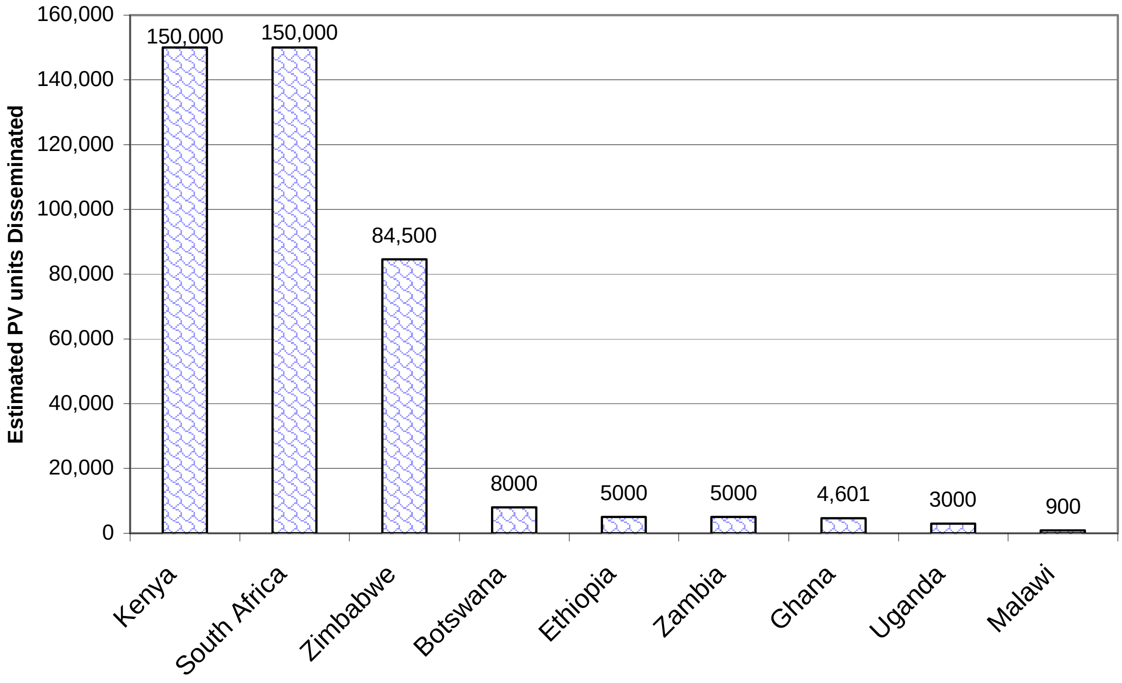
1.2 BACKGROUND CONSIDERATIONS

Many academic and policy studies, environmental organisations (e.g. Kaufmann *et al*, 2000), world summits and many national energy agendas have advocated photovoltaic energy as a panacea for the energy problems of rural populations, whilst also helping to reduce greenhouse gas emissions. According to Alsema and Nieuwlaar (2000) "photovoltaic energy conversion is widely considered as one of the promising renewable energy technologies which has the potential to contribute significantly to a sustainable energy supply and which may help to mitigate greenhouse gas emissions" (p.999). Many also argue that this energy source is environmentally benign and fits the energy needs of these rural areas. Other rationales behind the strong pro solar energy advocacy include the views that a large percentage of rural population in developing countries (in dispersed settlements) are without electricity and solar PV offers more reliable, efficient, and cost effective measures compared to grid electricity. According to Karekezi and Kithyoma (2002) "conventional wisdom perceives photovoltaic (PV) energy as the most attractive renewable energy option. As the least electrified continent in the world, rural Africa is often portrayed as the most important region for the dissemination of PV technology. Consequently, national renewable and rural energy strategies have given priority to the dissemination of PV technology" (p.1073). Similarly, Erickson and Chapman (1995) observe that "among the many renewable energy options available for remote power (i.e. biomass, wind, solar thermal), PV is most often promoted" (p.1130). Meanwhile, the big question still remains regarding its potential for meeting the modern energy needs of the rural poor in the developing world.

It can be argued that the key driver to the interest in disseminating PV technology in the developing world and Africa in particular, is a preoccupation with electricity (which arguably is not the essential energy need of the rural poor). For instance, a number of multilateral agencies, individual governments and non-governmental organisations (NGOs) have actively supported various initiatives to promote the dissemination of PV technologies in rural communities of Africa and other developing countries in the past. Some of these multilateral initiatives included the UNDP/GEF and IFC/GEF (see list of abbreviations and acronyms) projects in many African countries. Examples of countries which benefited from the UNDP/GEF and IFC/GEF funding include Zimbabwe, with $7 million, Ghana, with $2.5 million and Kenya, with $5 million (Bacon, 1998; Edjekumhene et al, 2001; Hankins, 2001a; Karekezi, 2002b). The intention of these initiatives was to get many of the rural homes in Africa to install PV systems.

Despite these considerable levels of investment and expectations, rates of dissemination and adoption of PV in sub-Sahara Africa (and Ghana for that matter) are still low (Figure 1.1). The expectation that millions of rural people would install solar PV household systems (SHSs) does not seem to have materialised. According to Hankins (2001a) "none of the PV … development projects in east and southern Africa has been as successful as anticipated, and the market remains a loss leader" (p.3). The estimated dissemination in Figure 1.1 shows even a worse case scenario for such countries as Ghana, Malawi, Ethiopia and Uganda compared to others such as Kenya, Zimbabwe and South Africa. Even though some of these countries have comparatively higher adoption rates than others, the facts are that the beneficiaries are almost never poor rural households, or rural women, who are the target consumers. For example, assessments of the Zimbabwean UNDP/GEF PV project by a number of energy analysts (Karekezi and Kithyoma, 2002, Bacon, 1998, Mulugetta *et al*, 2000) suggest that it was the middle-class rural households in Zimbabwe who purchased most of the PV systems; the majority of rural households did not because they could not afford them. Their lack of affordability was partly attributed to their inability to meet the financial requirements needed to apply for loans.

Figure 1.1 Estimated Number of solar PV Systems Disseminated in Selected African Countries



Sources: Edjekumhene et al (2001), van der Vleuten-Balkema (2003), Karekezi *et al* (2004), Keiffenheim (2004), Karekezi and Kithyoma (2002).

Besides the uncertainty surrounding the uptake rates of the technology by poor individual rural households in the less developed countries, less is known about the sustainability of the systems that were acquired through some of these aforementioned donor/non-governmental organisations funded projects.

Available statistics clearly show the lack of electricity in many rural parts of the developing world. However, using the estimated statistics of the PV units disseminated in the selected African countries, the argument is that while SHS might be useful to middle-class rural households, the same cannot be said for poor rural households. Poor rural households have their own unique socio-cultural, economic, and techno-political characteristics, which influence their need for any technology, as well as determining its usefulness. Mackenzie and Wajcman (1985) argue that “the characteristics of a society play a major part in deciding which technologies are adopted” (p.6). This is because the socio-cultural and political situation of every social group shapes its norms and values, which in turn influence the meaning the social group gives to any technology (Pinch and Bijker, 1987). Moon (2004) for example, points out that “for any technology to be truly useful to the poor in Africa, including renewable energy technology, it must address their special social and economic circumstances” (p.8). The key issue here is that rural populations in Africa and Ghana for that matter are predominantly poor. There is a widespread lack of potable water, inadequate housing facilities, a lack of modern farming implements, and a lack of water for livestock during the dry seasons in most parts of rural areas in Africa. Poverty levels in rural Africa range from over 50 to 77 percent (Karekezi, 2002a), if national poverty references are used. Their main sources of subsistence are farming, pastoralism, small scale industries (e.g. brewing of local beer, sheanut oil extraction, pottery making, palm oil processing and production of local soap by women), and small scale trading.

The energy needs of these poor rural communities will be linked to these sources of subsistence. In addition, energy will also be needed at the household level. Households require energy for cooking, lighting, and in some instances space heating.

Cooking accounts for between 90 to 100 percent of energy consumption in rural areas, through the use of biomass (Karekezi and Kithyoma, 2002). Lighting accounts for the rest of the other consumption, derived through wood fuel (cooking fire), kerosene lamps, torchlight, candles, 'bobo' (locally manufactured lanterns). In cold climatic areas and cold weather conditions, wood fuel is often used for space heating. It can therefore be argued that, poor rural communities of such characteristics will need energy systems that will boost their productivity. Thus, a range of modern energy technologies that can generate income generation benefits at a relatively low cost and help start up small micro-enterprises might tie in with their development aspirations. In consequence, renewable technologies that can be used to process agricultural produce and increase its value, those that can be used to pump water for irrigation and for livestock in the dry season, those that can provide clean potable water and reduce water borne diseases and those that will reduce the cooking burden of women are more likely to play a valuable role in their livelihoods. Simple lighting, which is supplied by SHS, is unlikely to offer equivalent production opportunities.

Despite the promotion of SHS as the answer to energy needs of the rural poor, there is no clarity regarding how it can meet these hoped-for benefits. In many cases, modern lighting system and the use of electronic equipments such as television, mobile phones (which the solar home PV systems support) are not the priorities of poor rural communities. As Hankins (2001a) notes "… lower income groups in general have other priorities than getting lighting or entertainment" (p.7). Thus, the technology's dissemination to the poor rural part of the developing world raises concerns on both supply and demand. Arguably, demand for this technology has been low in poor rural households, while supply is high[1]. It can therefore be said that, the widespread advocacy of photovoltaic technology for poor rural households (because of its economic cost-effectiveness against the conventional grid) may be no more than a "supply push" rather than a response to demand. Erickson and Chapman (1995) citing Agarwal *et al* (1983) comment that "…most (renewable energy) systems were installed not because there was a local consumer demand for them but because a Northern entrepreneur was able to find a Northern aid agency to support their establishment as "demonstration" projects" (p.1130). Nevertheless, with two billion people lacking electricity in the developing world, PV technology would seem to have great potential.

At the community level, PV technology is used in several ways. For instance, in many rural clinics and hospitals in Africa, PV driven refrigerators are being used to preserve medical vaccines. About 15 PV-based refrigerators have been installed in remote hospitals and clinics in the northern parts of Ghana by the Danish International Development Agency (DANIDA) (Edjekumhene *et al,* 2001). Some rural community schools are also using this technology. In addition, most telecommunication industries, such as mobile phone companies in the urban centres, are using PV technology to supply their energy needs. Even though some rural communities might benefit from PV installations in clinics and schools, the concern here relates to the economic benefits of the technology at the level of individual households.

On the whole, most developing countries' rural energy strategies put PV in the forefront of other modern alternative energies, but this does not necessarily address

[1] There are a lot PV companies from the developed countries that are in operation in developing countries.

rural poor energy needs in a comprehensive way. Meanwhile, there are other types of modern energy, whose main focus is not only on the provision of light, but also the support of income generation ventures - agriculture, small and micro-rural enterprises. These include small hydro plants, efficient biomass technologies, wind energy, solar crop dryers, biogas plants and diesel generators. Because of the diverse utility of these types of renewable technologies, coupled with the needs of rural communities in Africa, it can be argued that such renewables might have some prospects of fitting well into these rural communities.

1.3 AIM

The main aim of this research is to examine the social, technical, cultural, institutional, political and economic issues that mediate the up-take and application of photovoltaic energy in rural Ghana. It is envisaged that this research will reveal the essential technical, economic, cultural and the social elements that need to be considered in rural energy advocacy and policy discourse. These could then serve as some of the building blocks for reshaping the Ghana government's rural energy policies.

1.4 OBJECTIVES

The following specific objectives are outlined to support the main purpose of the study:

- to examine critically Ghana's demand for energy (i.e. rural and urban) and the potential role of photovoltaic energy in the rural sector;
- to examine critically Ghana's rural electrification programme;

- to examine critically the social, technical, cultural and economic conditions in rural Ghana, in order to determine both the scope for PV adoption and the types of energy sources that need emphasis;
- to explore the main institutional, policy, regulatory frameworks and models available for photovoltaic development in rural Ghana;
- to examine critically the different implementation strategies of PV in Kenya and Zimbabwe as comparators for Ghana

1.5 SIGNIFICANCE OF THE STUDY

This study will contribute to existing knowledge about the application of photovoltaic energy in the developing world, with a particular focus on Ghana. In a broader perspective, it will facilitate our understanding of the interplay between socio-cultural, technical, economic, policy and institutional elements in the diffusion of technological innovation − from international, national and local perspectives. It is hoped that research findings will identify the opportunities and challenges in utilizing this form of energy technology in rural Ghana; and could be useful to governments, energy planners, policy makers, utilities and international organisations that are engaged in assessing its up-take potential in Ghana.

1.6 RATIONALE

While a considerable degree of literature abounds regarding PV development and dissemination in Africa, a greater proportion of it has been focused on East and South African countries to the neglect of West Africa. Thus, the choice of rural Ghana (a West African country) is motivated by the lack of literature on this energy technology. The research topic itself has been chosen because the discourses surrounding the socio-cultural-economic, technical, political and institutional dimensions influencing the diffusion of PV in rural areas are little explored in Ghana. As Nsiah-Gyabaah (1994) notes "For a long time, talk about new and renewable energy technologies has been approached from purely scientific perspectives by those in the pure and applied sciences. The socio-economic aspects have always been relegated to the background" (p. 97).

1.7 STRUCTURE OF THE THESIS

The thesis is organised into eight chapters. This introductory chapter deals with the background issues of my study: aim, objectives, significance and rationale. Chapter Two provides an overview of the literature and theory which inform this thesis. It reviews the energy literature that relates to the interconnected issues in the adoption process of solar PV in the developing world. In particular, the chapter looks at rural electrification processes in Africa, an assessment of the potential of renewable energy technologies, the dynamics of solar PV rural electrification and the debates on solar PV business models. In addition, the chapter reviews a range of theories to help develop a suitable framework for this thesis.

Chapter Three focuses on the research approach and methodology which this thesis adopts. The chapter provides a background to the case study areas and discusses the various approaches that were devised to collect data in the field, and how the data is analysed and interpreted for this research. The chapter also discusses practical issues concerning the two fieldwork programmes in Ghana and Kenya.

Chapter Four contextualises solar PV energy provision in Ghana by assessing the energy scenarios and rural electrification programme in the country. In consequence, the chapter considers first and foremost, the general political and economic geography of Ghana, its people and energy resources. Following from that it discusses the relative energy consumption patterns of both urban and rural Ghana, the backgrounds to the various approaches to rural electrification in Ghana, and activities leading to the incorporation of renewable energy concepts in rural electrification programmes.

This leads on to Chapter Five, which provides a critical analysis of the various dimensions influencing solar PV technology's adoption and non-adoption in rural Ghana. Against this backdrop, the chapter explores the questionnaire data for households and the transcripts of the formal and informal interviews that were collected in the field and analysed within the framework of the social construction of technology theory. The different ways in which solar PV is used by adopters are discussed in the chapter. In addition, the social and households' characteristics of respondents in the three case study areas are explored vis-à-vis the ownership and non-ownership of solar PV.

Chapter Six examines the interface between the barriers limiting the adoption of solar PV (as identified in Chapter Five) and institutional, policy (international and national) and regulatory frameworks surrounding solar PV in Ghana. Primarily, it outlines and discusses challenges to the dissemination of solar PV from a global perspective, and the approaches used by some countries to foster its dissemination. The chapter also chronicles the policies, programmes, and other institutional measures adopted by Ghana for PV development in the three phases of renewable energy policy in the country. It also evaluates the effectiveness of these three phases of Ghana's renewable energy policy.

Chapter seven lays out a comparative analysis of the different solar PV development trajectories in Kenya, Zimbabwe and Ghana in a bid to answer the question: what drivers or interactive historical and contemporary factors account for or help to explain the disparities in the dissemination rates of solar PV in these three countries? As a result, the geographic and economic profiles of each of the three countries, their energy generation mix and the historical accounts of solar PV development are extensively discussed, whilst the main drivers that have influenced the disparity in solar PV diffusion in these countries are teased out and juxtaposed.

Finally, in Chapter Eight, the main findings of the study are summarised and key issues that emerged are discussed.

CHAPTER TWO

CONTEXT, EXISTING KNOWLEDGE AND THEORY

2.1 INTRODUCTION

Solar photovoltaic (PV) cells have attracted increasing attention in recent years as a technology capable of delivering sustainable electricity supplies and reducing the burden of fossil fuels on the environment (Jackson and Oliver, 2000). More especially, emphasis has been put on dissemination to the rural parts of the less developed countries of the world. The belief is that it is the answer to the energy needs of rural people and capable of reducing the pressure they put on the environment. However, looking at the complex social, technical and economic strands of rural communities in the developing world, coupled with less than perfect institutional arrangements, the rate at which PV will penetrate into these communities is very uncertain. As Mozaharul *et al* (2003) note "…the diffusion potential of renewable energy technologies is complex and difficult" (p. 88). In their view, issues related to the availability of the particular renewable energy, remoteness and isolation of rural households where grid electricity will not reach in the foreseeable future, socio-economic conditions, affordability and willingness to pay, policy support and institutional capacity all play a role in the wider shaping of any renewable energy diffusion. Besides all these issues, there could also be other cultural and behavioural factors, which are potentially influential in an individual's innovation adoption process.

The main thrust of this chapter is to review the energy literature that relates to these issues in the process of adoption of PV technology in the developing world, by way of contextualising the problem of this thesis. Consequently, the rest of the chapter is structured as follows. In section 2.2, the focus is on energy issues in the developing world, especially Africa. Rural electrification is part of this picture, simply because, at least in Africa, most people live in rural areas. Consequently, its rationale shall be examined, and the cohort of energy sources (including renewable energy technologies) that have been used for this rural electrification drive is assessed. Following from this, the potential of renewable energy technologies is examined, particularly solar PV technology, in section 2.3. This involves an exploration of the technical history of PV technology and its economic development over time, the dynamics of PV rural electrification, including a range of solar PV business models. In section 2.4 various theories and models are reviewed and discussed to contextualise this thesis. Section 2.5 concludes the chapter.

2.2 RURAL ELECTRIFICATION IN THE DEVELOPING WORLD

Rural electrification in the developing world and particularly in sub-Saharan Africa has been the subject of numerous studies and the theme at countless conferences. The concept of rural electrification also reflects divergent interpretations by many researchers. For instance, Mbewe (1992) notes that "Rural electrification is a rather general term which can have different meanings … In one context, rural electrification may only mean grid extension, while in another it may include isolated systems. In some countries where electrification is still in its nascent stages the term rural electrification means electrifying remote and peri-urban areas to improve living standards" (pp.24-25).

Alternatively, Barnes (1988) views rural electrification as "the availability of electricity for use in rural communities, regardless of the form of generation", while Yaron *et al* (1994) observe that "rural electrification is the process of bringing electricity to rural communities" (cited in Zomers, 2001:40). Munasinghe (1988) restricts rural electrification to connections to a central grid. While others such as Mason (1990) and Foley (1990) argue that definitions of rural electrification vary considerably between countries. They contend that in one country 'rural' also includes provincial towns with a population up to 50,000 and in another it refers to small farming villages and surrounding areas.

Here, and in the context of this study, a simple and inclusive definition is used. Rural electrification simply refers to the electrification of remote areas — farming and non-farming villages of the developing world.

Across the developing world, considerable progress has been made in rural electrification programmes, in extending electricity services to isolated villages. According to Amulya *et al* (2000) "Between 1970 and 1990, 800 million people in rural areas gained access to electricity" (p.374). However, of the three billion people living in rural areas of the developing world in 1990, two billion were still without access to electricity (ibid). In other words, in that 20-year period, only 40 percent of anticipated needs were met. Moreover, the World Energy Council and Food and Agriculture Organisation (WEC/FAO) (1999) note that "The global totals mask the significant variations between regions and countries…a number of Asian countries have made impressive progress, most notably Malaysia, Thailand, the Philippines and China" (p.61). This report added that China's rapid electrification programme in the period 1970-90, through which 365 million more rural residents gained access to electricity, significantly increases the world totals. If China were excluded, then current levels of access would drop from 44 percent to 33 percent (ibid). Indeed, if we review the 1970 and 1990's figures in terms of regional impact, Africa (and particularly Sub-Sahara Africa) lags behind the rest by a considerable margin (Table 2.1).

Table 2.1 Rural access to electricity by region in the developing world

Region	1970		1990		Increase in Population with access to electricity
	Population	Access	Population	Access	
North Africa and Middle East	77m	14%	108m	35%	27m
Latin America	121m	15%	125m	40%	32m
Sub-Sahara Africa	222m	4%	340m	8%	18m
South Asia	579m	12%	836m	25%	140m
China	675m	40%	794m	80%	365m
East Asia & Pacific	930m	25%	1 072m	45%	249m

Source: World Bank, 1995 (cited in WEC/FAO, 1999).

Table 2.2 shows similar data for 2000, with Sub-Saharan Africa still the least electrified. According to these data, in 2000, approximately 310 million Sub-Saharan Africans were without electricity. Agumba (2002) notes "More than 83 percent of Africa's rural population are without electricity. It's worse in the Sub-Saharan Africa where more than 92 percent of the rural population is unelectrified …" (p.1). Authors such as Karekezi and Kithyoma (2004) have attributed the low level of rural electrification in Sub-Sahara Africa to rural poverty, but the situation is more complicated than that.

Table 2.2 Developing country electrification rates (%)

Region	2000		
	Total Electrification Rate (%)	Urban Electrification Rate (%)	Rural Electrification Rate (%)
North Africa	90.3	99.3	79.9
Sub-Sahara Africa	22.6	51.3	7.5
Africa	34.3	63.1	16.9
South Asia	40.8	68.2	30.1
Latin America	86.6	98.0	51.5
East Asia/China	86.9	98.5	81.0
Middle East	91.1	98.5	76.6

Source: Adapted from IEA, 2002.

In the past, rural electrification has often been viewed as a remedy to a number of problems, including deforestation for fuelwood, poverty, and migration to urban areas (Zomers, 2001). Though well intentioned, the question however, remains as to whether the various rural electrification approaches and programmes have helped solve or can solve these problems. According to Amulya *et al* (2000) "Rural electrification programmes have typically concentrated on connecting villages and remote areas to a national grid—often owned and operated by a public utility" (p.374). The tendency has been to extend the grid incrementally, reaching towns and settlements in order of increasing capital costs, and as a result, remote areas with small populations are likely to be the last to receive electricity (Amulya *et al,* 2000; WEC/FAO, 1999). In Sub-Sahara Africa, almost every country in the region has this centralised approach (i.e. grid) of rural electrification programme (Karekezi and Kithyoma, 2004). Even so, rural access to electrification is still very patchy.

The decentralised rural electrification which involves the utilisation of decentralised energy generation technologies (diesel-engine generator sets and renewable energy technologies — small-scale hydropower, solar PV, wind), is another approach. Many regard this approach as more ideal than the grid in the rural electrification drives of the third world, especially Sub-Sahara Africa. For instance, Amulya *et al* (2000) are of the view that "Because of the problems of supplying grid electricity for small, scattered, peaky loads, decentralised electricity generation is becoming more attractive. With decentralised systems, the high costs of transmission and distribution networks can be avoided" (p.375). While not disputing the advantages of this decentralised approach over the grid approach, it could be argued that this approach has not also worked well so far in Sub-Sahara Africa, if its rural electrification figures are anything to go by.

2.3 ROLE/POTENTIAL OF RENEWABLE ENERGY TECHNOLOGIES (RETS)

Many contemporary debates portray renewable energy technologies as having the capacity to solve the world's energy needs in an environmentally benign manner. Notionally a good number of the arguments are very sound, however, in practice a lot more is needed to translate theory into actuality. In order to realise their real potential, renewable energy technologies (RETs) must accommodate a range of non-technical conditionalities. In their discussion on the 'diffusion potential of renewable energy technology in Bangladesh', Mozaharul *et al* (2003) argue that the achievement of the real potential of renewable energy systems "…depend on the availability of cost-effective technology, affordability, acceptability, and effective management" (p. 89). There is also the need for political support. The positive effect of political support is felt in increased budgetary allocation and research. For example, the achievement of the real potential of renewable energy technologies was emasculated in the OECD countries between 1984 and 1995 because it was devoid of political support (WCRE, 2004). According to WCRE (2004), within the aforementioned period, "an amount of 106,205 billion dollars was earmarked for energy research, however, while 67% and 16% of this portfolio were spent on nuclear and fossil energy research respectively, only 8% was allotted to Renewable Energy technologies research" (p.24).

Examples of renewable energy technologies include solar, wind, and geothermal systems. Other sources of renewable energy include biomass, hydropower, and to some extent garbage. The World Council for Renewable Energy (WCRE) (2004) defines renewable energy as "solar, wind, hydro, oceanic, geothermal, biomass, and other sources of energy that are derived from the "sun energy", and are thus renewed indefinitely as a course of nature. Forms of useable energy include electricity, hydrogen, fuels, thermal energy and mechanical force. More broadly speaking, renewable energy is derived from non-fossil and non-nuclear sources in ways that can be replenished, are sustainable and have no harmful side effects" *(*2004:12*)*.

By virtue of their inexhaustibility, substantial resource base and cleanliness, renewable energy technologies have been promoted as the sources of energy to change the world energy paradigm from atomic/fossil energy to renewable energy in the 21st century. There is a broad range of literature (Johansson et al, 1993; WEC, 2000; IEA, 1995; Karekezi and Ranja, 1997; Painuly, 2001; Mozaharul *et al*, 2003; WCRE, 2004) which discusses the range of renewable energy technologies; the various theoretical constructs as well as their current application.

Arguments based on the physical potential of renewable energies indicate their high availability (20,000 times that of the daily consumption of atomic and fossil energy) and their adequacy to meet all energy needs for the world population. Authors such as Johansson *et al* (1993) for example, argue for the world's ubiquitous energy resources of renewable energy on the grounds of their technological potential. Also noted are such factors as climate and organisational conditions (including available amounts of water, wind, biomass, structure of urban development and land use) as constraints in the drive to realise this potential. On a continental level, Karekezi and Ranja (1997) also point to the abundant wealth of Africa's physical renewable energy resources base including "more than 3,140Twh of exploitable technical hydro-power potential, more than 9,000 megawatts of geothermal potential, abundant biomass potential, substantial solar potential and …wind potential" (p.1). Also at the country level in the world, there is literature that indicates the sufficiency of renewables to satisfy these countries energy needs. Bangladesh has been cited as an example. According to

Mozaharul *et al* (2003) "the total annual solar radiation falling on Bangladesh is equivalent to 1010 x 10^{18} joules (J), 0.1% of which can meet the total annual energy requirement of Bangladesh" (p.89).

Writing with the same cornucopian view, the WCRE (2004) not only points to the vast physical availabilities of renewable energy, but also its economic and technological potential. Research supports this view: "many scientific studies over the past several decades have documented the technical possibility of a complete energy supply using renewable energy on local, national and global levels" (WCRE, 2004:24). Furthermore, it sees the negative views of RETs' economic potential as flawed, because they do not take externalities into account: "Social and environmental costs of conventional energy consumption, such as the costs of climate change, health damages, and military costs, are not reflected in the market price, but are covered by public tax money and hidden subsidies" (WCRE, 2004:25).

However, these views consider the potential of renewable energy technologies' based on their resource availability alone, without considering their failures (especially PV) in certain parts of the world as a result of other conditions. It should be noted that the viability of any technology cannot be assessed purely on the basis of the physical resource base. The real potential of renewables, especially PV technology, depends on a range of economic, technical, institutional and socio-cultural factors.

The actual contribution of RETs to global energy supply is poor considering the technical, technological and physical potentials which these glowing accounts suggest. Current data shows that a large fraction of the existing electricity supply from renewables comes from hydroelectric schemes that were established many years ago, leaving a small role for the new renewables. In 1990, 2,900TWh of electricity were derived from renewable energy sources – 24 percent of the world's total electricity supply (IEA, 1995). In 1993, renewables supplied about 18 percent of global electricity demand, assuming traditional uses of biomass are added (WEC, 2000). Recent statistics from Painuly (2001) suggest that renewables supply 15-20 percent of total world energy demand. Differences, however, exist regarding the relative contributions that these new renewables make towards the energy supply needs of developing countries, for example PV (see Figure 1.1).

Several world bodies, such as IEA, WEC, and UN suggest that the use of renewable energy technologies will increase if environmental constraints are placed on CO_2 emission (as well as setting renewable use targets). Some examples of proposed renewable energy target scenarios include:

1. International Energy Agency: 7.5-8.5 percent annual growth in the commercial use of energy from 'new' renewables to 2010;

2. World Energy Council:

Business as usual scenario: growth from 18 to 21 percent of world needs by 2020

Ecologically driven scenario: growth from 18 to 30% of world needs by 2020;

3. United Nations: growth to 30 percent of world needs met by renewables by 2025 and 45 percent by 2050 (IEA, 1997, cited in Painuly, 2001).

In addition, WREC (2004) views pricing and taxing reform for ecological sustainability as a means of accelerating the use of renewables. Pricing and taxing reform are advocated because "…this will make it more expensive to use non-renewable energy, mineral raw materials and environmentally harmful chemical stock than more benign renewable supplies" (WREC, 2004:39).

These scenarios pose many questions; where should non-renewable energy be made more expensive to encourage renewable sources? Can the rural poor of the developing world leapfrog these non-renewable energies when their basic needs are not met and at what cost? Who will benefit and who will pay? How should policy be framed? Moreover, which RET would be most appropriate in what circumstances? As indicated in chapter one, conventional wisdom perceives solar PV technology as the most attractive renewable energy option for rural Sub-Sahara Africa, because of the ubiquity of solar radiation as well as the dispersed nature of its households. Consequently, solar PV technology is the focus in the next section.

2.3.1 Solar Photovoltaic Technology (PV)

The word photovoltaic or in its abbreviated form PV, is derived from *photo* – denoting light and *voltaic*, meaning electrical current or electricity. Consequently, photovoltaic energy refers to the electrical current or electricity which is obtained from the light of the sun through the utilisation of photovoltaic/solar cells. According to Harmon (2000) “the photovoltaic effect is enacted when sunlight, comprised of positively charged photons, is absorbed by the solar cell, transferring energy to the electrons that become part of a current in an electrical circuit” (p.2). Two main subsystems of hardware (modules and Balance-of-Systems) form a PV system. Modules accommodate an array of solar cells that deliver direct current (dc) power; and Balance-of-system (BOS) include power-related hardware, such as inverters, batteries, and charge controllers, as well as area-related costs, such as wiring and interconnections, installations, and site preparation (ibid). There are two broad types of PV technologies - crystalline and thin-film. The former includes panels built from both mono-and poly crystalline cells, while the latter include a wide range of different deposition technologies (Duke *et al*, 2002).

2.3.1.1 History of Solar PV Technology Development

Photovoltaic energy history takes us back over 150 years when, in the 1830s[2], the physicist Edmund Becquerel discovered that certain materials would produce electricity when exposed to light. Even though his observations were very intriguing, the inability to put these observations into practice at that time prevented his efforts to develop a working model. The most important impact of Becquerel's work, however, is that it laid the foundation for research into photovoltaic energy. In consequence, four decades later, in 1873 Willoughby Smith, reported his observation of the light sensitivity of the element selenium. This was followed by Charles Fritz's production of a solar cell with 1-2 percent conversion efficiency in 1883. Though the invention brought great joy, it was short-lived because it could not be used in industries and on a commercial basis.

However, progress in quantum theory in the early part of the 20th century led to the development of photovoltaics. In the words of Green (2000) "solar cells have their origins from some of the most important scientific developments of the 20th century, combining the Nobel Prize winning work of several of the most important scientists of that century" (p.989). The postulation by Mark Planck in 1900 about the nature of light emitted by hot bodies, such as sun, and Albert Einstein's postulation in 1905 that, light was made of small 'particles' called photons marked the dawn of quantum mechanics formulation and development. The beginning of quantum theory stimulated scientists' interest in understanding the physics of photovoltaic systems. Therefore, more scientific research was conducted after the work of Planck and Einstein.

[2] Even though Becquerel discovery took place in the 1830s, the exact year has been subjected to different interpretations in the literature. Some point to 1838, while others point to 1839.

Important scientific breakthroughs in the development of photovoltaic systems included: Edwin Schrödinger's work in 1926 about wave equation; Wilson's proposal of quantum theory of solids in 1930; the work of Mott and Schottky in the development of the theory of solid-state rectifier in 1940; and the creation of the first silicon-based solar cell in the 1940s by Russel Ohl[3]. Others include the work of Bardeen, Brattain and Shockley, who invented the transistor in 1949; and the improvement of the electricity conduction efficiency of silicon to 4.5 percent in 1954, by the working group of Daryl Chapin, Calvin Fuller and Gerald Pearson. The 1954 innovation stirred up research once again, and within seven years, efficiency figures of silicon had jumped to 14 percent.[4] Despite this technical progress in photovoltaic silicon solar cells development, commercially, success could not be achieved because of price. At the time, a one-watt cell cost almost $300 per watt in 1956 while a commercial power plant costs 50 cents a watt to build (Perlin, 2002). This caused demand for the product to stagnate.

In 1958, the first long-term practical application of PV cells in satellite systems took effect. The orbiting satellite system, Vanguard I, was launched, being powered by PV cells. Photovoltaic utilisation in space programmes gained ground in the 1960 and early 1970s but at high cost. From space flight, size, efficiency and durability of the cells were more important than cost, but on the ground, the use of these high costs constrained growth. The economics of photovoltaics changed in the early 1970s, with the development of a cheaper PV by Dr. Elliot Berman, through using poorer quality silicon and packaging the cells with cheaper materials (Perlin, 2002).

[3] Russel Ohl found the first silicon cell by accident when he shone a flashlight on a pure rod of silicon (Riordan and Hoddeson 1997)
[4] See http://stage.itp.tsoa.nyu.edu/~pr442/solar/pv_history.html (Accessed: 13/04/04).

2.3.1.2 Costs of Solar PV Technology

For cost purposes, a PV module is measured in dollars-per-peak-watt ($\$/W_p$); where "peak watt" ($W_p$) denotes the power of full sunlight at sea level on a clear day, representing the power generated at 1000 W/m^2 of sunlight at 25 ^{0}C (Harmon, 2000:6; Acker and Kammen, 1996:87). However, photovoltaic system costs encompass both the module and Balance of System (BOS). Typical systems range from 50 watt (W) to 1 kilowatt (kW) for stand alone systems with battery storage and small water pumping systems, from 500W to 5kW for roof-top grid connected systems and larger water pumping systems; and from 10 kW to megawatts for grid-connected ground-based systems and larger building-integrated systems. At present, there are between 400,000 and 800,000 photovoltaic systems installed across the globe, with a combined capacity of approximately 1,200 MW (UNEP, 2004). Module costs typically represent only 40-60 percent of total PV system costs, with the remainder for the BOS (Lenardic, 2004).

The historical decline in PV costs has been widely noted by Oliver and Jackson 1999; Harmon 2000; Payne *et al*, 2001; Perlin, 2002; Erickson and Chapman, 1995; Kammen[5], 1996; and Balint, 2004, who all consider that cost reductions will continue in the PV industry and propel demand. Oliver and Jackson (1999) for instance, acknowledge the declining cost of PV and point to the creation of larger markets as a result: "…prices have dropped from hundreds of dollars per watt in the early 1970s to ten dollars per watt in the early 1980s and to less than 5 dollars per watt in the early 1990s" (Oliver and Jackson, 1999:372). They postulate that if demand for PVs continues to grow at the 1997 rate of 40 percent per annum, the annual market will

[5] Kammen (1996) indicates that, the delivered PV costs have gone down to as low as \$4-5W_p and \$0.25/kWh.

reach 9525 MWp by 2010 (ibid). Such optimism should be tempered by the chequered history of PV market growth rates. For instance, PV market growth rates ranged between 18-27 percent in the late 1980s, slumped to 5 percent in the early 1990s, and grew by 40 percent in 1997. On the whole, the average growth rate of PV market has been about 21 percent between the middle of the 1980s and the late 1990s (Oliver and Jackson, 1999). Despite the decline in costs, it is questionable whether the rural poor in the developing world can afford this technology. For instance, at present over 70 percent of PV production is sold in the North; increasingly for subsidized PV rooftops in Germany, Japan and California (Hankins, 2001). Lower cost needs to be accompanied by other equally important policy measures from the governments, donor agencies, utility companies, such as maintenance arrangements, payment, if take-up rates in the developing world are ever to rise.

Harmon (2000) argues that cost reductions in PVs are linked to either a decrease in manufacturing cost or an improvement in module efficiency. Before commercialisation, laboratory-based PV modules cost $\$90/W_p$, but with the advent of commercial manufacture of solar cells in 1976, crystalline silicon PV module prices declined from $\$51W_p$ to $\$3.50/W_P$ by 1998 (Harmon, 2000). While Harmon places the annual PV market growth since 1983 to be in the range of 15-16 percent, he does, however, expresses some reservations about the long-term future market for photovoltaic technology. "The market for PV technology in the long-term is uncertain, though it is reasonable to presume that it will not diverge radically from its past annual growth rate of 15% in the next decade" (Harmon, 2000:5). Variations in total PV system costs have also been noted. In 1996 for example, installed costs in Western Europe, North America and Japan ranged from "approximately $\$14/W_p$ to $\$27.60/W_p$ for off-grid PV systems between 100-500 peak watts. And for 1-4 KW_p

off-grid systems, costs ranged from $10/$W_p$ to $15/$W_p$" (Harmon, 2000:6). In other parts of the world, especially the developing world, installation cost was more expensive. For example, a survey of Solar Home Systems (SHS) in 1996 showed an average cost of $37/W in the Gambia (Kammen, 1996).

Similarly, while Erickson and Chapman (1995) agree that costs of PV systems have declined, they see some aspects of cost analysis to be incomplete and wrong. Factory prices of PV as low as 30¢ to35¢ per kWh have been contested, because these exclude "dealer markups, import tariffs, and BOS costs that can triple the initial capital outlay" (Erickson and Chapman, 1995:1131). Additionally, many system efficiency losses are not accounted for in cost estimates, which at times, add 20 percent to the final cost (ibid). For practical application, the PV module costs a small proportion of the total. For example, the cost of KL 15-Lighting Kit[6] (15 watts solar module, K10 charge controller, 10 watts solar lights, 35 Ah leisure batteries, accessories) in Kenya is $324. The installation cost is not included, meaning the actual cost is much more than $324. Also, UNEP (2004) points out that solar home systems to power lights and small electrical gadgets for rural villages in the developing world can be bought for a small sum of $350.

Nevertheless, Balint (2004) argues that the prices of PV technology have gone down to such an extent that they are now affordable for a large proportion of poor households in the developing world. According to Balint (2004) "over the past 10 years…the cost of solar panels has fallen 50 percent, from approximately $6/W in the

[6] This kit is the smallest of all the PV kits at Kenital Solar Company in Kenya. It provides 6-10 hours light, and can operate small black and white TV.

early 1990s to about $3/W in 2002" (p.3). Forty watt systems cost about $300 in many areas and eighty watt systems sell for approximately $600 (ibid).

The cost figures for PV quoted by Balint (2004) and UNEP (2004) can be challenged as being small and affordable by poor rural household in the developing world. They represent only the costs of panels and do not include installation costs. Besides, they have underestimated how much $300 to $600 is to a poor rural farmer. All of these cast doubt on the applicability of PV in poor rural household in the developing world.

For many poor rural households in sub-Saharan Africa, $350 is a very substantial amount of money. This amount will be enough to uplift the livelihood of many poor rural households on a number of issues compared with using the entire amount to buy PV (Table 2.3).

Table 2.3 Comparative costs of solar panels and other energy devices

Costs of various Solar PV Panels in Kenya in 2001	
SIZES OF PANELS	*COST OF PANEL ONLY (IN US$)*
40W	210
50W	261
60W	350
110W	529
120W	580
COMPARATIVE COSTS	
Improved Firewood Stove	2
Kerosene Stove	5
Solar Dryer	10
300Wmicro-hydropower Generator	30
Manual Grinder	56
Manual Water Pump	63
Animal-Drawn Cart	70
Animal-Drawn Plough	100
Sewing Machine	115

Source: AFREPREN, 2001; Karekezi and Kithyoma, 2002.

It is evident from Table 2.3 that the cost of one 60W PV panel ($350) is equivalent to a 300W micro-hydropower generator, an animal-drawn cart, an animal-drawn plough, a sewing machine, a kerosene stove, a solar dryer, and an improved firewood stove, all together. These alternative devices can enhance living conditions (preservation of crops, generation of income, improved farming tools and improved crops yield) much more than the more meagre lighting benefits from 60w PV panel. Alternative investments are considered by Karekezi and Kithyoma (2002): "In Kenya, the typical cost of a PV system can purchase up to 3 cows, which can transform the lives of typical rural family. Alternatively, the household may prefer to purchase 4-5 bicycles (more if procured on the second hand market), which can be leased out and provide the family with a steady stream of income" (p.1076).

Nevertheless, the cost trends of PV over the years have led others such as Harmon (2000), Oliver and Jackson (1999), UNEP (2004) to conclude that the technology is still in an early stage of its development/experience curve. According to Harmon (2000) an "experience curve is a tool used to describe past - and future - cost trends. Experience curves are based upon phenomena observed within many industries that production costs decline with experience of production" (p.8). To all intents and purposes, the theory looks at how unit costs decline with cumulative production. According to UNEP (2004) since 1975 PV costs have fallen by 20 percent for each doubling of cumulative sales. This gives a "learning rate"[7] of 20 percent. Harmon (2000) argues similarly. Based on an extrapolated historical PV module costs data from 1968 to 1998, Harmon (2000) concludes that "between 1968 and 1998, PV module costs declined by an average rate of 20.2 percent each time the total cumulative installed capacity doubled (for a total of greater than thirteen doublings)"

[7] Learning rate is the cost reduction each time the cumulative experience is doubled

(p.12). Thus, within this period the resultant overall learning rate for PV modules stands at 20.2 percent. The general view is that the costs of PV energy technology will decrease dramatically with an increase in market and an increase in module efficiency.

In general, the historical development of photovoltaic energy technology benefited from inputs from a variety of sources. The beginning of quantum theory brought a landmark success to the development of this energy technology, with its first application in the Vanguard 1, in 1958. Even though the average cost since the commercialisation of the technology has declined, there is still a disparity in regional cost. In addition, some costs are incomplete. While the current cost of PV might be affordable for some rural inhabitants in the developing world, for many it is still too expensive. Moreover, the elements of affordability and cost reduction alone are not enough to assure the adoption of the technology by rural people. If postulated future growth rates (in developing countries) are to be achieved, a range of social, cultural, economic, technical and institutional measures are needed. An example of a failed PV project attributable not only to cost, but socio-cultural and technical issues is that of the Casa Blanca project studied by Balint (2004).

Giving an overview of the failures of an NGO project in Casa Blanca in El Salvador, Balint (2004) observes that “the Casa Blanca project did not realise its anticipated benefits, not because the underlying economics were inherently unfavourable, but because social and cultural obstacles were overlooked and other barriers to the establishment of markets were underestimated” (p.7). Rural communities were unable to grasp the technical aspects of PV or it did not appeal to them because they were unsure of its ‘fit’ into their households’ budgets (ibid).

2.3.1.3 The Dynamics of Solar PV Rural Electrification in the Developing World

As the literature indicates, from early on solar PV and other renewable energy systems have been seen as alternatives for the grid extension, as their small modular character makes them particularly suitable for remote and dispersed populations. The early development and diffusion of the technology to the developing world can be traced back to the 1970s. According to van Campen *et al* (2000) "The developments of PV technology for rural electrification can be roughly described in three phases… [the 1970s, 1980s, and the 1990s]" (p.5). In their work, Campen *et al* (2000) outlined the characteristics of these three phases as seen below.

The first phase — the 1970s — has been described as the stage in which PV demonstration projects were undertaken. Most of these demonstration projects were tailored to water pumping, telecommunications and community centres, and as a result of their demonstration character, the focus was often to test technologies, which is out of context with real local needs and conditions (van Campen *et al*, 2000).

Phase two in the 1980s was characterised predominantly by the dissemination of Solar Household Systems (SHS) through grassroots non-governmental organisations (NGOs) and small private dealers as pre-commercial pilot projects (van Campen *et al*, 2000). The Dominican Republic, Sri Lanka, Kenya, and Zimbabwe are examples of countries where NGOs and grassroots private dealers pioneered the sale of SHS in the 1980s.

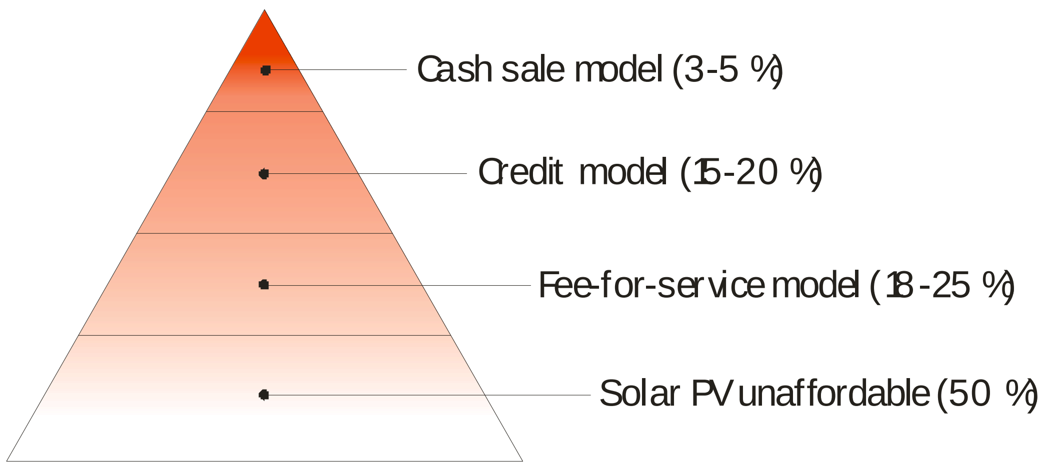
The 1990s, which marked phase three, has been described as the stage of attainment of large scale commercialisation of solar PV. According to van Campen *et al* (2000) "…by the mid-90s various initiatives were launched to scale up [SHS] into large commercialisation programmes and government sponsored programmes" (p.6). The mainstream of international policy in support of solar electrification efforts in the developing world shifted from a focus on centralised donor funded solar PV projects to an emphasis on the development of solar markets in the 1990s (Jacobson, 2004). Countries such as China, India, Sri Lanka, Vietnam, Kenya, Indonesia, Mexico, South Africa, Morocco, and Argentina, all witnessed the initiation of commercial solar PV programmes either by the private sector, the public sector or jointly by both the public and private sector. As of 1996 around 500,000 SHSs had been installed worldwide with an estimated annual installation of at least 80,000 (Village Power, 1997; van Campen *et al,* 2000).

The emergence of commercial solar PV markets in the 1990s brought into sharp focus debates on the appropriateness of the various financing mechanisms or models, which were intended to stimulate wider dissemination, especially in the poor rural areas of the developing world. For instance, the commercialisation of solar PV has brought in its wake high initial up-front costs. Some therefore argue that "greater financial sophistication is needed to enhance [PV] energy service, choice, and access in rural areas" (Barnes *et al*, 1998:2). In addition, others are also of the view that "…PV market demand increases by a factor of ten with the provision of reasonable levels of end-user financing" (Jacobson, 2004:169-170, citing Eckhart *et al,* 2000; Martinot *et al,* 2002; and others). Various financing models have been promoted: the cash sale model; the credit model (which encompasses the dealer credit, the end-user and the lease/hire purchase); the concession model; and the fee-for-service/fee-for-energy model. Drawing from Cabraal *et al* (1996); Barnes *et al* (1998); IEA PVPS Task 9, Report IEA PVPS T9-02 (2003); Banks (2004); and Hankins (2004), these models are described below.

Under the cash sale approaches, the entire solar PV systems or the components are sold through one time cash transactions to end-users, who usually, but not necessarily, do the installations themselves. Barring the diversity in roles being played by stakeholders, the dealer and end-user credit models involve the sale of complete PV systems on a consumer credit or instalment payment system. A down payment is generally required, while the balance of the cost for the system is paid through periodic instalments. The lease/hire purchase arrangement involves a PV Company or an intermediate financial institution, which offers the PV system on a hire-purchase basis. In both lease and hire-purchase models, the lessee pays a regular fee for a limited rental period – (2 or 3 years), at the end of which the ownership of the system is transferred to the lessee. With respect to the concession model, a private company or NGO is selected through a competitive bidding process and given the exclusive right to provide PV electricity services to rural customers in delineated areas. Additionally, in fee-for-service sales arrangements, an Energy Service Company (ESCO) installs the solar PV systems in individual houses and retains full ownership. While the electricity from these systems is then sold to customers for a fee, the ESCO maintains, repairs, and replaces faulty PV systems (See Appendix 3 for diagrammatic representation of these models).

Authors such as Cabraal *et al* (1996), Martinot *et al* (2000), Martinot *et al* (2001), Miller and Hope (2000), who are proponents of the credit, concession and the fee-for-service models, argue that these models are the best for stimulating solar PV sales growth among both the rural elite and the poor in the developing world. They contend that these models make solar PV systems more affordable to the rural poor by spreading the up-front cost or reducing the high initial investment barrier through instalment payments. This attribute is lacking in the cash model and only the few wealthiest in the rural areas can afford to buy solar PV under the cash sales approaches. Figure 2.1 offers a graphic representation of conventional views about cash, credit and fee-for-service financing models. According to Jacobson (2004) "…this figure was developed by Soluz International based on market data and experience in Central America and the Caribbean… [and]…widely regarded in mainstream policy circles to apply broadly to developing country solar market" (p.170).

Figure 2.1 Affordability of solar PV systems by rural people in Latin America



Source: Jacobson, 2004 (Reproduced from Eckhart *et al*, 2003).

While only 3-5 percent (presumably the elite) can afford solar PV systems under the cash sales model, consumer affordability under the credit and fee-for-service models is about three to four times and four to five times respectively. Note that 50 percent of the rural households are still unable to afford solar PV even with the use of credit models and fees-for-service. Some (including Jacobson, 2004), argue that this framework acknowledges explicitly the fact that without the integration of subsidy in these models, the 50 percent of the unelectrified rural households at the bottom can't afford solar PV.

However, protagonists of the cash sales model counter that this model has resulted in the widespread ownership of solar PV systems beyond the rural elite to the rural middle class. They also argue that consumer credit and fee-for-service approaches may not always be the most appropriate model. One strong advocate of the cash sales model is Hankins (2000, 2004), who argues that cash sales of small solar PV systems through a "modular" purchasing pattern (i.e. the purchase of solar PV components over time), has already made solar electricity affordable to a fairly wide segment — 25 percent of the rural population in Kenya and Zimbabwe (Hankins, 2000). In other words, he is of the view that the cash sales model in Kenya has resulted in ownership that goes well beyond the top 3-5 percent of the rural population.

Hankins (2004) criticises the credit and fee-for-service models as not being the most appropriate models for solar market development in all contexts. He argues that "consumer credit is expensive to administer…and maintaining low interest rates and long payback periods can be difficult. Also, consumer financing depends on the existence of a rural finance network, which in many countries simply does not exist. In addition, consumer loans do little to extend the PV market beyond the reach of affluent rural consumers" (Hankins, 2004:16). The fee-for-service arrangement has also been criticised because of high transaction costs, and that efforts to use it in South Africa have required massive subsidies to move things forward (Duke *et al,* 2002; Hankins, 2004). Set against this, Hankins (2004) argues that the cash sales model involves relatively simple transactions as a result of minimal stakeholder involvement. His conclusion is that, in some cases, international donors should assist the development of solar PV cash-based markets rather than the exclusive focus on consumer financing models, such as credits and fee-for-service (Hankins, 2004:20-22).

The diversity of views surrounding the debate on the appropriateness and inappropriateness of these financing models of solar PV in the developing world, give a perspective of the dynamic nature of the development of the technology. Rapid or slow progress may simply be the result of an appropriate – or in appropriate – financing mechanism.

The next section looks at the conceptual framework of this study by reviewing various theories.

2.4 THEORISING TECHNOLOGICAL INNOVATION DIFFUSION

Over the years, the relationship between innovation diffusion, society and technology has attracted much attention, with a diversity of models and theories of innovation diffusion and social construction of technology developed. Four of these models and theories of innovation diffusion, along with two theories of social shaping of technology, are considered here in order to develop the theoretical background for this study. A unifying feature of all these theories is that none of them considers income alone as a factor of innovation adoption.

2.4.1 Theories/Models of Innovation Diffusion and the Social Construction of Technology

Diffusion of innovation concerns the spread of a new technology from its source of invention to its ultimate users or adopters (Strang and Soule, 1998; Surry, 1997; Clark, 1984). Diffusion research has been of paramount interest to social scientists for many years. However, while a lot of work has been carried out on the theory of diffusion, there are still divergent views in the theorisation and understanding of the term. As Surry (1997) notes “the most important fact to consider in discussing diffusion theory is that it is not one, well-defined, unified, and comprehensive theory.

A large number of theories, from a wide variety of disciplines, each focussing on a different element of the innovation process, combine to create a meta-theory of diffusion" (p.2). Early and classical diffusion studies emphasised different conditions.

Tarde (1903) pioneered diffusion research, but it was not until the 1940s (Ryan and Gross, 1943) that a wider interest emerged (Rogers, 1995). According to Rogers (1995) "the Ryan and Gross (1943) study of hybrid seed in Iowa is the most influential diffusion study" (p.31). Other rural sociologists (e.g. Fliegel and Kivlin, 1962) and geographers (e.g. Hagerstrand, 1967; Bowden, 1965, Brown, 1967) have built on Ryan and Gross' work to conduct studies and develop theories related to the diffusion of innovations (Rogers, 1995). All these studies which are either early or classical diffusion emphasised different conditions.

In the early studies of diffusion research, for instance, these conditions are noted: flows of information, the effects of class hierarchy, power and influence, and public opinion (Walsh-Russo, 2004). In addition, early studies of diffusion research also placed emphasis on "compatibility - that is, the goodness of fit between the attributes of a diffusing item and the social and psychological attributes of the potential adopter…" (Katz, 1999:149). The most successful cases of diffusion and adoption occurred when the innovation was most fitted well with pre-existing structural and cultural conditions (ibid). The work of Sorokin (1959) on social and cultural mobility provides an interesting early account of the influence of class hierarchy and power in the diffusion of an idea or thing. Sorokin (1959) observes that, due to the influence of class hierarchy and power, an idea or thing used to spread downwards (vertically descending movement) from the upper class, to the middle and lower classes (pp. 182-184).

However, later classical diffusion researchers including, Rogers and Shoemaker (1971) and Hagerstrand (1967), focused on the roles and interactions between interpersonal relations and the use of tools, for example, radio, for mass communication in the diffusion of an idea or thing (Katz, 1999; Strang and Soule, 1998). To these classical diffusion theorists, the focus on the roles of interpersonal relations in diffusion studies was important because, “interpersonal relations, it was found, act both as custodians of social norms and as networks of information and influence” (Katz, 1999: 146).

Diffusion theories and models reviewed in this work are the cultural lag theory, the threshold model of collective behaviour, the interactive model of innovation diffusion, diffusion of innovations theory, actor-network theory and the theory social construction of technology.

2.4.1.1 The Cultural Lag Theory

The theory of cultural lag, propounded by Ogburn (1964), is one of the classical theories of technological diffusion and adoption. It addresses the time lag between an innovation’s invention, its distribution through society, and the social adjustment that follows (Westrum, 1991:53. Cited in Fisher and Wright, 2001). The theory stipulates that the invention of some technologies is quickly followed by social institutional change, while others do not experience this rapid change.

According to Ogburn (1964) cultural lags exist because “technology moves forward while the social institution lags behind in varying degrees” (1964:133). As he notes “A cultural lag occurs when one of two parts of culture which are correlated changes before or in greater degree than the other part does, thereby causing less adjustment between the two parts that existed previously” (ibid: p.86). In this theory, technology is seen as an independent variable, which is responsible for most social change. As Ogburn (1964) observed “In our times in the western world, technology and science are the great prime movers of social change. That this is so is an almost universal observation” (p.91).

The theory of cultural lag also posits that not all members of a given society change in response to a new technology. Ogburn (1964) identified four stages to the cultural lag theory: technological, industrial, governmental, and social philosophical. When a new technology is introduced, different sectors of society accept and adopt it at different speeds. Industry, according to this theory is always the first sector to adjust to and acquire the technology. This then causes a change in social institution, such as the family or government, which finally causes a change in the social philosophy of the people (Ogburn, 1964:134).

In addition, the theory of cultural lag posits that more examples of cultural lag are found in societies that experience rapid changes than societies where changes occur slowly. Thus, using the current world development parameters, it is claimed that the rapid and slow changing societies are the western and developing worlds, respectively.

Ogburn (1964) illustrated this theory with the lag in the construction of highways for automobile traffic in the 1910s. According to Ogburn (1964) “These two parts of culture [i.e. the highways and automobile] were in good adjustment in, say, 1910, when the automobile was slow and the highways were narrow country roads with curves and bends over which had been laid a hard surface” (p.86). However, with time the automobile underwent many changes, especially the engine, which developed high speeds. While the automobile underwent these changes, there was not a corresponding change in the narrow highways: some automobiles ran off the sharp bends of these highways. According to Ogburn (1964) “The old highways, the dependent variable, are not adapted to the new automobiles, so that there is maladjustment between the highways and the automobile. The adjustment as measured by speeds, was better for local travel around 1910 than it is for long-distance travel on these roads at present” (p.87). This means that while the automobile culture moved forward, the highways culture lagged behind.

A shortcoming of the theory of cultural lag is that it is technologically deterministic (Walsh-Russo, 2004). As indicated above, in this theory technology is seen as an independent variable which always affects culture — the dependent variable. For instance, Ogburn (1964) notes that "in nearly all cases [of cultural lag] the independent variable proved to be a scientific discovery or mechanical invention" (p. 90). However, it is not in all cases that the introduction of a new technology leads to a change in the culture it affects. Therefore, technology is not always the independent variable and culture the dependent variable. For example, there was not a change in the culture of felling trees for the charcoal industry in rural Ghana when the chain saw machine was introduced. While some people adopted it as part of the eclectic mix of tools including axes and cutlasses for the felling of trees, others did not. However, the culture of trees felling did not have to change to suit the chain saw technology.

Notwithstanding its weaknesses, however, the theory of cultural lag has the advantage of clarity and simplicity. Indeed, the theory has been useful for understanding the diffusion of recent communication technologies including, the telephone, television, fax machine and internet. For instance, the application of this theory has aided understanding of the extreme responses to applications such as Napster, an internet-based music sharing software, and other technologies of the internet, in the United States (Fisher and Wright 2001).

2.4.1.2 Threshold Model of Collective Behaviour

Granovetter (1978) proposed the threshold model of technological innovation diffusion, which stresses the significance of individual motivation and of less dense ties over strong ties in the spread of innovative information and practices. His analysis focused on the sound judgement and decision-making of aggregated, individual behaviour. The model assumes that if all individual actors are rational and operate with the same information, the spread of social actions will depend on their thresholds. According to Granovetter (1978) "The threshold is simply that point where the perceived benefits to an individual of doing the thing in question … exceed the perceived costs …" (p.1422). A person's threshold for joining a riot, for example, is the proportion of the group he would have to see join before he/she would do (ibid). The model asserts that an actor makes decisions on the basis of not only the influence of pre-existing norms, but also on the interdependence of decision-making by others.

The theory emphasises the importance of networks[8] — weak ties and strong ties in the spread of information about an innovation. Granovetter (1978) refers to weak ties as individuals' acquaintances and strong ties as individuals' close friends. Accordingly, our acquaintances (weak ties) are less likely to be socially involved with one another than are our close friends (strong ties). Consequently, Granovetter (1983) notes that "… the set of people made up of any individual and his or her acquaintances comprises a low-density network whereas the set consisting of the same individual

[8] Networks are formed through the interaction of actors, including people, group of people and organisations

and his or her close friends will be densely knit (many of the possible lines are present)" (pp. 201-202).

Granovetter (1983) illustrated the overall social structural picture of this theory by considering the situation of, for example, a particular individual. He observes that such an individual will have a collection of close friends, most of whom are in touch with one another, thereby forming a densely knit cluster of social networks. In addition, the individual will have a number of acquaintances, few of whom know one another. Each of these acquaintances, however, is likely to have close friends in his/her own right and therefore to be enmeshed in a closely knit cluster of social networks of their own, though different from the first individual. Granovetter (1983) argues that "the weak tie between that individual and his/her acquaintance, therefore, becomes not merely a trivial acquaintance tie but rather a crucial bridge between the two densely knit clumps of close friends (strong ties)" (p.202).

Following from this illustration, the model asserts that individuals with few weak ties will lack information from distant parts of the social system and will be limited only to the views of their close friends (strong ties), without getting to know information on latest innovations (Granovetter, 1983). This is because, close friends (strong ties) may reaffirm a particular clique's cohesion, leaving unopened the space for the spread and sharing of innovations or coalition formation with other ties and networks.

One major shortcoming of this theory is its over-emphasis of the strength of weak ties in diffusing an innovation. According to Granovetter (1973) "whatever is to be diffused can reach a larger number of people, and traverse a greater social distance, when passed through weak ties rather than strong" (p.1366). This is, however, not true for whatever is to be diffused. The influence of media (radio, television, newspapers) and other communication technologies such as the Internet are equally important and faster in spreading innovation information to a large number of people.

Another criticism of this theory is that the adoption of an innovation does not necessarily always depend on an individual threshold as it stipulates, but also on other factors such as individual needs, affordability, and social status.

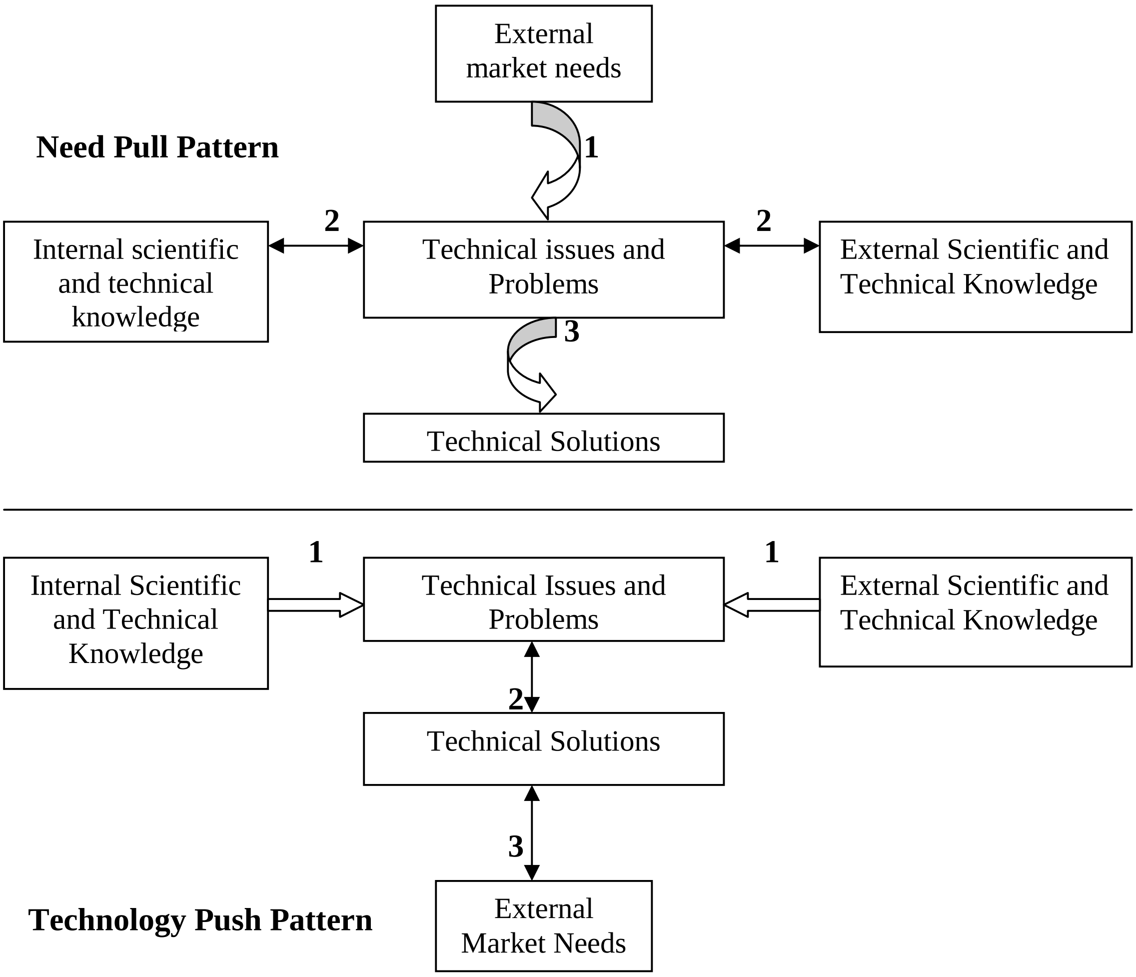
This theory is, however, useful in understanding how social networks and oral forms of communication channels act in the diffusion of an innovation to localities that are untouched by the media. In particular, it helps in understanding the decision-making process (the thresholds) of some individuals, prior to adopting a particular innovation. These include individuals who doubt the efficiency or potential of a particular innovation, and usually wait to see the results of its use from others before adopting. The rich and poor, formally educated and non-formally educated also have different thresholds in the process of adopting an innovation.

2.4.1.3The Interactive Model of Innovation Diffusion

The interactive model stresses both technology-linking and needs-linking to ensure the successful diffusion of an innovation (Burgelman and Sayles, 1986; Baskerville and Pries-Heje, 2001). It conceives innovation diffusion as a complex activity that takes place through interactions amongst a group of actors and institutions involved and affected (Williams and Edge, 1996). The non-linear push-pull model of Burgelman and Sayles (1986) is an organizational example (Figure 2.2).

From the top of Figure 2.2, it is seen that the need-pull pattern begins when external market needs are related to technical issues and problems. From there, scientific and technical knowledge come into play, in the search for technical solutions. In the end, the solutions are put into the market and the needs are catered for. However, due to the relatively minor potential of most easily identified needs and the characteristic absence of serious champions, the need-pull model is not sufficient to bring about the successful diffusion of an innovation (Burgelman and Sayles, 1986). The linear attribute of the model also presents a false sense of orderliness or a rational path of an innovation diffusion process. This is because in the real world, the diffusion process is less orderly or direct, but more circuitous.

Figure 2.2 The flow of activities in the interactive model



Source: Burgelman and Sayles, 1986; Baskerville and Pries-Heje, 2001.

Looking at the lower half of Figure 2.2, the technology-push pattern begins when internal and external scientific and technical knowledge are associated with technical issues and problems which are unsolved. Once solutions are found, the organisation searches for external market needs that could be fulfilled by the solutions. Again, on its own, the technology-push pattern/model is not adequate to bring about the successful spread of an innovation. This is because on its own, the "pattern lacks interest from prospective users and elevates a particular technical solution to a degree that eclipses alternatives" (Baskerville and Pries-Heje, 2001:252). Similarly, the linear attribute of this model also presents a false sense of orderliness or a rational path of an innovation diffusion process.

The limitations of these two linear models (technology-push and the need-pull) have led to the formulation of the interactive model (push-pull model). As indicated above, this interactive model stresses the link between the two linear models. While the market needs drive the technology, the technology in turn "enables a market strategy…market and technology strategies are interdependent and need to be developed concurrently" (Lucas,1994:256).

A major limitation of the interactive model is that a weakness in either pattern, technology-push or need-pull, will stymie the diffusion of a particular innovation. This is because the successful diffusion of an innovation, according to this model, depends on the active interaction of both patterns.

This theory, however, could help to understand the influence of technology-linking and needs-linking in innovation diffusion. Particularly, it could help improve our understanding of the needs prioritisation of rural people in Ghana in a bid to determine whether there is a 'need-pull' for solar PV, a technology 'push' or both.

2.4.1.4 Rogers' Diffusion of Innovations Theory

Rogers' diffusion of innovations model looks at the way innovations are taken up in a population (Rogers, 1995). According to Rogers (1995) "Diffusion is a special type of communication concerned with the spread of messages that are perceived as new ideas" (p.5). Though interacting factors influence innovation diffusion, Rogers maintains that four elements are crucial. These are the innovation itself, communication channels, time, and the nature of the social system into which the innovation is being introduced. Thus in Rogers' view, diffusion research in its simplest form investigates how these four factors combine to mediate the adoption of a specific product or practice among members of a particular adopter group.

2.4.1.4a Innovation

Innovation is the lynchpin of Rogers' (1995) theory. According to Rogers (1995) "innovation is an idea, practice, or object that is perceived as new by an individual or other unit of adoption" (p.11). Citing Rogers and Shoemaker (1971), Brown (1981) also refers to an innovation as "…an idea, practice, or object perceived as new by an individual" (p. 2).

The rate at which an innovation is adopted or fails, hinges on the attributes of the innovation and the potential adopters' opinions. According to Hahn and Schoch (1997) "…the diffusion of … innovations suggest that acceptance or adoption is significantly influenced by innovation characteristics and adopter perceptions" (p.1). In general, the innovation diffusion theory proposes five attributes of innovations that shape adoption or rejection: relative advantage, compatibility, complexity, trialability and observability.

For relative advantage, the theory indicates that an innovation will be adopted if it surpasses existing practices. Thus, a cost-benefit analysis is made to determine the merits (e.g. economic profitability, social prestige, or other benefits) of the innovation over existing practices. If superior, the innovation is adopted. For instance, some technologies are adopted because they demonstrate economic advantage over the existing practice, while other technologies are adopted because of social prestige.

However, according to the theory, economic benefits and social prestige alone may not necessarily lead to adoption. The innovation must also be compatible with the adopters' existing values, culture, past experiences and needs. Supporting Rogers' views about compatibility, Brown (1981) notes that "…the ease with which a given innovation will diffuse through a population depends upon its congruence with …personal characteristics and social norms associated with that population" (p.264). The emphasis on the need for an innovation's compatibility with social groups' existing habits, principles, cultural norms, before it is adopted, indicates the diversity in the felt needs of different societies. It follows, then, that irrespective of the great qualities of any innovation, its adoption or rejection are dependent on its compatibility with the cultural and social norms of the societies it is introduced to.

The perceived difficulty of learning to use and understand an innovation system or technology (i.e. complexity attribute) will also determine willingness to adopt. A question like 'is this innovation difficult to use' is often asked. If an innovation is perceived as being difficult to understand, learn and use, it will probably not be adopted or adoption will be very slow.

Trialability is also important in determining the extent of an individual's willingness to adopt or reject an innovation. According to Sonnenwald *et al* (2001) "trialability refers to the ease of experimenting with an innovation" (p.2). Most potential adopters want to test the innovation before adopting: "an innovation that is trialable represents less uncertainty to the individual who is considering it for adoption…" (Rogers, 1995:16).

Finally, observability refers to the degree to which the results of an innovation are easily seen and understood (Rogers, 1995, Sonnenwald *et al*, 2001). Observability is instrumental in building confidence in a potential adopter. More often than not, individuals' trust in anything stems from visualising its positive outcomes. The view of Rogers (1995) is that "such visibility stimulates peer discussion of a new idea, as friends and neighbours of an adopter often request innovation-evaluation information about it" (p.16).

These attributes (relative advantage, compatibility, complexity, trialability and observability) as others observe, form the basis for determining the likelihood of adoption (Brown, 1968; Brown, 1981; Garland, 1991). Brown's (1968) opinion is that "culture, social, political and economic or cost space …must be considered as forming a terrain which affects…diffusion pattern" (p.27). In addition, Brown (1981) observes "…a given innovation is not adopted in isolation of one's social, economic, locational and institutional context…" (p. 239). Garland (1991) on the other hand stresses that "major barriers to be considered in diffusion and adoption of innovation are people issues, including cultural traditions, risk aversion, lack of knowledge and user acceptance” (p.283).

2.4.1.4b Communication Channels

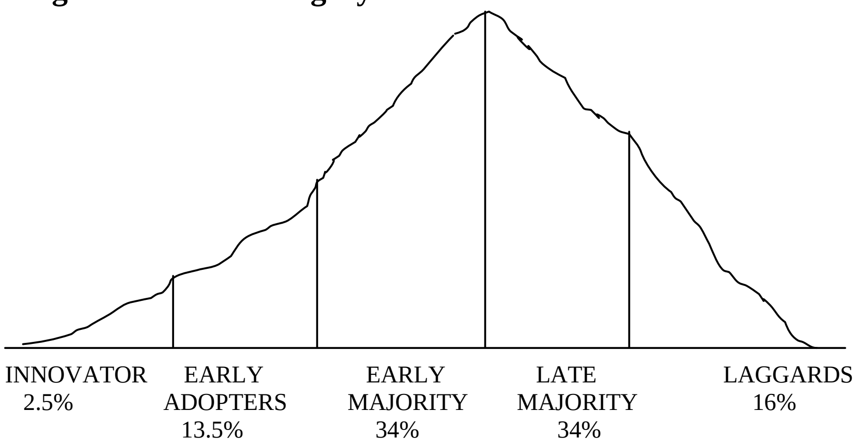
Another element within Rogers’ (1995) innovation diffusion theory is the communication channel, the means by which messages travel from one individual to another. In fact, diffusion itself is a form of communication wherein the spread of a message concerns something new. Hagerstrand (1967) argues that the spread of innovation is primarily the outcome of a learning or communication process. Indeed, communication will create the awareness of an innovation to the potential adopter, helping him/her to form a kind of attitude that will eventually determine the decision to adopt or reject.

According to Rogers (1995) “mass media channels are often the most rapid and efficient means to inform an audience of potential adopters about the existence of an innovation” (p.18). Personal communication (face-to-face) is also important and tends to be more effective in transmitting information and changing attitudes (Howard, 1969, Coleman, *et al*, 1957).

2.4.1.4c Time

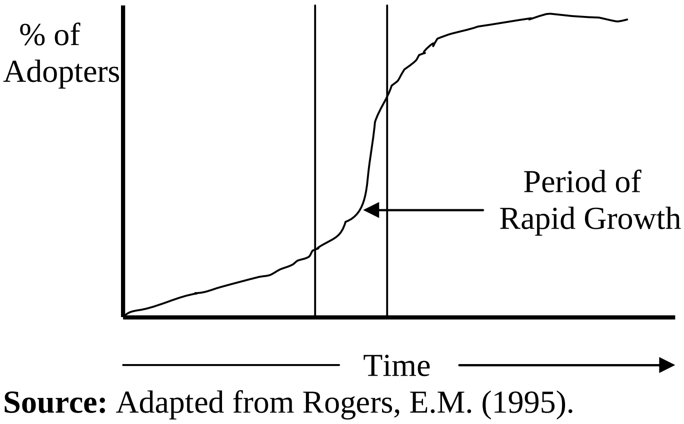
Time, the third general area Rogers (1995) suggests, plays a critical role in any technological progress because it defines both the pace at which progress occurs and the positions individuals occupy amid the evolution of such progress. According to Rogers (1995), individuals who are predisposed to being innovative will adopt an innovation earlier than those who are less predisposed. He suggests five adopter categories of innovation in relation to the rate of adoption[9]: innovators, early adopters, early majority, late majority and laggards. Rogers (1995) uses a bell-shaped curve to illustrate these categories and their respective percentages (Figure 2.3). Rogers (1995) theorised that the spread of innovations in a society through this bell-shaped curve will eventually turn to an S-shaped curve (Figure 2.4). This S-shaped curve is achieved because an innovation goes through a period of slow, gradual growth before experiencing a period of relatively dramatic and rapid growth (Rogers, 1995; Surry, 1997).

Figure 2.3 Bell-shaped curve showing categories of individual innovativeness and percentage within each category.



Source: Adapted from Rogers, E.M. (1995).

Figure 2.4 S-shaped curve representing rate of adoption of an innovation over time



Source: Adapted from Rogers, E.M. (1995).

[9] "The relative speed with which an innovation is adopted by members of social system" (Rogers, 1995:20).

1. Innovators:

Innovators are the first 2.5 percent of the population to adopt a new idea. They are the venturesome types, possibly rash, daring, risk-takers, enjoy being at the cutting edge and with access to substantial financial resources (Rogers, 1995:264). This interest in new ideas leads them out of a local circle of peer networks and into more cosmopolitan social relationships.

2. Early Adopters

As illustrated in Figure 2.3, early adopters are said to comprise around 13.5 percent of the individuals in the system to adopt an innovation. They use the information provided by innovators' implementation and confirmation of the innovation to make their own adoption decisions. If the opinion leaders observe that the innovation has been effective for the innovators, then they will be encouraged to adopt. This group earns respect for its judicious, well-informed decision-making, and thus it is the group in which most opinion leaders in a social system are located (Rogers, 1995).

3. Early Majority

The early majority constitutes around a third of the potential adopting population. According to Rogers (1995) "the early majority interact frequently with their peers, but hardly hold positions of opinion leadership in a system" (p.265). They need solutions with minimum discontinuity. As a result they deliberate for some time before completely accepting an idea.

4. Late Majority

Like the early majority, the late majority comprise around a third of the potential adopting population. In the case of the late majority, adoption of an innovation may be influenced by networks' peer pressure (ibid: 265). They exercise a lot of restraint in the face of any innovation, doubt its value, and do not adopt it until most people in the social system have adopted it. The late majority are characterised by precarious economic conditions, and as a result they only make the move to adopt an innovation once every uncertainty about the innovation is eliminated.

5. Laggards

The last adopters, laggards, can either be very traditional or be isolates in their social system with almost no opinion leadership. If they are traditional, they are suspicious of innovations, change agents and often interact primarily with others who hold traditional values just like them (Rogers, 1995:265). If they are isolates, their lack of social interaction reduces their awareness of an innovation's demonstrated benefits. Laggards also have precarious economic position; hence they must be certain that an innovation will not fail before they can adopt.

2.4.1.4d. The Social System

The fourth main element in Rogers' (1995) diffusion of innovations theory is the social system. "A social system here is defined as a set of interrelated units that are engaged in joint problem-solving to accomplish a common goal" (Rogers, 1995:23). Members of a social system may be made up of individuals, informal groups, organisations, and/or subsystems. The social system constitutes a boundary within which innovation diffuses because, the structure of the social system, the social system's norms, the roles of opinion leaders and change agents all have an influence on the adoption of the new idea.[10]

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[10] "Structure is defined as the patterned arrangements of the units in a system; Norms are the established behaviour patterns for the members of a social system; opinion leadership refers to the degree to which an individual is able to influence informally other individuals' attitudes or overt

One shortcoming of Rogers' (1995) theory of innovations diffusion is that it is very limiting with respect to the factors that influence innovation adoption. While a number of interacting factors can influence the adoption or rejection of a certain innovation, Rogers asserts that only the four elements discussed above are crucial. Rogers (1995) has not taken into account the influences of power, politics and institution in innovation diffusion. In some rural areas in the developing world, for instance, the adoption or rejection of certain innovations hinges on politics, and not because they are compatible or incompatible with the existing socio-cultural values and norms.

Another shortcoming of this theory is that not all innovations will have the five adopter categories — some innovations will have less. An innovation can have only innovator and majority adopters, with probably a few laggards, if such an innovation plays an important role for the well-being of a certain group of people. An example is the introduction of a new vaccine to combat a certain endemic disease.

These criticisms notwithstanding, Rogers' (1995) theory of innovations diffusion is very useful in conceptualising the adoption behaviours of people. For instance, through the application of this theory, Agarwal *et al* (1998) have been able to conceptualise Information Technology innovations, for example, the adoption behaviours of Web registration system at a large university in America. The theory also helped Surry (1997) to unearth the underlying causes of instructional technology's diffusion problems. In addition, in Andersson and Hedman's (2007) work, the theory aided understanding of the different mechanisms that promote and

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behaviour in a desired way with relative frequency; and change agent is an individual who attempts to influence clients' innovation-decisions in a direction that is deemed desirable by a change agency" (Rogers, 1995:27).

inhibit the diffusion of advanced mobile services by business organisations in Sweden. Therefore, this theory could inform certain aspects of this thesis.

2.4.1.5 Theories of Social Shaping of Technology

Theorists of the social shaping of technology (SST) include Bruno Latour (1987, 1991), Michel Callon (1986,1997), Bijker (1995a, 1995b) and Pinch, Bijker and Hughes (1987). Latour (1987) and Callon (1986) are known for the Actor-Network Theory (ANT) while Bijker, Pinch and Hughes are associated with the Social Construction of Technology Theory (SCOT).

2.4.1.5a Actor-Network Theory (ANT)

The aim of Latour (1987, 1991) and Callon's (1986, 1997) actor-network theory (ANT) is to describe a society of humans and non-humans as equal actors tied together into networks built and maintained in order to achieve a particular goal. As Callon (1987) notes "Like networks [actor network] is composed of a series of heterogeneous elements, animate and inanimate, that have been linked to one another for a certain period of time" (p.93).

Central to the actor network theory is the idea of heterogeneous associations/networks, comprising the technical, social, economic, cultural and natural elements, in the success of an activity (Callon, 1986; Latour, 1987). Each of these elements as the theory posits, is considered an important actor in the continual function of the network. Hence, the removal of some actors will cause the network to break down. In other words, the removal or poor functioning of some elements/actors in a particular activity will hinder the success of the activity. For instance, with reference to the EDF's (Electricité de France) engineers proposed project to manufacture an electric car (VEL) in France in the early 1970s, Callon (1986) argued that the success of this project was dependent on the longevity of such heterogeneous elements including, electrons, catalysts, batteries, social movements, industrial firms, consumers, and ministries, which were linked together (Callon, 1986, pp. 92, 93). Meanwhile, the elements in an actor network are not considered perfectly well defined and stable. In the perspective of Callon (1987) "…the entities [an actor network] is composed of, whether natural or social, could at any moment redefine their identity and mutual relationships in some new way and bring new elements into the network" (p.93). The views of the actor-network theory can further be captured in the interpretation below.

Take for example, the riding of a motorcycle by someone; there are a lot of things that influence the way the person rides it. He/she might be influenced by traffic regulations, prior riding experience, state of the road and the motorcycle's manoeuvring abilities. All of these factors are related or connected to how the person acts. The person does not go about riding the motorcycle in a total vacuum, but rather under the influence of a wide range of surrounding factors. In this illustration, the act (the riding of the motorcycle), which the person is carrying out and all of the influencing factors are all considered together in actor-network theory. This underscores the theory's emphasis on the heterogeneous linkages of both technical and non-technical elements in the successful conduction of an activity.

A major criticism of actor network theory is its treatment of human and non-human entities as equivalent in a network. Although the attributes of a non-human element can influence human behaviour, humans and non-humans entities cannot be treated equally, because humans are distinct from non-humans in many ways. For instance, humans have the ability to take decisions, judge things and reflect, unlike non-humans. As Williams-Jones and Graham (2003) observe "…humans have different (superior) moral status from machines or corporations and are thus due special regard" (p.278). For instance, in relation to the riding of the motorcycle example above, sometimes the person can make a conscious decision to over-speed or to move slowly. In which case, his/her riding of the motorcycle is not influenced by the traffic regulations nor the other factors mentioned above.

Despite its shortcomings, ANT is useful for analysing the coupling and interaction between the social and technical components of socio-technical systems. For example, through the application of this theory by Williams-Jones and Graham (2003), there has been an understanding of what is happening in the development of commercial genetic testing. This was achieved through an in-depth study analysis of all the elements in the various complex networks and sub-networks. ANT also provides a base for understanding the reasons behind the successes or failures of technologies and/or social endeavours as the direct result of changes in their network forms. For example, ANT could help improve our understanding of the factors that influence the decisions of individuals in rural Ghana to adopt or reject solar PV.

2.4.1.5b Social Construction of Technology (SCOT) Theory

Pinch and Bijker (1987) and Bijker (1995a, 1995b) as theorists of social construction of technology, examine the development of technologies, defining 'working' or 'non-working' not as intrinsic properties of an *artefact* but as a socially constructed meaning attributed by *relevant social groups*. As Bijker (1995a) points out "One artefact comprises different socially constructed artefacts, some of which may be 'working' while others are 'non-working" (p.75). In their analyses, they used the word ‘artefact’ to refer to technology with a clearly defined user or consumer group on the ground that it is a term that minimizes social and technical distinctions by refusing the language of objects and machines (Oakes, 2000).

In Bijker’s (1995b) version of social construction of technology theory, he notes that artefacts are not only shaped by the power strategies of different groups but also form part of the micro-politics of power themselves, forming part of the plans of differing agencies, and acting to cement existing relations. Central to this theory is that the meaning of a technical artefact does not reside in the technology itself; rather, its shape and meanings are acquired through the heterogeneity of social interactions. As Bijker (1995b) notes “artefacts are…described through the eyes of the members of relevant social groups” (p.252). In other words, social groups, which may or may not be homogenous, define which technological issue or ‘artefact’ is a problem to be addressed (Pinch and Bijker, 1987: 30 and 33-34).

Central to SCOT’s conceptual framework are four concepts: the relevant social groups, interpretative flexibility, closure and stabilisation, and the wider context (Pinch and Bijker, 1987). These concepts are defined as follows.

The concept of *relevant social groups* denotes “institutions and organisations (such as the military or some specific or some specific industrial Company), as well as organised or unorganised groups of individuals …[that] share the same set of meanings, attached to a specific artefact” (Pinch and Bijker, 1987: 30). In SCOT the relevant social groups are considered the agents, and the meanings they attribute to an artefact are traced to their actions. Thus, relevant social groups consist of both consumers/users of a particular artefact and non-users. They may be identified by two approaches: "roll a snowball and follow the actors" (Bijker, 1995:46).

Secondly, the concept of *interpretative flexibilit*y denotes that "different social groups have radically different interpretations of one technological artefact" (Pinch and Bijker, 1987:41). In other words, a technological artefact is culturally constructed and interpreted in society by different social groups. The diverse interpretations which social groups accord an artefact help to unravel the *problems* and *conflicts* they have with respect to this artefact; and how these problems and conflicts are solved.

The third core concept of SCOT is *closure and stabilisation.* They are two aspects of the same process (Bijker, 1995a). It involves the process by which different interpretations (especially conflicts) of an artefact by social groups, lead to its continual design in order to bring about solutions to these conflicts. At a stage, when the design of the artefact no longer poses a problem to any social group, then a closure to its design is achieved as well as the stabilisation of its final form. As Bijker (1995a) notes "Closure leads to a decrease of interpretative flexibility—to one artefact becoming dominant and others ceasing to exist. As part of the same movement, the dominant artefact will develop an increasing degree of stabilisation within one (and possibly more) relevant social groups" (p.87). Pinch and Bijker (1987) identified two closure mechanisms: rhetorical closure and closure by redefinition of the problem (pp.44, 45, 46). With respect to rhetorical closure, a declaration is made that no further problems exist concerning the design of a particular artefact, thereby terminating all additional designs. As the name implies, closure by redefinition of the problem involves redefining unresolved problems to ensure that they no longer pose problems to social groups (ibid. p.46).

The fourth key concept of SCOT is the *wider context.* It refers to the wider socio-political milieu of the development of a technological artefact (Pinch and Bijker, 1987).

SCOT therefore advocates that in order to understand the development of a particular technology, this method should be followed: Firstly, the relevant social groups should be identified and described in more detail. Secondly, we should identify the problems and conflicts (interpretative flexibility) which each social group has with respect to that artefact and find possible solutions to them. Lastly, the stabilisation of the artefact should be examined.

Bijker (1995a) illustrated the analytical strengths of SCOT with reference to the history of bicycle design in Britain from the 1870s. With respect to the high-wheeled Ordinary bicycle or “Penny farthing” (the prototype bicycle in Britain), Bijker identified two relevant social groups: the users and non-users. These distinct relevant social groups therefore constructed the Ordinary bicycle in ways that have meanings (*interpretative flexibility*) for them. The social group of non-users, for instance, described it as an *Unsafe Bicycle:* because it could easily topple over, leading to a hard fall; it was difficult to mount and dismount especially by women, and risky to ride. However, the social group of users described the Ordinary bicycle as *Macho Bicycle.* According to Bijker (1995a) “For …the users of the Ordinary, the machine was also seen as risky, but rather than being considered a problem, this was one of its attractive features. Young and often upper-class men could display their athletic skills and daring by showing off in the London parks” (p.74). Therefore, to the Ordinary users, this machine was “working” whereas the non-users deconstructed it as “non-working”.

The above two different interpretations of the Ordinary bicycle therefore gave rise to *problems* and *conflicts.* One problem was how to make the Ordinary bicycle safe for both genders and a cross-section of ages to ride. There was also a conflict between the users of the Ordinary bicycle and the "anticyclists" social group, who sometimes threw stones and sticks into the wheels of the Ordinary bicycle (Bijker, 1995a:41). To solve the safety problem of the Ordinary bicycle and the conflict it had generated, a range of new designs of bicycles were implemented: the manufacture of the tricycle, moving the saddle of the Ordinary backward, reversing the position of the small and large wheels, adding auxiliaries (the "Non-Header") (Pinch and Bijker, 1987; Bijker, 1995a).

The multi-design process of the Ordinary bicycle continued until the late 1890s when the "safety bicycle" was invented. According to Bijker (1995a) "the "safety bicycle" denoted unambiguously a low-wheeled bicycle with rear chain drive, diamond frame, and air tires" (p.93). The low-wheeled safety bicycle therefore brought closure to the problems and conflicts of the Ordinary bicycle, and stabilised within the relevant social groups of users and non-users of the Ordinary bicycle. For instance, with its invention, a cross-section of social groups in Britain, including, the young and athletic, the lords and ladies, began to use the bicycle without problems (Bijker, 1995a). Especially, "with the low-wheeled safety, the two main problems presented to women by the Ordinary bicycle — indecency and lack of safety, were solved" (Bijker, 1995a:94).

SCOT has been criticised for being more agency-centred in its approach to the neglect of structure (Russell, 1986; Klein and Kleinman, 2002). For instance, with respect to consensus building in the design of a particular technology, SCOT posits that it comes about as a result of the interaction of different relevant social groups (agents). Deriving consensus in this manner therefore neglects the roles and influences of social structural factors, such as economics, politics, power, ideology in the design of a particular technology. As Russell (1986) argues “An explanation of technological change must show not only what different social groups think of an artefact, but also what they are able to do about it — their differing abilities to influence the outcome of its development and adoption” (p.336). These differing abilities include resources of knowledge and power (ibid.).

Another shortcoming of the SCOT lies in its methodological approach of identifying the relevant social groups by “rolling a snowball”. The snowball method involves “… using one contact to help you recruit another contact, who in turn can put you in touch with someone else. Through this, recruiting gains momentum, or ‘snowballs’ as the researcher builds up layers of contact” Valentine (2005:110). However, the problem with this method in SCOT is that some relevant social groups may not be captured in the process, and their absence may not be noticed. The absence of such relevant social groups’ influences, could therefore distort the complete understanding of a particular technological artefact’s development. As Klein and Kleinman (2002) point out, in applying the snowball method “…both the exclusion [of a relevant social group] and the reasons for it would remain hidden, with the concomitant risk that a major factor in technological change would go undetected” (p.32).

Notwithstanding these weaknesses, SCOT is an effective tool for analysing the social shaping of a technology’s development and diffusion processes. It is particularly useful for this study because of its advantages over other theoretical approaches discussed: it offers simple and clear, step-by-step approaches for studying the processes involved in the development and diffusion of a technological innovation, it examines the content of an innovation and the processes involved in its development. SCOT is therefore capable of providing a more complete insight into the study of the dissemination processes of solar PV in rural Ghana. In other words, the features of SCOT fit the main aim of this research, because it helps to examine the social, technical, cultural, institutional, political and economic issues that mediate the up-take and application of photovoltaic energy in rural Ghana.

Using this theory's line of reasoning, for instance, it may be supposed that different *social groups* (poor, rich, youth, farmers, civil servants) within rural parts of Ghana will not hold the same meanings and perceptions (*interpretative flexibility)* for solar PV technology and other types of energy technologies. Thus, solar PV will be defined differently in ways that have meanings for the different social groups. These different interpretations may be underpinned by their different socio-cultural and economic backgrounds. It can therefore be argued that these diverse interpretations will give rise to different patterns of PV adoption and application in rural Ghana. At the international level too, the diverse interpretations could also play part in the disparate rates of PV dissemination in Kenya, Zimbabwe and Ghana.

2.5 CONCLUSION

This chapter has situated the interconnected issues in the adoption process of solar PV in the developing world mainly through reviewing energy literature, especially, rural electrification in the developing world, and renewable energy technologies, to which solar PV belongs. The review reveals that the adoption and application of a particular innovation especially, in the developing world, depends on a number of factors. These revelations therefore bolster the need to research into the current topic for more insight on the dissemination dynamics of solar PV in rural Ghana.

In order to establish a conceptual or theoretical framework that best informs and guides this thesis for the realisation of its main aim, a number of diffusion theories and models have been reviewed and discussed. These include the cultural lag theory, Ogun (1964); the threshold model of collective behaviour, Granovetter (1978); the interactive model of innovation diffusion, Burgelman and Sayles (1986); innovation diffusion theory, Rogers (1995); actor-network theory, Latour and Callon (1991); and social construction of technology theory, Bijker *et al* (1995).

The SCOT framework is particularly useful for bringing understanding to the main focus in this thesis, because of its many advantages. This does not, however, mean that all the other diffusion theories and models discussed above, are not entirely useful to this study. Despite their shortcomings, some of these theories and models such as Rogers' diffusion of innovations theory and interactive model of innovation diffusion have complemented SCOT in parts of this thesis for enhanced understanding of the needs prioritisation of rural people and the behaviours of different adopter groups.

CHAPTER THREE

RESEARCH APPROACH AND METHODOLOGY

3.1 INTRODUCTION

The viability of any technology cannot be assessed purely on the basis of its technical properties or the physical resource base alone. Rather, the resource base of any technology, coupled with a range of other factors, determine its success or failure. In the context of this study, what stands out about the technology of solar PV (for rural areas in developing countries) is the advocacy for its deployment by a wide range of international bodies, environmental organisations and donors. Although sunshine, the natural resource base for solar PV technology (in many developing countries) is virtually unlimited, the literature review (see Chapters 1 and 2) showed that the adoption of this technology has been very poor. Multiple factors could be accounting for this. In order to understand the factors involved in the adoption patterns, a multi-stranded approach is needed.

This chapter discusses the methodological tools that have been employed in this research to gather and analyse data relevant to this issue. In addition, it discusses practical issues concerning the two field programmes in Ghana and Kenya.

3.2 RESEARCH DESIGN AND TECHNIQUES

As indicated in Chapter 1, the broad aim of this study is to examine the socio-technical, cultural, institutional, political and economic issues that affect the up-take and application of photovoltaic energy in rural Ghana. Specifically, the study has five objectives: (1) to examine critically Ghana's energy demand and the potential role of photovoltaic energy in the rural sector; (2) to examine critically Ghana's rural electrification programme; (3) to examine critically the various socio-technical, cultural and economic conditions in rural Ghana, to determine both the scope for PV adoption and the types of energy sources that need emphasis; (4) to explore the main institutional, policy, regulatory frameworks and models available for PV development in Ghana; (5) to examine critically the different implementation strategies of PV in Kenya and Zimbabwe as comparators to Ghana. These overarching objectives provide a framework for the following research questions:

- What are the current patterns and trends in Ghana's energy landscape (sources of energy, energy demand and supply in both rural and urban areas, energy utility companies)?
- Do the current rural electrification programmes in Ghana serve the needs of the rural people, especially PV? Are they supply-pushed or demand-pulled?
- What are the technical, cultural and economic contexts within which adoption or non-adoption of PV takes place?
- What are the appropriate institutional structures, policies, regulatory frameworks and market models that may promote PV development in rural Ghana?
- What are the general characteristics of PV development programs in Kenya, Zimbabwe and Ghana; and what lessons can be learnt?

These questions suggest that a range of empirical data is needed for this research project - both primary[11] and secondary data; and qualitative and quantitative data. The

[11] Primary data represent the information the researcher generates, such as from survey data (for example questionnaires and interviews). By contrast, secondary data or documentary information represents information that has been sifted and sorted from other sources and may be used to supplement other information, for instance, to provide a context or to aid interpretation.

research therefore employed multiple methods found within the qualitative and quantitative approaches to gather the required data. The adoption of a mixed methods approach helped to draw on their respective strengths in providing answers to the research questions and objectives of the study. This emphasises the point that epistemology should inform rather than dictate methodological choices (Philip, 1998).

The use of multiple methods in research projects has been widely supported. For example, pragmatists hold the view that a false dichotomy exists between qualitative and quantitative approaches and as such researchers should make the most efficient use of both methods in understanding social phenomena (Creswell, 1994). Similarly, Robson (1993) points out that "the main advantage of employing multiple methods is … triangulation" (p.290). One other advantage of multiple methods application noted by Robson (1993) is that, instead of focusing on a single, specific question, multiple methods may be used to address different but complementary questions within a research project.

3.3 SOURCES OF DATA AND METHODS OF DATA COLLECTION

The range of methods that were applied in this research were dictated by the research questions. Taken together, these methods included household and business surveys, unstructured interviews, document gathering, direct observation, diary-keeping and informal conversations. Direct observation was used as supportive technique to complement the information from interviews and questionnaire surveys. A camera was used to take relevant pictures and a portable tape recorder to record interviews. According to Valentine (2005) "There are a lot of advantages to using tape recorders rather than trying to make notes. Recording equipment allows the researcher to concentrate on the interview without the pressure of struggling to get the interviewee's words down on paper, and allows the interviewee to engage in a proper conversation with the researcher without trying to pause and talk slowly so that the note-taker can keep up. A tape also produces a more accurate and detailed record of conversation (including capturing all the nuances of sarcasm, humour and so on) than notes, and…has the added advantage that the researcher can listen to the interview again and again and therefore pick up on ideas and inferences which they may have missed…" (p.123). Photographic evidence also helped to provide a visual account and record of things on the ground, which enhanced analysis. Table 3.1 below, gives a detailed summary of the linkages between the research objectives, the research questions and the methods of data collection.

Table 3.1: Summary of the linkages between the research objectives, research questions and methods of data collection

Research Objectives	Research Questions	Methods
To critically examine Ghana's energy demand (rural and urban) and the potential role of photovoltaic in the rural sector	What are the current main patterns and trends in Ghana's energy landscape (i.e. sources of energy, energy demand and supply in both rural and urban areas, energy utility companies)?	-Academic and policy documents on Ghana's energy, census data, and register of small businesses data -Open-ended interviews with key informants at EC-GH, ECG Ltd, and MOE-GH -Rural households questionnaire surveys
To critically examine Ghana's rural electrification programme	Do the current rural electrification programmes in Ghana serve the energy needs of the rural people especially, PV? Is it supply-pushed or demand-pulled?	-Documents and reports -Interviews with energy think-tanks, PV private companies, advocates of PV, schools and hospitals -Rural households and businesses questionnaires
To critically examine the various socio-technical, cultural and economic conditions in rural Ghana, to determine both the scope for PV adoption and the types of energy sources that need emphasis	What are the technical, cultural and economic contexts within which adoption or non-adoption of PV takes place?	-Interview private PV companies -Direct observation of rural communities livelihood -Rural households questionnaires surveys -Informal conversation and interviews with rural people
To explore the main institutional policy, regulatory frameworks and models available to promote photovoltaic development in rural Ghana	What are the appropriate institutional structures, policy, regulatory frameworks, legality/act and market models that will promote PV development in rural Ghana?	-Textual analysis of PV policy documents -Interviews with advocates of PV,energy think-tanks, PV private companies, household questionnaire -Informal conversation &interviews with rural people
To critically examine the different implementation strategies of PV in Kenya and Zimbabwe to compare with the experience of Ghana	What are the general characteristics of PV development programs in Kenya, Zimbabwe and Ghana—what lessons can be learnt?	-Academic literature, policy documents, Internet search, all on PV issues in the three countries -Interviews with PV private companies, EC-GH. -Interviews conducted with PV private companies, energy think-tanks & the energy Ministry in Kenya

3.3.1 Secondary/Documentary Data Sources

The initial academic and policy literature search began in the Brynmor Jones (BJL) and Map Libraries of the University of Hull. The development of the entire research proposal was greatly facilitated by both the electronic and textual database of these libraries. Furthermore, literature searches concerning Kenya and Ghana were carried out while conducting fieldworks in the two countries. Table 3.2, outlines the specific documents that were gathered, the stakeholders from whom these documents were derived, and the research questions they addressed.

Table 3.2: Stakeholders, documents gathered and research questions relationship

Stakeholders	Documents Gathered From Stakeholders	Research Questions, which they Addressed
1. Ghana Ministry[12] of Energy (MOE-GH)	-Annual Reports on Ghana energy consumption pattern -Ghana energy sector development programme's document -National Energy Plan Project' document -Energy and socio-economic survey documents of Ghana	**1**
2. Ghana Ministry of Energy (MOE-GH), Energy Commission of Ghana (EC-GH), Volta River Authority (VRA), Kenya Ministry of Energy (MOE-Kenya)	-Rural Electrification policy documents -Annual Reports of rural electrification implementation programme -National renewable energy technologies policy and implementation documents -Documents of GEF sponsored PV pilot project in Ghana -Map of villages, which were selected for GEF PV pilot project	**2**
3.University of Ghana's Library, District Assemblies, VRA Library, ISSER Library-Ghana	-Academic literature and reports on the socio-cultural background of rural population, and their sources of livelihood	**3**
4. Ghana Ministry of Energy (MOE-GH), Energy Commission of Ghana	-Documents of the Institutional structures and regulatory frameworks on PV in Ghana -Documents of the market models on PV in Ghana	**4**
5.Energy Commission of Ghana, Kenya Ministry of Energy, AFREPREN/FWD,	-Documents of PV deployment, utilisation and acceptance in Ghana -Documents of market models on PV in Ghana -Reports on Kenya's PV energy -AFREPREN/FWD research literature on Kenya and Zimbabwe's PV industry	**5**

3.3.2 Primary/Raw Data Sources

Primary data were gathered through two phases of fieldwork. The first stage of the fieldwork was conducted in Kenya, in 2004, the second stage in Ghana, between May

[12] See section 3.14 about the total number of ministries that were interviewed, why specific organisations were chosen and the success rate rates in each category of interviewees.

and September, 2005. While the fieldwork in Ghana employed both quantitative and qualitative approaches to gather primary data, only qualitative methods were used in Kenya.

Mainly, raw data were gathered through informal interviews, formal standardised questionnaires, informal conversations, diary-keeping and direct observations in Ghana as indicated above. However, there was a bias in favour of formal standardised questionnaires compared to informal interviews and observations. The reason behind the use of large-scale standardised formal questionnaire surveys is that by asking respondents the same questions under controlled conditions, comparisons are possible and observer-induced bias is minimised considerably (Hooko, 1999 citing Sayer, 1992). Nonetheless, extreme standardisation, which does not take into consideration the differences in the types of respondents and the contexts that are causally relevant to them, may produce data that make comparisons not very meaningful (Hooko, 1999). This situation may occur because the research loses sight of the fact that the same question can have different significance for different actors. This shortcoming, however, was addressed in this research, when the formal standardised questionnaires were constructed – different questions were formulated for different respondents based on the contexts relevant to them (See Appendix 1 and Table 3.4). Table 3.4 indicates the respondents involved, the type of data they provided and the research questions they answered. Moreover, the use of the qualitative approaches such as less formal, less standardised and interactive interviews and discussions (See Appendix 1 and Table 3.3) as well as observations during the field surveys complemented the questionnaire survey and aided interpretation.

Table 3.3: Interviews, data and research questions relationship

Interviewees	Scope of Interview Guidelines Themes	Research Question, which data addressed
Key Informants at ECG, MOE-GH, MOE-Kenya	-Policy discourse on energy in Ghana -Outcomes of the rural electrification programmes, especially, PV -Insight into the rationale behind PV energy advocacy for the rural areas -PV regulatory framework	**1 and 2**
2 energy think-tanks in Ghana and Kenya	-An assessment of the potential of RETs, especially PV, in rural Kenya vis-à-vis their energy needs -An evaluation of the adequacy of the institutional structures, policy, regulatory frameworks and market models of PV development and dissemination in rural Ghana	**2, 4 and 5**
Environmental organisations: FOE-GH	**-**Insight into the rationale behind PV energy advocacy for the rural areas **-** An evaluation of the adequacy of the institutional structures, policy, regulatory frameworks and market models of PV development in rural Ghana	**2 and 4**
PV companies: BEST Solar Company, Solar Light Company, Solar Utilisation Network (S.U.N) Ltd, Kenital Ltd, Solarnet Ltd.	**-**The demand patterns of PV by the different social groups— rich, poor, youth, associations, in rural Ghana -Modes of disseminating PV information to the rural areas - An evaluation of the adequacy of the institutional structures, policy, regulatory frameworks and market models of PV development and dissemination in rural Ghana -The work structure of PV companies in rural areas -Operational procedures of PV technology	**2,3,4 and 5**
Binde hospital & Wechiau health post, Najong No. 2 Catholic church, Binde Primary school, Olooltoto Primary school, Najong No. 2 primary school.	-History of the PV installations -The main functions of the PV installations in these institutions -Technical requirement to service the PV facility -Measures to sustain these PV installations	**2**
Doweni clinic, Najong No.2	-Types of energy in use, and why they are used -Exploration of their knowledge around other sources of energy	**2**

Table 3.4: Questionnaire survey, guideline themes and research questions relationship

Respondents	Scope of Questionnaire Guideline Themes	Research Question, which data addressed
Rural Households – PV owners and non-PV owners in Najong No.1, Najong No.2, Binde, Wechiau and Kunsu	-Household structure:-population of the house, male and female ratio, age -Sources of livelihood -Household income structure and their sources -Socio-cultural background: education, religion, leadership position in the village, norms, knowledge of the outside world, network practices -Households social activities during the day and in the night -Sources of energy consumption and their relative importance -Households expenditures on energy -Knowledge about the existence of PV -Uses of PV -Indigenous Knowledge about energy technologies -History of PV installation -Procedure of PV acquisition -An overview of PV performance - efficiency -Procedures of household decision making in the use of a particular type of energy -Households needs assessment -Households views on government policies on energy and PV dissemination to the rural areas	**1, 2, 3 and 4**
Rural businesses: -1 Drinking bar with PV -1 Drinking bar without PV -1 Provisions shop with PV -1 Provisions shop without PV - Coffee/tea seller with PV - 2 sheabutter producers without PV -2 local beer brewers without PV	-Rural businesses profiles -Annual income -Energy demands of rural businesses -Rural businesses perceptions on PV energy dissemination to the rural areas.	**2**

3.4 SIGNIFICANCE OF FIELD WORK IN KENYA AND THE SELECTION OF THE STUDY AREAS

The fieldwork in Kenya was conducted in August and September, 2004. The fieldwork in Kenya was necessary because an early literature review for this study revealed that more solar PV systems had been disseminated in Kenya than in Ghana. Consequently, the main aim of the Kenya fieldwork was to explore and develop an understanding of Kenya's PV energy issues (i.e. the functioning aspects), in a bid to help develop themes for the main fieldwork in Ghana, and also to help create room for comparative analysis of the solar PV development trajectories in Ghana, Kenya and Zimbabwe.

This fieldwork was based on a qualitative approach, including unstructured interviews, conversations, and observations to collate raw data (See Appendix 2). These methods were used due to the short duration of the fieldwork and because it was very preliminary in outlook. As Bell (1999) notes "preliminary interviews are held to give you ideas about which topics to include in the study, and so an unstructured approach is needed" (p: 139).

Three areas were chosen for data collection in Kenya - Nairobi, Mai-mahiu in the Rift Valley Province and Olooltoto, also in the Rift Valley Province. The factors below influenced the selection of these sites.

1) Nairobi was selected because, as the capital city, it houses the Kenya Ministry of Energy, the head offices of most of the solar PV companies in Kenya and NGOs dealing in solar PV.

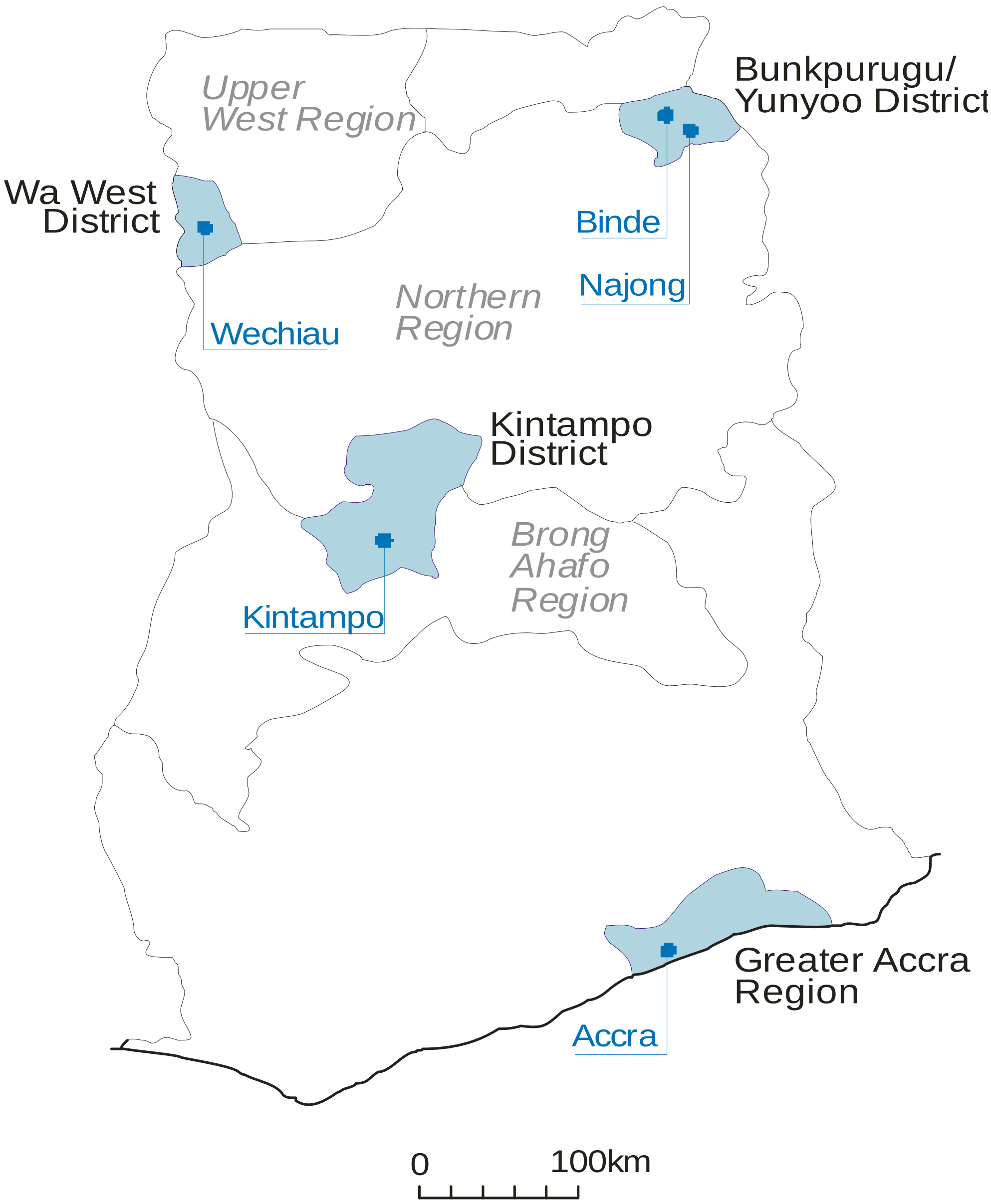
2) Mai-mahiu and Olooltoto were chosen for practical reasons and because of their rurality, especially Olooltoto. Also, both villages had solar PV installations. Mai-

mahiu is approximately 100km from Nairobi, while Olooltoto is approximately 250km from Nairobi.

3.5 STUDY AREAS AND SITES IN GHANA

In Ghana, the study sites were located in four districts; Bunkpurugu/Yunyoo District, Wa West District, Kintampo District and Accra Metropolitan Assembly (see Figure 3.1). These districts are located in four different regions in the country.

Figure 3.1 Map of Ghana showing the Study Areas



Source: Fieldwork, 2005.

Bunkpurugu/Yunyoo District is located in the north-eastern part of Northern region (bordered by East Mamprusi District to the west, Garu-Tempane District to the north and Saboba-Chereponi District to the south-east). Wa West District is also located in the western part of Upper West region and shares boundaries with Wa Municipal Assembly to the east, Nadowli District to the north and Sawla-Tuna-Kalba District to the south. On the other hand, Kintampo District is situated in Brong Ahafo region, in the middle belt of the country. It is bordered by Central Gonja District to the north, East Gonja District to the east, Techiman and Nkoranza Districts to the south and Sawla-Tuna-Kalba District to the west. Accra Metropolitan Assembly (AMA) too is located in Greater Accra region, the capital region of the country and bordered by the Atlantic Ocean to the south, Ga West District to the west, Ga North District to the north and Tema Municipal Assembly (TMA) to the east.

Specific field sites were chosen in Bunkpurugu/Yunyoo District, Wa West District and Kintampo District for data collection. These included the following villages; Najong No.1, Najong No. 2 and Binde in Bunkpurugu/Yunyoo District; Wechiau and Kunsu in Wa West and Kintampo Districts respectively. These sites are shown in Figure 3.1. In the case of Accra Metropolitan Assembly, the entire metropolis was considered. Many factors informed the choice of these specific sites for the collation of data.

First and foremost, the whole of Accra Metropolis was selected because the head offices of the energy policy-making institutions in Ghana, environmental organisations and most of the solar PV companies' offices are located there. Consequently, data collection from the various energy institutions, environmental organisations and some solar PV companies through interviews, took place in Accra Metropolis.

Secondly, Najong No.1, Najong No.2 and Binde under Bunkpurugu/Yunyoo District, are the villages that benefited from the UNDP/GEF solar PV pilot project. Najong No.1, Najong No.2, and Binde have population of about 1,909, 1,793, and 1,234 respectively (Mamprusi East District Statistics, 2000). The entire population of the Bunpkurugu/Yunyoo District is approximately 120,000 (ibid). The main occupation of the village is subsistence farming, petty-trading and livestock rearing.

The village of Wechiau in the Wa West District was also chosen as part of the field study sites, because it also benefited from a solar PV pilot project. This solar PV pilot project is entirely different from what was carried out in the Bunkpurugu/Yunyoo District in terms of its approach, and the time it was carried out (see Chapter 5). The Wechiau area was therefore chosen in order to broaden the scope on the discussion of solar PV projects' implementation and sustainability in rural Ghana. Wechiau has a population of about 1,200, while the entire population of the district is approximately 82,000 people (Wa Municipal Assembly statistics, 2002). The main economic activities of the village include peasant and commercial farming, petty-trading and livestock rearing.

In addition, the village of Kunsu was selected in Kintampo District as one of the study sites, because of the economic activity that is undertaken and the non-use of solar PV by the community. Kunsu has abundant virgin lands, which are suitable for the production of cash crops such as rice, yams and beans. The nature of the land has therefore attracted many migrants from the northern part of the country, who are currently engaged in commercial crop production. This site therefore offered the opportunity to collate data on farmers who are relatively ‘richer’ than the peasant farmers in Wa West and Bunkpurugu/Yunyoo Districts. Data from these farmers helped to understand the factors that influence adoption (or non-adoption) of solar PV in rural Ghana from a holistic perspective - using data from both ‘rich’ and the poor. Kunsu has approximately 2000 people (Kintampo District Statistics, 2002).

3.6 PROCEDURES INVOLVED IN THE SELECTION OF FIELD SITES IN GHANA

There were two processes involved in the selection of the four field sites in Ghana. One involved the selection of two sites — Accra Metropolitan Assembly and Kunsu, through my prior knowledge of the two areas. I lived in Kunsu some years ago and also undertook my University education in the Accra Metropolitan area. My knowledge of the backgrounds of these two places enabled me to choose them before travelling to Ghana for the field work.

However, Najong No.1, Najong No.2, Binde (in the Bunkpurugu/Yunyoo District) and Wechiau (Wa West District) were chosen whilst I was in Ghana, through the first interviews — the second process. It was not possible to identify solar PV project sites from documentary sources prior to travelling to Ghana for the fieldwork. Consequently, the first task was to interview personnel of the Ghana Energy Ministry (MOE-GH) and the Energy Commission (EC-GH) to identify possible field sites. In the course of these interviews, questions were asked about the locations of the solar PV projects, and the names of the above sites were mentioned: Bunkpurugu/Yunyoo District in the Northern region, Wa West District in the Upper West Region and Nkwanta District in the Volta Region. However, for practical reasons (time), only two of these three districts could be studied. As a result, I used simple random sampling to choose the Bunkpurugu/Yunyoo District and Wa West District.

3.7 QUESTIONNAIRE, INTERVIEW QUESTIONS DESIGN AND PRE-TESTING

Questionnaires and interview questions used in the field were partially developed at the Department of Geography, University of Hull and were completed in Ghana. Final versions of the questionnaire were only established in situ and after locating solar PV pilot areas. Moreover, completion of these questionnaires was deferred because of the need to contextualise, following the institutional (i.e. MOE-GH, EC-GH) interviews. On the whole, the content and physical design of the questionnaires and interview questions were informed by the aims and the theoretical framework of the study.

The questionnaires contained both factual and opinion questions, while the interview questions were wholly depended on opinions. Factual questions were structured as closed-ended, with pre-coded responses. Conversely, opinion questions were constructed in an open-ended form, with no pre-coded responses given. In this case, respondents were at liberty to provide their own answers to the questions.

The questionnaires were divided into various sections to address specific issues and concerns of the thesis (See Appendix 1), and structured to enhance the flow of questions under each specific issue or concern. The main themes addressed in these questionnaires included: sources of energy in rural areas, socio-economic features of rural households, cultural practices of rural households, technical knowledge of rural households and policy framework on rural electrification. Informal interview questions, however, did not have such divisions, because an answer to a question could elicit comments and queries on a different issue. The Likert scale of measurement was employed as one of the units of measurements in the questionnaires. In using this method of measurement, respondents were asked to indicate the strength of agreement or disagreement on series of statements.

Prior to administering the questionnaires, some time was spent in pre-testing them in Accra. A blend of people with both formal and non-formal education was used for this. These two categories of people were used in this exercise, because of the need to find out their reactions and feelings towards the questions. The reality is that the target population or prospective interviewees in the rural areas to this research had similar backgrounds. The pilot test helped to streamline and clarify the questionnaires. Most especially, it resulted in improved wording of the questions and resolved repeats or ambiguities. For example, one issue the exercise brought to bear relates to questions on income. Respondents in the pilot exercise reacted with discomfort to questions on income, because they felt the questions were too direct and specific. Consequently, the structure of questions on income was changed — other indirect forms of determining income (e.g. material wealth in the household, diverse sources of household income activities) were built into these questions (See Appendix 1). Notwithstanding the changes made to the income questions, the administering of such questions in the case study sites still needed tact because of the sensitive nature of the issue.

In addition, the pilot interviews helped to assess the length of time spent on the questionnaires with an interviewee. This was very important, because respondents are easily bored with long interviews. As Hooko (1999) points out "When interest dwindles it is likely to affect co-operation, and the accuracy of responses could suffer as a result" (p.172). The exercise revealed that about 35 minutes to 55 minutes were spent on the questionnaires with interviewees with formal and non-formal education, respectively. The two different time-frames used were understandable, because with the people with formal education, explanations were rarely needed, while explanation and translation had to be undertaken for those with non-formal education. On the whole, judging from the reactions of the pilot interviewees, the two time scales used for the interviews were appropriate to sustain the attention and enthusiasm of the respondents over the duration of the interviews.

3.8 SELECTION AND TRAINING OF INTERVIEWERS

By the end of the field survey in Ghana, three interviewers had been involved in the data collection process. As a result of the dispersal of the field sites, these interviewers were chosen and trained at different places.

3.8.1 Bunkpurugu/Yunyoo District

With the administering of the households questionnaires starting from the Bunkpurugu/Yunyoo District, two interviewers were first chosen for the sites in this District. The first interviewer, a student at Tamale[13] Polytechnic, was recruited in Tamale, and the second interviewer, a student at the Kwame Nkrumah University of Science and Technology (KNUST), was selected in Najong No. 2. The reasons that influenced the selection of these interviewers at the different times and locations are as follow.

The Tamale Polytechnic student was chosen because he had prior experience in questionnaire delivery, comes from Bunkpurugu/Yunyoo District (although resident

[13] Tamale is the regional capital of Northern region, under which Bunkpurugu/Yunyoo district is located. Bunkpurugu/Yunyoo is about 250km from Tamale.

in Tamale), and can ride a motor cycle[14]. The choice of the second interviewer (the student at KNUST) was also informed by his experience in research work and because he is a native of Najong No.2. In the end, the choice of these two interviewers was very significant because it solved problems concerning transportation of the researcher to and from the research sites in Bunkpurugu/Yunyoo District; a communication gap was bridged especially with the non-literate respondents[15]; and it dispelled rumours that the researcher was part of RESPRO[16] or the Ghana government.

After selecting the second interviewer at Najong No.2, they were both given refresher training on questionnaires administering (for approximately 2-3 hours), during which the overall aim of the study and the specific objectives of the field survey were explained. This measure was to equip them adequately to explain properly the context and the purpose of the research to the interviewees, in order to avoid any misconceptions. Most often, non-literates respondents in rural areas of Ghana do not distinguish between academic research and government research. Their main line of reasoning is that every research results in a direct benefit of a sort.

3.8.2 Wa West District

Wa West District was the second field study area visited. One interviewer was chosen for the field work in this study area. This interviewer (a student at KNUST) was

[14] A motor cycle is the most appropriate means of transport to this district for somebody who would want to be mobile while staying in the district. This is, because there is only one vehicle that plies between Bunkpurugu and Tamale in a day. It usually departs from Tamale around 10a.m, and gets to Bunkpurugu at around 12midnight and vice versa. A motor bike and a good rider like this interviewer, was needed to facilitate the researcher's movements to Najong No.1, Najong No.2, and Binde.

[15] The main dialect of the Bunkpurugu/Yunyoo district is Bimoba, which the researcher does not understand. Consequently, most of the non-formally educated respondents were interviewed by the research assistants. When the researcher was interviewing respondents with non-formal education, one of the research assistants did the translation.

[16]Before and during the Bunkpurugu/Yunyoo district's field survey (i.e. July to August, 2005) solar PV users in the district were very hostile towards RESPRO and its personnel.

chosen at Wa[17], after which the researcher moved with him to Wechiau - the study site. One research assistant was chosen primarily, because both the researcher and the research assistant could speak the native language of this case study area.

In addition the interviewer had experience in research work; he could ride a motor cycle[18]; and he also knew the location of Wechiau. Survey refresher training was also undertaken for this assistant interviewer, similar to that for the Bunkpurugu/Yunyoo district's assistant interviewers.

3.8.3 Kintampo District

This study area was the third place where survey work was carried out in the field site - Kunsu. Here, no other interviewer was involved in the survey as the main researcher could manage the sample size (i.e.10 respondents) alone, and transportation was not a problem - cars were plying between Kintampo and Kunsu every day unlike the other two districts. Also the researcher can speak both languages[19] that are spoken in Kunsu.

3.9 GAINING ACCESS TO COMMUNITIES AT THE FIELD SITES

Before data can be collected, especially in surveys, it is necessary first of all to gain access to local communities of the field sites involved. Cassell (1988) outlines two main stages in the process of penetrating a 'closed access' group - getting in (achieving physical access) and getting on (achieving social access). Entering a field site therefore demands detailed planning, which may include a number of discrete

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[17] Wa is the regional capital of Upper West Region, under which Wa West district is located. Wechiau is about 57km from Wa.
[18] Cars go to Wechiau only on its market day in the week.
[19] Twi is the native language of the indigenes of Kunsu, while Dagaare is spoken by the northerners from Upper West region, who have settled there. The researcher can speak both, because he is northerner and had lived in Kunsu.

issues. Firstly, access to a group of research subjects or a setting may require extensive negotiation and the permission of ‘gatekeepers’ (Kesby *et al*, 1997). Secondly, co-operation from individual members of the study sample or respondents in a setting is required in order to maximise response, while ensuring informed consent (Acheampong, 2003, citing Arber, 1993).

In this project, access to the field sites was not a problem, because firstly, my fluency in Twi and Dagaare languages, which are spoken in Kunsu and Wechiau respectively, helped. Secondly, accessing field sites became less difficult because of the involvement of locals at the case study sites in Bunkpurugu/Yunyoo District, where I could not speak the local dialect - Bimoba.

Access to the field site in Wa West District (i.e. Wechiau) was first sought from the Wa West District Co-ordinating Director - the political head of the district administration. After that, permission was also sought from the traditional ruler of Wechiau - Wechiau Naa[20]and his elders. Also informed was the Wechiau assembly member, because he is one of the civic leaders of the village and can therefore assist visitors in diverse ways.

In the case study sites in Bunkpurugu/Yunyoo District, permission to interview residents was sought mainly from the elders, Assembly members, and opinion leaders of the three villages - Najong No. 1, Najong No. 2, Binde. Permission was not sought from the District Coordinating council, because the district administration, which is located in Bunkpurugu town, was far ahead of these villages.

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[20] Naa is a Dagaare word, which means chief. Thus, Wechiau Naa means the chief of Wechiau.

Prior knowledge of Kunsu made access easier. The village chief was informed of my reasons for wanting to interview people there, and permission was granted. In all, in the process of negotiating access to the case study sites, the leaders and respondents in all the villages of the chosen field sites were assured of confidentiality.

3.10 OBSERVATION

The research also employed non-participant observation to gather in-depth information on the following issues.

- Types of energy in the household and their uses
- Culture - social activities in the day and night.
- PV utilisation rate
- Efficiency of installed PV facility

} Data on these issues addressed research questions **2** and **3**

3.11 RESEARCH DIARIES

Another methodological instrument that was used to collate data was the keeping of a field diary in all the field sites. The purpose of a field diary according to Cook (1997) "is to keep some kind of record of how your research has progressed …day by day…" (P.180).

In this study, the field diary helped to record details on how access to the field sites was gained; on what emerged during the non-participant observation; on the processes of selecting interviewers. In addition, through the use of field diary, dates of interview were noted, those interviewed, daily schedules and any problems that surfaced.

3.12 INFORMAL CONVERSATIONS

An important if slightly unorthodox methodological instrument that was adopted while the researcher was in the field is the informal conversation method of data collection. Informal conversations occur whenever a researcher is in the field, walking around the village, stopping to chat with the people (Khan and Manderson, 1992).

Informal conversations were incorporated in the methods of data collection after the researcher arrived at the field sites, because of the need to elicit relevant information from certain categories of people, who were not comfortable with formal interviews. These included women and people who were more approachable in an informal setting. Through such informal conversations, data on the uses and impacts of solar PV were gathered from five people in the case study areas: three women at a PV driven water standing pipe in Wechiau, a customer at a drinking bar in Najong No. 2, and the organiser of National Democratic Congress (NDC) in Wechiau.

3.13 INTERDISCIPLINARY APPROACH OF THE RESEARCH

The different dimensions (economic, cultural, technical, social, political) intrinsic to the topic under consideration imply that knowledge from a single discipline is not enough to treat the subject matter. Rather, it can be addressed if disciplinary boundaries are crossed. Consequently, this study has adopted an interdisciplinary approach in its methodological framework. According to Acutt *et al* (2000) "an interdisciplinary approach is an eclectic approach integrating different disciplines for solving complex problems, encompassing methodologies, methods and worldviews. It involves an interactive, communicative, information based and holistic way of thinking. It is fluid and adaptable to the problem that has to be solved" (p.4)

3.14 TARGET POPULATION AND SAMPLING UNITS

To secure the range of data needed to address the research questions of this work, the following stakeholders, which constituted the sampling frame, were approached and interviewed, or provided data and literature (see Table 3.5).

Table 3.5 Categories of stakeholders/interviewees and the actual number of people interviewed in each category in Ghana and Kenya

Category of Stakeholders/Interviewees	Number of People Interviewed in Ghana	Number of People Interviewed in Kenya
Energy Commission (EC-GH)	2 (2)[21]	0
Electricity Company Ltd	1 (2)	0
Ministry of Energy	1 (2)	1 (2)
Private PV Companies	4 (5)	2 (3)
Environmental organisations	1 (2)	0
Rural businesses	9 (10)	0
Energy think-tanks	1 (5)	1 (2)
Rural schools	3 (6)	1 (2)
Rural heath Units	2 (4)	0
Church	1 (2)	0
Civic leaders	3 (6)	0
Rural households with PV	20 (20)	3 (3)
Rural households without PV	30 (30)	2 (3)
Solar PV technicians	3 (4)	2 (2)
Total	**81 (100)**	**12 (17)**

As shown in Table 3.5 above, in total, 93 people were interviewed, representing approximately 80 percent of the original sample units of 117 that were targeted. Factors such as limited time and other practical challenges (see Section 3.17) accounted for the reduction in sample units. The actual sample units were therefore made up of two people from the Energy Commission of Ghana, one person from the Ghana Ministry of Energy, one person from Kenya Ministry of Energy, one person from the electricity Company Ltd of Ghana and two persons from Friends of the Earth

[21] Numbers in bracket represent the original sample units for the targeted stakeholders in both countries, while the actual number of people interviewed are without the brackets.

(an environmental organisation) in Ghana. One or two persons from the above organisations were considered sufficient to answer the interview questions set for these organisations. Friends of the Earth (Ghana), was chosen because it was the only environmental organisation among the targeted environmental organisations dealing in energy issues that could be contacted. While other environmental organisations were there, they were not selected because their scope of activities does not include energy issues. In addition, the Energy Ministries in Ghana and Kenya, the Energy Commission and the Electricity Company of Ghana, were chosen rather than any other government departments because they are the public institutions responsible for energy activities in the two countries.

Six people were interviewed from five different private PV companies (three in Ghana, two in Kenya): B.E.S.T Solar Company in Tamale, Ghana (1); Solar Light Company in Accra, Ghana (1); Solar Utilisation Network (S.U.N) Company in Accra, Ghana (2); Kenital in Nairobi, Kenya (1) and Solar Energy Network Company (Solarnet) (1) (see Table 3.3 and Table 3.5). Five solar PV private companies were chosen because of the need to involve the different sizes of PV companies, small and large. Two solar PV private companies were chosen in Kenya and their personnel interviewed because of the exploratory nature of the Kenya fieldwork. The two solar PV private companies were therefore not representative of the solar PV companies in Kenya. On the other hand, the three solar PV companies that have been selected in Ghana were representative of the estimated solar PV companies (i.e. between six and seven) in Ghana (see Appendix 5 for solar PV Companies in Ghana).

Two energy think-tanks with different professions or backgrounds were also selected (see Table 3.3) to articulate a range of views on energy issues in Ghana and Kenya.

Five interviewees from a cross-section of five different rural businesses were selected at the study sites. They were selected to ensure that the different types of businesses in the rural areas were covered. These included two drinking bars (one with and one without solar PV), two provisions shops (one with and one without PV), and one coffee/tea selling shop with solar PV (see Table 3.4). Four people from two cottage industries were also interviewed: two sheabutter producers without solar PV and two local beer brewers, also without solar PV (see Table 3.4). This selection represented a reasonably high percentage of shops, bars, cottages industries in the study villages. Together, there were four bars, three shops, one coffee/tea selling shop in the four villages visited.

In addition, interviews were conducted with three officials from three different rural public schools with PV (Binde Primary school, Ghana, Wechiau Primary school, Ghana, and Olooltoto Primary school, Kenya), and one official from a rural public school without PV (Najong No.1 and Najong No.2 Primary school, Ghana). Two officials from two rural health units with PV (Binde and Wechiau, Ghana), and a Catholic church in Najong No.2 with PV were also chosen (See Table 3.3). In fact, interviews were conducted with personnel at all the schools and health units in the study villages. However, only one church official could be interviewed due to other practical reasons (see Section 3.17). Moreover, these sample sizes of the hospitals and the schools were selected, because from the literature there were few hospitals and schools with solar PV units in northern Ghana, in dispersed locations. Other respondents included the past and present Assembly members of Wechiau and Wechiau Naa (i.e. civic leaders), one technician at the Wechiau solar PV battery charging station, two former technicians of the Renewable Energy Services Project

(RESPRO) in Ghana, one technician at Kenital in Kenya, and one technician at Solarnet in Kenya .

The household interviews involved 20 rural households (with solar PV) in Bunkpurugu/Yunyoo and Wa West Districts; and 30 rural households (without solar PV systems), 20 in Wa West and Bunkpuruguru/Yunyoo Districts and 10 in Kunsu commercial farming community, all in Ghana. There is unevenness in the interviewed number of households with and without solar PV, because there are no solar PV users in the Kunsu commercial farming community. These three study areas in Ghana were used for the intensive case studies, covering the issues detailed in Table 3.4. Three households with solar PV and two households without solar PV were also interviewed in Kenya as part of the exploratory studies.

3.15 SAMPLING TECHNIQUES

Three sampling techniques (simple random sampling, snowball sampling and purposive sampling) were utilised to select the sampling units, based on the nature of the research problem and the need for representative samples. As de Vaus (1996) notes, the choice of sampling method "[will depend on]… the nature of the research problem, the availability of good sampling frames, money, the desired level of accuracy in the sample and the method by which the data is collected" (p.6).

Simple random sampling[22] was used to select the three sampling units for PV private companies in Accra and Tamale, and the ten households in Kunsu, which are not using PV. This sampling method was chosen because, all of the private PV companies in Accra and Tamale and all the households within Kunsu were given equal chance of

[22] "Simple random sampling involves randomly selecting individual units from a sampling frame" (Mathew and Carole, 2004: 150).

being selected. Consequently, at the Kunsu's field site, questionnaires were administered to any household visited where the head of the family was present and willing to be interviewed.

Snowball sampling[23] was used to select the 40 households in Bunkpurugu/Yunyoo (Najong No.1, Najong No.2), and Wa West (Wechiau) Districts with and without solar PV. It was also used to select the rural businesses and public schools with and without solar PV, cottage industries without solar PV, and the rural health units with solar PV.

In Bunkpurugu/Yunyoo District case study sites (Najong No.1 and Najong No.2), the second interviewer - a local and resident of Najong No.2, was the first contact, who in turn helped to identify the first respondents (with and without solar PV). The first people interviewed also became the second layer or second contacts to identifying more of solar PV users and non-users. This process of contact building continued until the desired sample size (on households, rural businesses, cottage industries, schools and health units) was reached.

At Wechiau, the Assembly member was the first and main contact person used to identify users and non-users of solar PV. Because of his leadership position in the village, he knew all those who were using the solar PV technology, had used or were not using it. Information about Binde Primary school and hospital, both using solar PV, was given by an official of RESSPRO[24] in Tamale.

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[23] "Snowballing … describes using one contact to help you recruit another contact, who in turn can put you in touch with someone else. Through this, recruiting gains momentum, or 'snowballs' as the researcher builds up layers of contact" Valentine (2005:110).

[24] Solar PV technician **'C'.**

Purposive sampling was used to select key informants from EC-GH, MOE-GH, FOE, African Energy Policy Research Network (AFREPREN) and the energy think-tanks in both Ghana and Kenya. Within these organisations, high profile personnel were specifically selected for interviews, because of their involvement in the energy policy issues of Ghana and Kenya. Thus, they were deemed an appropriate repository of knowledge on energy issues in these two countries. Purposive sampling was also used to select the past and present Assembly members of Wechiau, the technician at the Wechiau solar PV battery charging station, the Wechiau Naa and the village organiser of the NDC party. Purposive sampling is done in a deliberate way, with some purpose or focus in mind (Punch, 2005); and the main merit of using it is that the sampling units are selected according to the researcher's own knowledge and opinion about which ones they think will be appropriate to the topic area (Mathew and Carole, 2004; Flowerdew and Martin, 1997).

3.16 DATA ANALYSIS

The data gathered were analysed and interpreted through qualitative and quantitative forms of analysis. Qualitative means of analysis that were used included transcription of audio recorded interviews, content analysis of secondary data and transcripts of interviews, institutional analysis and conversation analysis, to reveal key themes and issues. Transcription of audio recorded interviews was completed with computer transcription software called Olympus AS-3000 PC Transcription Kit (stereo headset, footswitch and DSS Transcription Software).

After transcription, content analysis was used manually to tease out themes and patterns from the empirical data as well as the relevant documents that were gathered in the field. This was done by breaking down the transcripts and texts of the secondary data into categories on a variety of levels--phrase and sentence. These categories were then examined using content analysis' basic method of relational analysis[25] to identify common relationships among them. The mutual relationships identified between these categories then became the themes. The authenticity of conversation data were analysed using conversation analysis. In order to maintain confidentiality of key informants and interviewees, their names were replaced with identifiable letters (e.g. civil servant 'A', 'B' 'C').

The Statistical Package for the Social Sciences (SPSS) and Excel were used for quantitative analysis of the questionnaires. Questionnaires responses were coded, and analysed using SPSS. Both SPSS and Excel were also applied to produce descriptive statistics (frequency distribution, percentage distribution), tables, graphs and diagrams of the questionnaires responses. In order to determine the association/relationship, agreement or disagreement between certain major independent and dependent variables in the dataset, bivariate analysis in the form of cross-tabulations were run (Rose and Sullivan, 1996).

3.17 CONSTRAINTS OF FIELDWORK IN GHANA AND KENYA

Some practical issues affected fieldwork activities in Ghana and Kenya. The following are some of the problems encountered in the field.

Some prospective interviewees and respondents were not available in both Ghana and Kenya. As shown in section 3.4 and Table 3.5 above, not all the sample units were covered in the fieldwork in Ghana. In all, 24 respondents could not be interviewed either because of non-availability or rebuff. For instance, in Ghana, targeted

[25] Relational analysis is a method of identifying concepts present in a given text or set of texts and exploring the relationships between the concepts identified (Colorado University, 2007).

interviewees such as energy think-tanks and personnel at VRA could not be interviewed, because they were not available. In Kenya, it was not possible to interview World Bank staff because of rebuff. Although the researcher went to the office of this organisation, the receptionist indicated that access could not be granted to any of their employees, unless the researcher mentioned the name of the specific employee he wanted to meet. Other constraints peculiar to the fieldwork in Ghana alone are discussed below.

It was difficult to retrieve income data from rural communities in Ghana. This problem arose because, firstly, the majority of non-solar PV users and a limited number of PV users (see Chapter 5) are without formal education and as such do not keep written documents of their finances. Secondly, some people initially thought the research was being carried out to identify the rich and the poor classes in the community for the purpose of giving help to the poor class. Thirdly, it was difficult to elicit income data from respondents because of the general mistrust of strangers. Some were very sceptical about my ability to maintain confidentiality. These types of problems are well known. For instance, Valentine (2005) observes that “Interviewing in different cultural contexts, particularly in less developed countries, requires heightened sensitivity…” (p.124). On the other hand, Howard (1997) notes the difficulties of collecting data on households incomes by observing that “…people the world over are generally reluctant to discuss how much money they make” (p.33). She also points out the need to maintain the confidentiality of informants and interviewees. Therefore, to overcome the fears of rural respondents in the field, a full and detailed explanation of the aims of this research was given at the beginning of every interview session.

Another limitation encountered in the field in Ghana was the absence of a proportional representation from the male and female gender in the household survey. There was a clear gender bias (towards males) among the interviewees (see chapter 5). Indeed, this is normal in Africa, where females did not want to be interviewed. Most declined to be interviewed and instead called their husbands. Some females stated that their husbands alone could answer the questions, because they are the main breadwinners and decision makers of the houses. It was often the case that women who agreed to be interviewed had to consult their husbands for some answers. This pattern of gender representation and behaviour in the process of data collection in the developing world is also well documented (see Howard, 1997; Robson, 1997). Accordingly, in some societies' customs female seclusion would make it difficult for a man to interview women or where gender segregation is the norm, men may find entry to the world of women impossible and vice versa (Howard, 1997; Robson, 1997). Because of this poor participation of females, their opinions and views were not fully represented, especially on the following issues:

- The types of activities for which energy is crucial;
- The benefits of perceived additional time which households with solar PV enjoy;
- Knowledge of government policy towards rural electrification; and
- Annual income earn by females from cottage industries[26] (e.g. trading, local brewery, sheabutter production).

Other problems encountered included some interviewees disliking the use of a tape recorder, although the importance of taping and my position as a student (and not e.g. a journalist or spy) were explained to them. In particular, some interviewees in one of

[26] It should be pointed out that in Ghana these cottage industries are carried out only by women.

the case study sites in Ghana only agreed to be interviewed provided their voices were not recorded. This could be due to cultural reasons or the misunderstanding that existed between the solar PV project implementers and the beneficiaries at that time. At any rate, the rejection of voice taping in the field in the developing world is also well known (see Valentine, 2005). A few institutions were also reluctant to release secondary information at the first visit because they needed more proof of identity. I was, however, able to negotiate this problem by assuring them of my status (student identity card and departmental letter).

3.18 CONCLUSION

This chapter has presented an overview of the various approaches that were devised to collect data in the field, and how they were analysed and interpreted for this research. Multiple methods found involving qualitative and quantitative approaches were used in the data gathering and analysis processes. The use of such a mixed approach helped to draw the respective strengths of both qualitative and quantitative approaches towards providing answers to the research questions and the objectives of the study.

In addition, the chapter has highlighted problems that affected the smooth collection of data, the number of sample units, and the ways in which some of the problems were solved. However, most of the constraints encountered in the field are well documented and not peculiar to this research alone.

CHAPTER FOUR

ENERGY SCENARIOS AND RURAL ELECTRIFICATION PROGRAMME IN GHANA: CONTEXTUALISING SOLAR PV ENERGY PROVISION IN GHANA

4.1 INTRODUCTION

Vital for economic development, energy is one of the principal indicators of economic growth (Entsua-Mensah, 1994). Energy literally fuels the global economy and affects life in all its forms by securing a steady flow of goods and services through the transformation of natural resources for distribution and consumption as well as enabling the production of other goods. Different countries are endowed with different levels of energy resources and have disparate levels of development in the energy sector, which means that they necessarily adopt different approaches to creating new capacity.

The main thrust of this chapter is a detailed examination of Ghana's energy situation, in particular the electricity generation sector, in an attempt to answer the following key question: what are the main patterns and trends in Ghana's energy landscape (i.e. sources of energy, energy demand and supply in both rural and urban areas)? This entails first and foremost, a consideration of the general geography of Ghana, of its people and its energy resources. Chapter Four also provides a detailed account of the energy consumption patterns of both urban and rural areas of Ghana. In addition, the backgrounds to the various approaches to rural electrification in Ghana are provided, including those activities leading to the incorporation of renewable energy concepts in rural electrification programmes.

4.2 AN OVERVIEW OF GHANA

4.2.1 Location

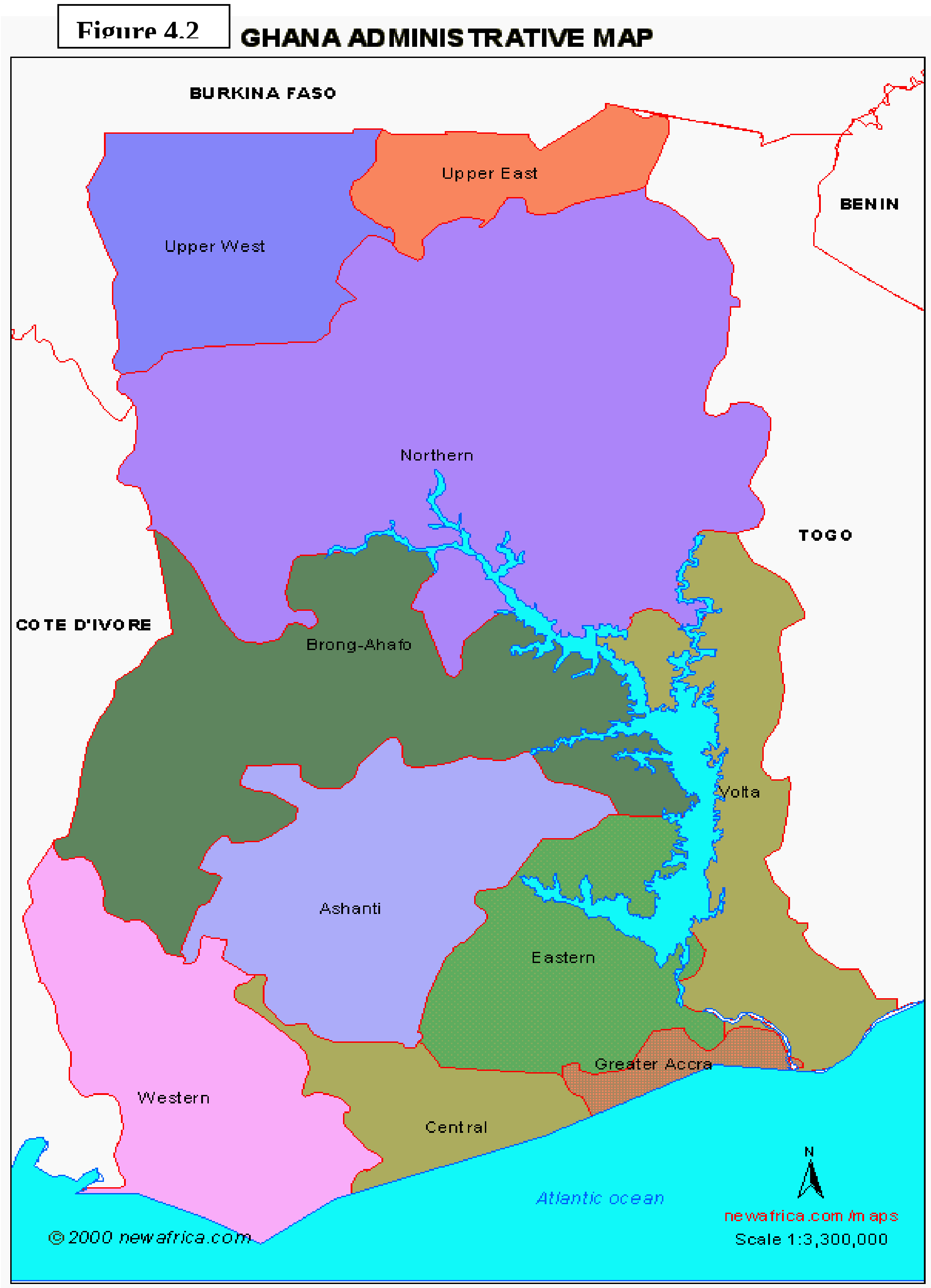
The Republic of Ghana is bordered by Côte d'Ivoire to the west, Togo to the east and Burkina Faso to the north (Figure 4.1) and was created from the merger of the British colony of the Gold Coast and the Togoland Trust Territory. In 1957 Ghana became the first sub-Saharan country in colonial Africa to gain independence.

With an area of 238,540 km^2, Ghana is a medium-sized African state, divided into ten administrative regions (Figure 4.2). As indicated in Chapter Three (see section 3.5), the main field areas for this research are located in four of these administrative regions - Greater Accra, Northern, Upper West and Brong Ahafo (Figure 4.2).

Figure 4.1 Geographic map of Ghana

Source : CIA World Factbook-Ghana, 2007a.

Figure 4.2



Source: Ghana Homepage, 2007.

4.2.2 Population

Ghana's population has increased steadily since independence in 1957. Data from censuses in 1960, 1970, 1984 and 2000, indicated a constant progressive growth rate

(Table 4.1). Ghana's population in 2000 was 18.9 million, a threefold increase from a 1960 total of 6.7 million. It is currently estimated at 21.1 million (2005).

Table 4.1 Population censuses of Ghana: 1960-2000

Dates	Population (Millions)	Growth Rate (%)
1960	6,726,815	-
1970	8,559,313	27.2
1984	12,296,081	30.3
2000	18,912,079	39.0

Source: Ghana Statistical Service, 2006 (cited in Geohive, 2000-2006)

This population is distributed unevenly across the ten regions of the country. Ashanti is the most populous and also one of the most developed regions, while the Upper West is the least populated (Table 4.2). One of the factors accounting for this disparity is economic migration from the least developed regions such as Upper East, Northern and Upper West to the relatively more developed ones such as Ashanti, Greater Accra and Eastern.

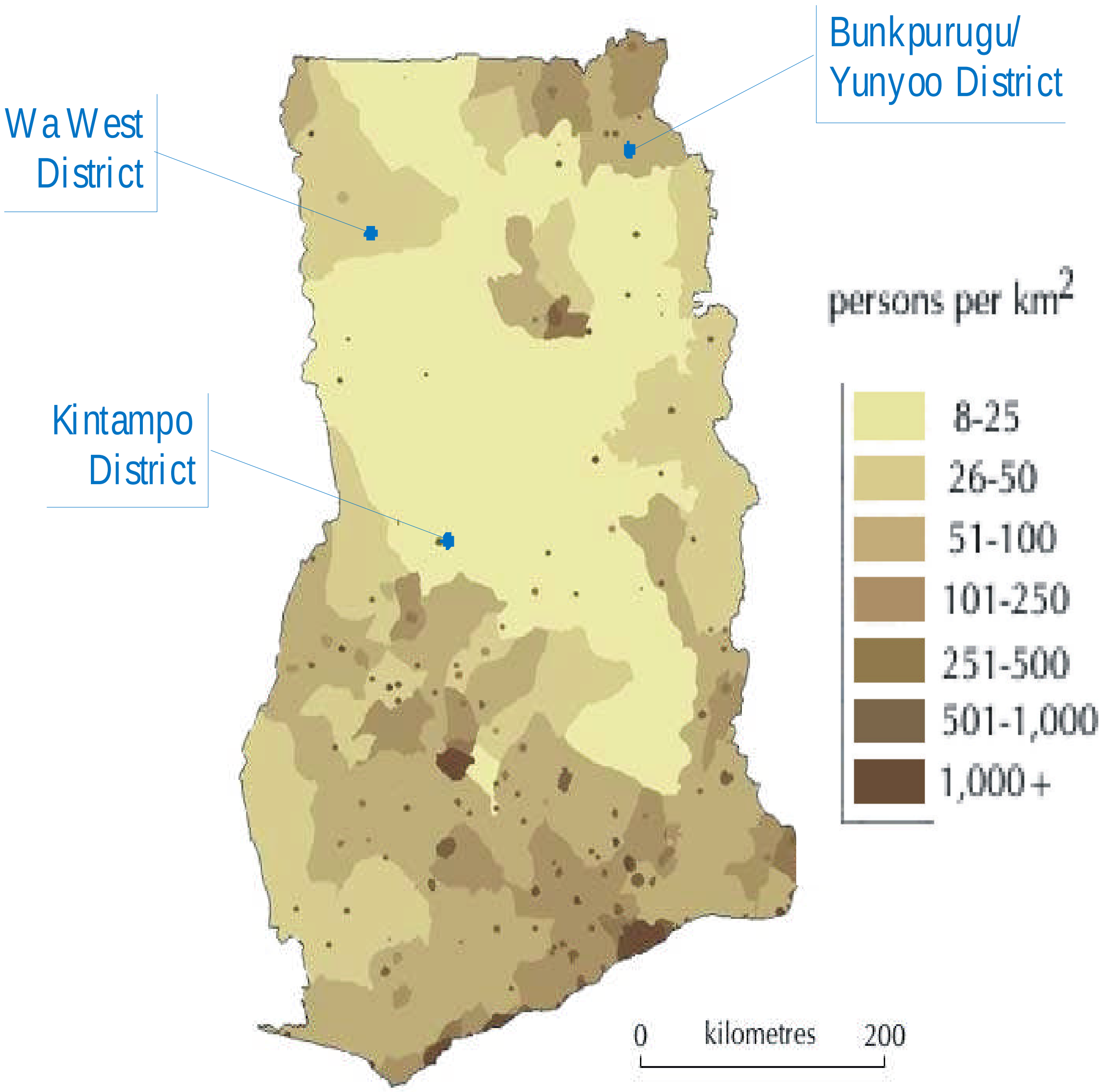
Table 4.2 Population distribution of regions and case study districts of Ghana

Region	Area (sq.km)	Population	(%) of Total	Population of Case study Districts	Percent of District
Ashanti	24,389	3,187,607	17.3		
Accra	3,245	2,909,643	15.8		
Eastern	19,323	2,108,652	11.5		
Northern	70,384	1,854,994	10.1	120,000	6.5
Western	23,921	1,842,878	10.0		
Brong Ahafo	39,557	1,824,822	9.9	146,943	8.1
Volta	20,570	1,612,299	8.8		
Central	9,826	1,580,047	8.6		
Upper East	8,842	917,251	5		
Upper West	18,476	573,860	3.1	82,000	14.3
Total	**238,533**	**18,412,247**	**100**		

Source: Ghana Population Census, 2000; Mamprusi East District Statistics, 2000; Wa Municipal Assembly Statistics, 2002; Kintampo District Statistics, 2002.

Since 1960, localities with 5,000 persons or more are classified as urban. Based on this criterion, the 1960 urban population totalled 1,551,174 persons, (23.1 percent), increasing to 28 percent in 1970 and 32 percent in 1984 (Owusu-Ansah, 1994). Notwithstanding this rate of urban growth, Ghana remains a nation of rural communities (68 percent of total population) (Ministry of Food and Agriculture-Ghana (MOFA-GH), 1997), although in 2000 the Ghana Statistical Service (GSS), (2003) estimated that 56.2 percent of the population was rural. Although the Upper West region is the least populated, the majority of its inhabitants live in the rural areas. The population density in the case study site in Wa West district, (i.e. Wechiau, in the Upper West region), ranges from 40-60 and 60-80 persons/km^2 (Figure 4.3). Population density figures in the other two case study areas (Kunsu in Kintampo district of the Brong Ahafo region and Najong No.1, Najong No.2 and Binde in Bunkpurugu/Yunyoo district of the Northern region), are also low: 40-60 and 60-80 persons/km^2 respectively (Figure 3.4).

Figure 4.3 Population Distribution Map of Ghana



Source: Adapted from MARA/ARMA (Mapping Malaria Risk in Africa / Atlas du Risque de la Malaria en Afrique), 2001.

4.2.3 Climatic Conditions and Vegetation Zones of Ghana

The characteristics of climate in Ghana are very important in this research. Knowing the climatic conditions of the country facilitates an understanding of the potential of solar PV energy utilisation (see section 4.3.2). Situated between 4° and 15° N, Ghana enjoys a tropical climate.

Ghana's climate is influenced by the hot, dry and dust-laden air mass that moves from the north east across the Sahara and by the tropical maritime air mass that moves from the south-west across the southern Atlantic ocean (Oppong-Anane, 2001). The climate ranges from the bimodal rainfall equatorial type in the south to the tropical unimodal monsoon type in the north. The mean monthly temperature over most of the country never falls below 25° C, a consequence of Ghana's low latitude and the absence of high altitude areas.[27] Mean annual temperature averages 27° C. Absolute maxima approaches 40° C, especially in the north, where the case study areas of this research are located, with absolute minima descending to about 15° C (Oppong-Anane, 2001). On the other hand, the annual range of temperature in the coastal areas is between 5 and 6° C, due to the influence of the sea breeze.

Rainfall decreases from the south to the north. The wettest area is the extreme southwest, with of over 2,000 mm per annum. In the extreme north, it is less than 1,100 mm. The driest area is in the south-eastern coastal tip where the rainfall is about 750 mm. The annual mean relative humidity is about 80 percent in the south and 44 percent in the north (Dickson and Benneh, 1988; Benneh *et al*. 1990, cited in Bawakyillenuo, 2002).

The two different rainfall regimes (i.e. the bimodal and unimodal) coupled with soil conditions, have influenced the pattern of vegetation zones distribution in the country.

[27] Ghana is generally characterised by low physical relief features. About one-third of the country is less than 150m above sea level, and half is between 150m and 300m; while a large part of the rest of the area lies between 300m and 600m in altitude. The highest elevation in the country is Mount Afadjato, with a height of 880m.

There are two major vegetation zones (see section 4.3.1a). However, little distinctions within these two major vegetation zones have resulted in the identification of six vegetation zones: Rain Forest, Deciduous Forest, Forest-Savannah Transition and Coastal Savannah in the south, which are influenced by the bimodal rainfall regime, while the Northern Savannah in the north, which comprises the Guinea and Sudan Savannahs, are influenced by the unimodal rainfall regime.

4.2.4 Economy

The economic structure of a country and the changes in that structure are key determinants of energy demand and supply. Ghana is well endowed with a diverse and rich natural resource base and has approximately twice the per capita output of the poorer countries in West Africa (CIA World Factbook- Ghana, 2007). Small scale agriculture is the mainstay of the economy, accounting for 37.3 percent of GDP (2006) and some 60 percent of the workforce (Table 4.3). The main export crop, cocoa, generates 30-40 percent of foreign exchange earnings. Gold, diamonds, manganese, bauxite and timber are the other main commodities.

Secondary industries account for 25.3 percent of GDP. Of this, manufacturing accounts for 9 percent (Institute for Security Studies (ISS), 2006). The service sector accounts for 37.5 percent of GDP. Tourism has become one of the country's largest foreign income earners (ranking third in 2003 at $600 million) (U.S. State Department Background Notes on Ghana, 2006). A summary of the current economic status of Ghana is shown in Table 4.3.

Table 4.3 Summary of current economic indicators of Ghana

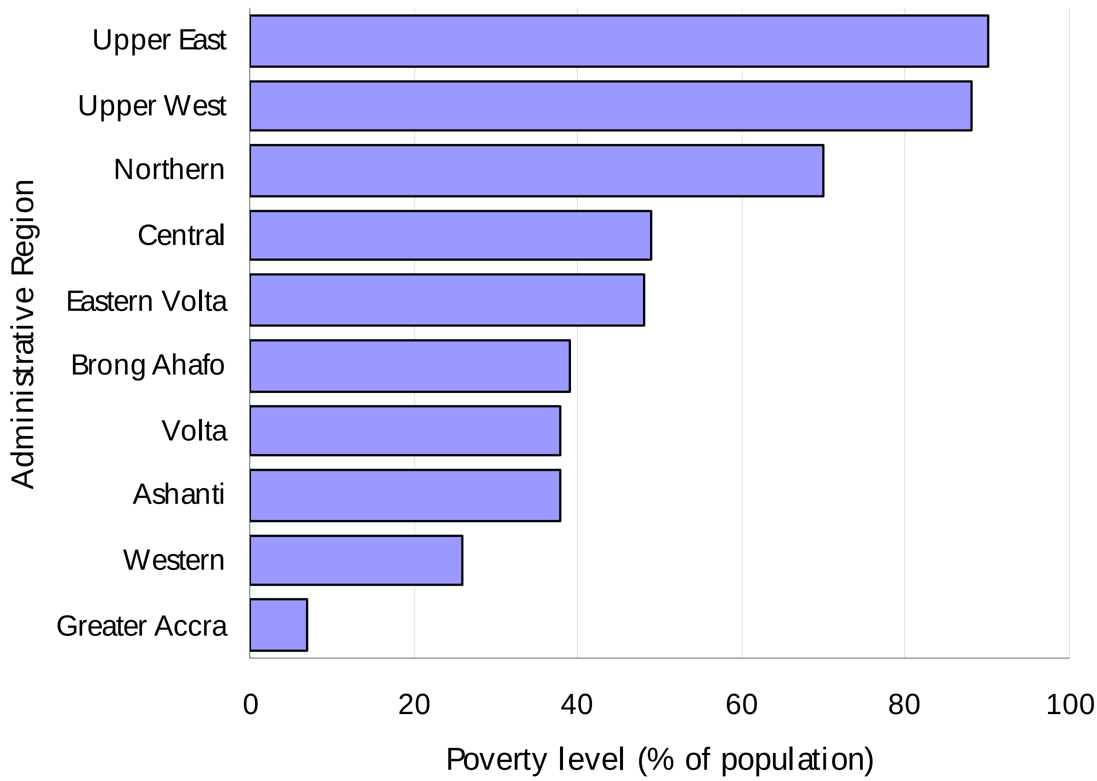
GDP - Real Growth rate	5.7% (2006 est.)
GDP - Per capita	Purchasing Power Parity -$2,600 (2006 est.)
GDP - Composition by sector	Agriculture:37.3% Industry: 25.3% Sevices:37.5% } (2006 est.)
Labour force - by occupation	Agriculture: 60% Industry: 15% Services: 25% } (1999 est.)
Population below poverty line	31.4% (1992 est.)
Inflation rate (consumer prices)	10.9% of GDP (2006 est.)
Currency	Cedi (GHC)
Exchange rates	Cedis (¢) per US dollar - [9,164.66 (2006)], [9,127.42 (2005)], [9,004.6 (2004)], [8,677.4(2003)], [7,932.7 (2002)], [7,170.8(2001)]

Source: CIA World Factbook- Ghana, 2007.

The rural economies within the three main belts of the country (coastal, middle and northern) are fundamentally based on rain-fed agriculture, 90 percent of which is peasant-based (ISS, 2006). The activities are fishing, farming and livestock rearing. However, the participation levels in these activities differ across the three belts. Fishing is the main occupation along the coastal belt (Greater Accra, Central, and parts of the Volta and Western Regions), followed by farming and livestock rearing. In the middle belt, which experiences a bimodal rainfall regime (see 4.2.4), farming is the main occupation, followed by livestock rearing and fishing in the rural areas. This zone covers the Brong-Ahafo, Ashanti, Eastern and parts of the Volta and Western regions (Amissah-Arthur and Amonoo, 2004). In the northern belt or savannah zone, (Upper East, Upper West and Northern Regions), farming and livestock rearing are the main economic activities, followed by sheanut oil extraction and beer (i.e. pito) production.

Although Ghana has twice the per capita output of poorer West African countries, rural people are still poor, especially in the north. The Ghana Living Standards Survey IV (GLSS), 2000, noted the high incidence of poverty in rural Ghana, accounting for 84 percent of Ghana's poor. Poverty[28] is highest in the north (Upper West, Upper East and Northern regions), followed by the Central and Eastern regions (Ministry of Finance and Economic Planning-Ghana (MOFEP-GH), 2000; Gyan-Baffour, 2003) (see Figure 4.4).

Figure 4.4 Poverty incidence by region in Ghana



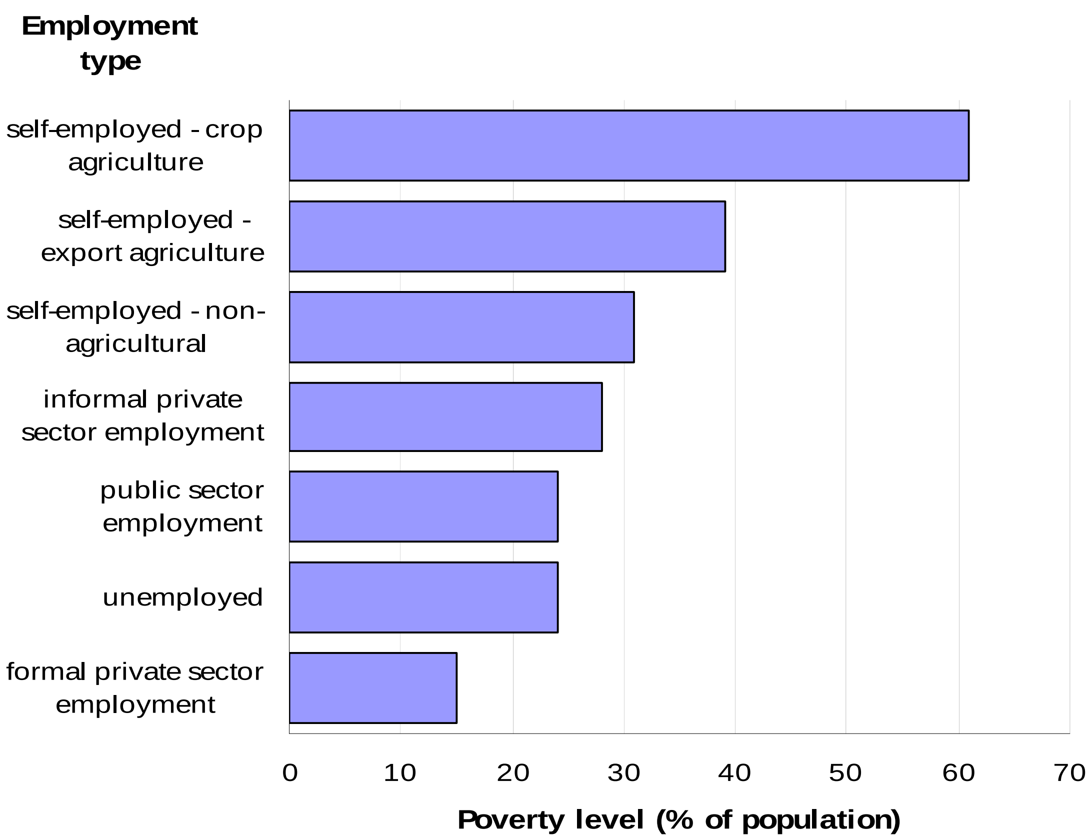
Source: Adapted from MOFEP-GH, 2000.

Along with this geographic pattern, there is a relationship between poverty and the main economic activities of these rural areas. According to Amissah-Arthur and Amonoo (2004), "those with the highest incidence of poverty, are food crop

[28]State of being deprived of the essentials of well-being such as adequate housing, food, sufficient income, employment, access to required social services and social status (UNDP, 1997).

farmers…" (p.6). As the MOFEP-GH (2000) also points out in the 2000 GLSS survey report, "at the national level almost 61 percent of those identified as poor are from households for which food crop cultivation is the main activity" (p.4) (Figure 4.5). Other categories that are relatively poor include export farmers (39%) and private informal employees (25%) (Gyan-Baffour, 2003).

Figure 4.5 Poverty incidence by economic activity (1998/9) in Ghana



Source: Adapted from Ministry of Finance - Ghana, 2000.

In the unimodal rainfall zone, unreliable rainfall can lead to poor yields and in years of extreme drought, none at all. Furthermore in the long dry season, no agricultural activities take place. Energy technologies, especially those that can help transform the single rain-fed agricultural economy of these rural communities into more diverse agricultural patterns could be very important, as a diverse agricultural economy can enhance more wealth creation.

4.3 ENERGY RESOURCES IN GHANA

Despite limited coal, oil and gas resources, Ghana possesses abundant alternative energy resources, all of which are renewable[29]. These include biomass, solar, wind and small hydro energy resources (Painuly and Fenhann, 2002).

4.3.1 Biomass Energy Resource

Biomass energy includes woodfuel (firewood and charcoal), wood, crop residues and human/animal waste, and is the most important energy resource in terms of endowment and utilisation (African Economic Outlook, 2003). About 69 percent of the energy consumed in Ghana is biomass (ibid, 2003), with woodfuel dominant. Petroleum products and electricity consumption account for 21 and 10 percent respectively. Edjekumhene *et al* (2001) group woodfuel-based products for energy into forest woodland resources, logging residues, wood processing residues and crops residues.

4.3.1a. Forest/Woodland Resources

The ecological zones of Ghana are broadly divided into savannah and the closed forest. The savannah zone covers a total estimated area of 9.6 million hectares of which 2.9 hectares is bush fallow (Nketia, 1992). The remainder is degraded savanna. At 8.2 million ha the closed forest zone covers a little more than a third of the country's total land area, 20 percent of which is demarcated either as forest reserves

[29] However, there are indications of oil and natural gas resources (but these are not in commercial quantities); no nuclear power plant in operation and no coal resource or coal plant (Ahiatahu-Togobo, 2005).

or fuelwood plantations (ibid, 1992). Altogether, forest reserves in the country cover about 2.47 million hectares (10.5 percent of the total land area).

Forest reserves are evenly split between production reserves (1.2 million ha) and protective reserves (1.3 million ha) (Edjekumhene *et al*, 2001). The production reserves are managed for both timber and non-timber forest products; whilst the protective reserves are managed for environmental protection and are closed for timber exploitation. Although Ghana's forest resources have declined, it is estimated that 1.4 million cubic metres of timber can still be produced annually for an indefinite period of time, assuming a felling cycle of 60 years (FORIG, 1992 cited in Edjekumhene *et al*, 2001).

4.3.1b. Logging Residues

Logging residues (stump trunk cut-offs and branch wood) constitute 50 percent of the timber felled ((Edjekumhene *et al*, 2001). These are left behind in the forest and according to Edjekumhene *et al* (2001) "in 1990 an estimated 688,262 tons of residue was generated from logging activities alone" (p.42). Unfortunately, only a small percentage of these logging residues are being utilised.

4.3.1c. Wood Processing Residues

Residues from the wood processing industry provide an abundant source of woody biomass in Ghana, especially within the tropical forest zone. Of the 806,000m^3 of log equivalent processed in Ghana in 1993, 518,000 m^3 went to waste (FPIB, 1993). Wastes from wood processing can be classified into "solids" and "fines". "Solids" comprise barks, slabs, edgings, off cuts, veneer waste; while "fines" include sawdust, planes, shavings and sander dust. A large percentage of wood processing residues in

Ghana belong to the “solids’” category (Edjekumhene *et al*, 2001). In 1988, 79 percent of processing waste was “solids” and 21 percent “fines” (ibid, 2001). Table 4.4 shows production of sawmill residue in Ghana from 1990 to 1994 in cubic metres of Solid Weight Equivalent (m^3 SWE).

Table 4.4 Sawmill residue production (m^3 SWE)

Year	*Slabs and edgings*	*Off-cuts*	*Sawdust*	*Total*
1990	38,220	393,120	158,340	**589,680**
1991	35,490	365,040	147,030	**547,560**
1992	39,935	410,760	165,445	**616,140**
1993	41,510	426,960	171,970	**640,440**
1994	38,850	399,600	160,950	**599,400**

Source: Forestry Commission, 1995.

Table 4.4 indicates that off-cuts (a solid) are the most abundantly produced sawmill residue in Ghana (approximately 67 percent of 1994 residues). Sawdust (a fine) represented about 27 percent of the wood residue generated in 1994, whilst the remaining 6 percent consisted of slabs and edgings. The bulk of this residue (largely the solids) is used off-site, 30 percent as firewood and 70 percent for charcoal production.

4.3.1d Crop Residue and Animal Wastes

Agriculture is the backbone of the Ghanaian economy - contributing about 36 percent GDP (Table 4.3), and employing 60 percent of the country’s labour force. All kinds of tropical crops are cultivated in Ghana, including maize, rice, palm nuts, coconuts, groundnuts. Post-harvest processing of these crops yields residues (maize cobs, rice straw and husks, palm branches, groundnuts shells, coconut shell and husk), which form part of the biomass resource of Ghana. These residues are used in small quantities as domestic fuels that burn rapidly. In many instances, they are used solely for heating purposes, such as in traditional palm oil processing, fish smoking, small scale smelting and palm kernel oil processing (Edjekumhene *et al*, 2001). Table 4.5 is a compilation of the production of some major crops in Ghana in 1990, and their corresponding residues.

Table 4.5 Major agricultural crops in Ghana and their corresponding residues

Crop	Residue	Residue Production (t/t crop)	Total Crop Production '000 tonnes	Residue Production '000 tonnes
Maize	Cob	1.00	553	553
Oil Palm	Shell	0.45	429	193
Paddy rice	Husk	0.23	81	19
Sorghum	Stalk	1.00	135	16
Millet	Stalk	2.00	75	150
Groundnut	Shell	0.50	113	56
Total			**1,3887**	**1,107**

Source : Adapted from Hagan, 1997.

Animal dung can also be used as an energy resource in the country. Livestock rearing, especially cattle, is a major agricultural occupation in the three northern regions and some parts of Greater Accra region. An abundant amount of cow-dung is available from these sources, along with residues. In addition, heaps of dung is generated from abattoirs and slaughterhouses across the country. This resource is available for biogas electricity generation. The first biogas production pilot project in Ghana was established in 1987 in Appolonia, (Greater Accra region), where the inhabitants are predominantly cattle keepers; and cattle dung has been the main source of raw materials feeding the biogas digesters (Osei-Safo, 1998).

4.3.2 Solar Energy Resource

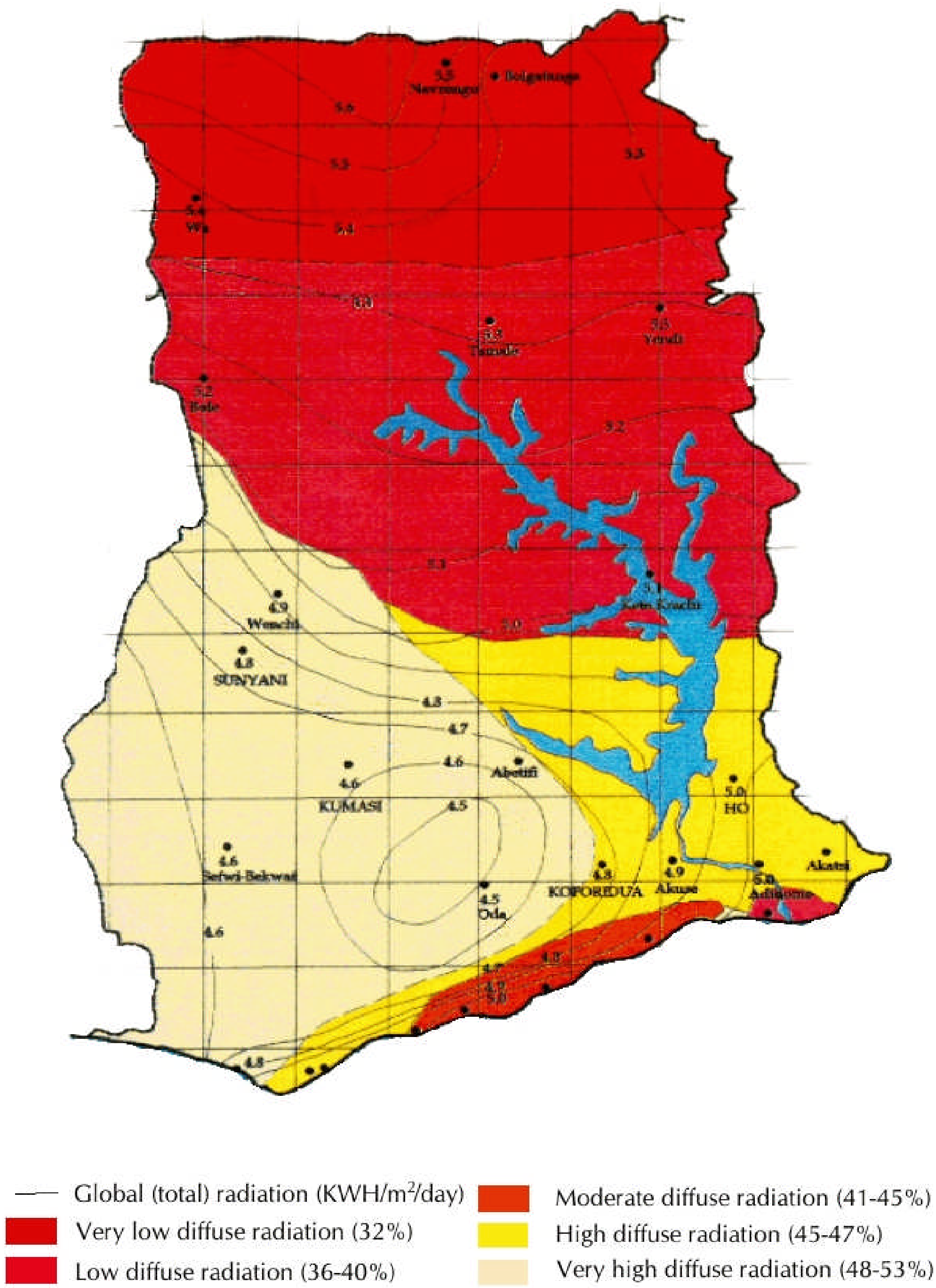
By virtue of its location in the tropics (see Figures: 4.1 and 4.2), Ghana has abundant solar energy. A daily solar irradiation ranging between 4 and 6 kWh/m^2 is available; with a corresponding annual sunshine duration of 1800-3000 hours (Essandoh-Yeddu, 1994; Hamlin and Ofori-Nyarko, 2005).

However, the amount of radiation, both direct and diffuse, which the country receives, shows strong geographic variations (Figure 4.4). The northern regions (the case study sites A and B of this research (see Figure 3.1 in Chapter three)) and the narrow coastal belt, stretching through Greater Accra and Central regions, experience very low diffuse[30] radiation levels (32 percent) (see Figure 4.4), due to their unimodal monsoon rainfall regime. A unimodal rainfall regime is characterised by long periods of dry seasons that stay cloudless and a very short rainy season. The absence of clouds for much of the year therefore gives rise to the very low diffused radiation. These regions have therefore got a very high potential for solar PV technology application.

By contrast and because of its bimodal rainfall regime, most of the southern parts of the country (especially, Brong Ahafo region, Ashanti region, the eastern section of the Eastern region, and the entire Western region) experience higher diffuse radiation (over 45 percent - see Figure 4.6). Solar PV potential is lower here.

[30] Diffusion radiation is radiation that has been scattered by atmospheric constituents (e.g. clouds, particulates, aerosols).

Figure 4.6 Solar Radiation map of Ghana



Source: Adapted from Edjekumhene *et al*, 2001.

4.3.3 Wind Energy Resource

It was formerly thought that Ghana lacked major wind energy resources. For instance the land wind resource assessment undertaken in 2002 by the Energy Commission of

Ghana, resulted in a very poor wind speed regime of less than 3m/s at 10 metres height for most months of the year. However, new studies have shown that, in fact, Ghana has considerable potential.

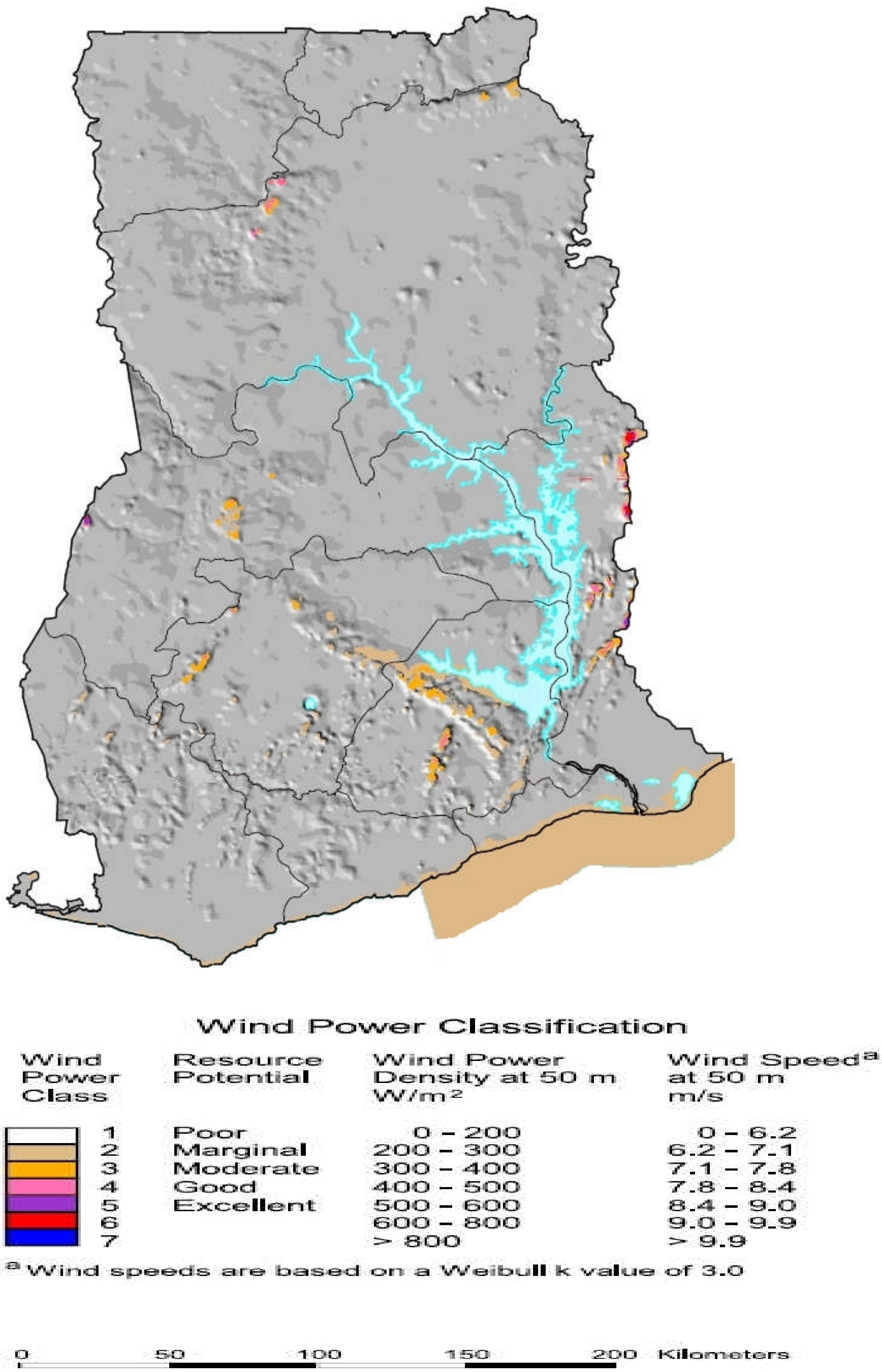
An initial assessment conducted in 2005 by the Energy Commission of Ghana and the UNDP, revealed more than 2,000 MW of wind energy potential (UNDP, 2005). A wind resource map has been developed for Ghana, from satellite data, which was taken at 70 m above ground level (Hamlin and Ofori-Nyarko, 2005) (Figure 4.5). As the map demonstrates, the Ghana-Togo border has the strongest winds in the country - with an annual mean of >9.0 m/s. High wind speed regimes are also observable along the coast, east of the meridian, the Accra Plains, and on the Kwahu and Gambaga mountains (each with an annual mean wind speed ranging from 5.5 to 6.5 m/s) (Table 4.6). In the same vein, there are considerable wind resources in the eastern part of the Upper East region as well as the western part of the Upper West region - the annual mean wind speed being >5.0 m/s.

Table 4.6 Wind Energy - Ghana

Location	***Annual Mean Wind Speed at 12 Metre Height Ground Level (Metre/second)***
Tema	6.0
Kpone	5.5
Lolonya	6.5
Adaoah	6.4
Pute	6.5

Source: Brew-Hammond, 1999.

Figure 4.7 Wind resource map of Ghana



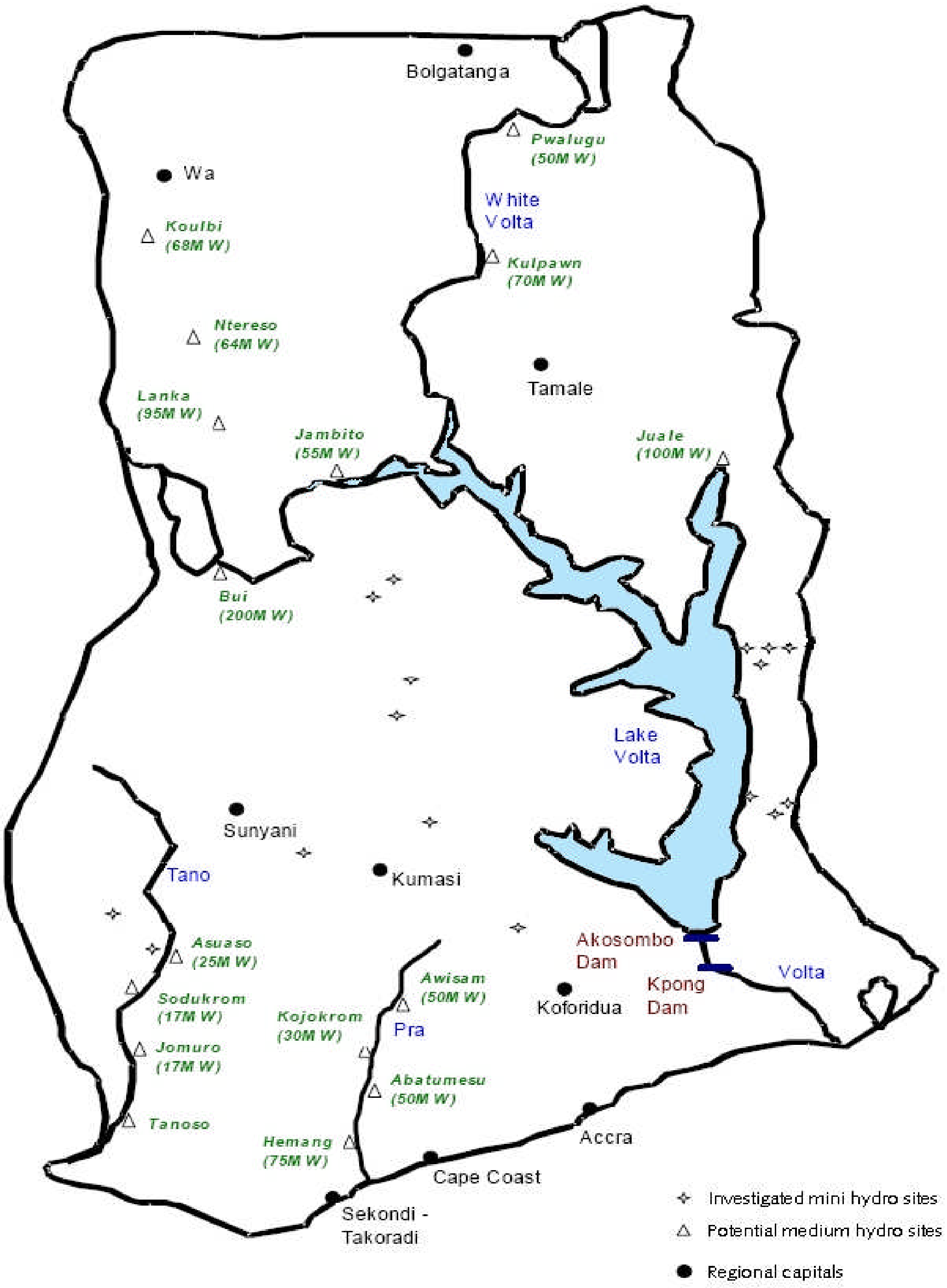
Source: Adapted from National Renewable Energy Laboratory, 2004.

4.3.4 Hydro Energy Resources

Ghana's rivers have considerable hydro electricity potential and hydropower has been the main source of electricity generation for many years. Until early 1998[31], virtually all of Ghana's electricity was produced from two large dams on the Volta River at Akosombo and Kpong, with a combined capacity of 1,198 MW (RCEER, 2005). It is now estimated that Ghana has new hydro electricity resource potential for a further 2,000 MW (Edjekumhene *et al* (2002), citing Akuffo, F.O. (1998). Approximately 1,205 MW of this is expected to be produced from proven large rivers, while the rest will come from small rivers. In a series of studies conducted since 1979 to assess the potential of Small Hydro Power (SHP)[32] approximately forty SHP sites were identified. In the view of ESI-Africa (2004), the most attractive of all these hydro resource potentials is the 200 MW Bui dam on the Black Volta. According to different models, small hydro potential in Ghana has been estimated between 1.2 MW and 14 MW (Painuly and Fenhann, 2002). Figure 4.8 shows the locations of the potential hydro resource sites in the country.

[31] In 1998, thermal electricity generation became incorporated into Ghana's electricity generation system after it experienced a shortfall in hydro-electricity generation in that year.
[32] Small Hydro Power (SHP) is defined as any hydro installation rated at less than 10 MW

Figure 4.8 Map of Ghana showing identified medium and small hydro sites



Source: Adapted from Kilitsi, 2003.

4.3.5 Other Energy Resources (Fossil Fuel Resources)

Ghana has no nuclear power plant in operation, and has neither coal resources nor coal-fired plants. However, there are indications of small amounts of oil and gas.

Offshore exploration began in the 1970s. In 1977 and 1978 small deposits were discovered off central Ghana (i.e. Saltpond) and in western Ghana (i.e. South Tano) (MBendi Information Services Ltd, 2006). Assessed at 37 million tonnes in 1992, this provided a moderate oil resource (EIC, 2004). Currently, proven land-based, recoverable oil reserves are estimated at 16.5 million barrels, located in five sedimentary basins -- Tano Basin, Saltpond Basin, Accra/Keta Basin, Voltaian Basin and the Cape Three Points Basin (MBendi Information Services Ltd, 2006). The potential of these reserves is yet to be fully realised. At present, Ghana imports all of its crude oil needs. Some gas reserves were also found in the Tano fields, but like the oil, they are not commercially viable.

4.4 THE HISTORY OF ELECTRIC POWER GENERATION AND CURRENT FACILITIES IN GHANA

The development of electricity generation in Ghana can be divided into three phases: pre-Akosombo, the hydro years, and the thermal complementation period (RCEER, 2005). Each of these periods have been characterised by different patterns of electricity generation.

4.4.1 Pre-Akosombo (1914 - 1966)

Between 1914 to 1966, the generation and supply of electricity came from a number of isolated diesel generators, dispersed across the country, in addition to stand-alone electricity supply systems, (privately owned) for mines, factories, municipalities, hospitals, schools, (RCEER, 2005).

In 1914, the first public electricity supply in Ghana was established in Sekondi (Western region) and was operated by the Gold Coast Railway Administration for the railways (RCEER, 2005). In 1928, the power supply was extended to another town called Takoradi[33].

Besides the railway system, the Public Works Department (PWD) also established and operated a public electricity supply in this period. A limited direct current supply to Accra in 1922 was established, switching to an alternating current supply in 1924 (RCEER, 2005). Other towns and municipalities were gradually included: Koforidua in 1926, Kumasi and Winneba in 1927, Cape Coast in 1932, Tamale in 1938, Swedru, Bolgatanga, Dunkwa and Ada in 1948, Nsawam in 1949, and Keta in 1955.

The total electricity demand within this period cannot be fully assessed because of the dispersed nature of supply and other constraining factors in electricity supply at that time. As RCEER (2005) notes 'most of the towns served had supply for only part of the day. In addition to being inadequate, the supply was also very unreliable' (p.17). The growth of electricity consumption was therefore limited during this period.

4.4.2 The Hydro Years (1966-Mid 1980s) - Akosombo and Kpong Hydroelectric Project

4.4.2a Akosombo Hydroelectric Project

The construction of the Akosombo Hydroelectric Dam was linked to the development of bauxite reserves of Ghana as part of an integrated aluminium industry[34]. The potential of the Volta River for hydroelectricity purposes was first identified by Sir Albert Kitson in 1915 (RCEER, 2005). In an official bulletin, he later outlined a scheme for harnessing the water-power and mineral resources of the country. However, the construction of the dam did not start immediately.

[33] This particular town was less than 10 km away from Sekondi.

[34] The development of the dam was very much dependent on the aluminium smelter (now called Volta Aluminium Company - VALCO). Without the presence of the smelter, the hydro dam would not have been established because; it was the industry that could boost its economic viability through offering ready market for the power that was generated.

By the 1950s, efforts to develop the hydroelectricity scheme on the Volta River were stepped up with the publication of a report by Halcrow in 1955[35]. Following an independent assessment on the Halcrow report, Kaiser Engineers[36] recommended the construction of the hydro dam at Akosombo (instead of Ajena as proposed by Halcrow). The main advantage in relocating the dam was that the width of the gorge at the proposed crest elevation of 290 feet was only 2,100 feet compared with 3,740 feet at the Ajena site (Ghana Homepage, 2007b). Also, at the Akosombo site, the maximum depth to bedrock was 80 feet (compared to 40 feet at Ajena).

The construction of the dam formally started in 1961. According to RCEER (2005) '…the first phase of Volta River Development project with the installation of four generating units with total capacity of 588 MW was completed in 1965 and finally commissioned on January 22, 1966' (p.18). Two additional generating units were installed in 1972, bringing the total capacity to 912 MW[37]. Prior to the construction of the dam, the Volta River Authority (VRA) was established in 1961 (through the Volta River Development Act - Act 46). The VRA was charged with generating electricity from the Volta River and supplying it through a transmission system. It was also given the responsibilities of constructing the Akosombo dam and a power station near Akosombo.

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[35] Sir William Halcrow and Partners implemented engineering studies on the possibility of producing power from the Volta River by constructing a dam at Ajena in the Eastern Region of Ghana. A report on this study was published in 1955 (RCEER, 2005).

[36] Kaiser Engineers is an American firm of consulting engineers.

[37] However, after retrofitting work was completed in 2005 March, the capacity increased to 1,038 MW.

4.4.2b Kpong Hydroelectric Project

Following a planning study in 1921[38], Kaiser Engineers proposed that the construction of the Kpong Hydroelectric Dam be located upstream of the Kpong Rapids, with the power station at Penu (RCEER, 2005). The Kaiser study also looked at other potential hydro sites including, the Bui Hydroelectric Plant on the Black Volta, the Pra, Tano and lower White Volta Rivers (Figure 4.6), and the expansion of the Akosombo Plant with the installation of additional units.

A review[39] was carried out on the Kaiser study in 1974 by Acres International from Canada. At the end of this review, besides changing the plant site from Penu to Akuse, the initial Kaiser's recommendation was approved. Construction started immediately and in 1982, the Kpong Hydroelectric Plant was successfully commissioned, with a capacity of 160MW.

4.4.3 Thermal Complementation Period

The thermal complementation period dates from the mid 1980s to the present time, and is characterised by efforts to expand power generation with thermal power plants. A major determining factor in this complementation drive had to do with the natural and inherent characteristics of the Volta River to have very high uneven flows from year to year[40]. Additional thermal generation capacity was therefore needed to serve as a buffer: 'the thermal generators were to serve as an insurance policy against poor hydrological years to meet the demand for electricity in Ghana' (RCEER, 2005: 20).

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[38] This planning study was under the title *"The Ghana Power Study: Engineering and Economic Evaluation of Alternative Means of Meeting VRA Electricity Demands in 1985"*.

[39] This review was also commissioned by VRA

[40] From 1982 to 1984, the Volta Basin recorded its most severe drought in history. 'Total inflow into the reservoir over this three-year period (1982-1984) was less than 15 percent of the long-term expected total' (RCEER, 2005:20). Also in 1998, the Volta Lake suffered low inflows, largely due to poor rainfall. This affected the power generation base of the Volta Lake and consequentially led to power rationing in that year.

Between 1985 and 1992[41] a number of feasibility studies were undertaken on the technical, economic and financial issues of incorporating thermal plants into the energy sector in Ghana. With emerging signs of poor financial viability, the operation was delayed for some time. According to RCEER (2005) "…the first 110-MW combustion turbine unit [to be produced in Ghana] went into operation in December 1997 and the second in January 1998" (p.22). In 1999, another 330-MW thermal power plant was commissioned at Takoradi. It was later retrofitted to a capacity of 550 MW[42]. With this addition, thermal generation began to have a positive impact in the power generation mix of the country.

4.4.4 Current Electric Power System Facilities of Ghana

Current installed electricity generating capacity stands at 1,778 MW. Hydro resources generate 1,198 MW (Akosombo Hydroelectric Power Plant - 1,038MW and Kpong Hydroelectric Power Plant - 160 MW). Thermal energy, mainly from the Takoradi Thermal Power Plant, supplies in total 550 MW. The 30 MW of electric power remaining are generated from the Tema Diesel Power Plant. In addition to local generation a further (ca. 220 MW) supply is imported from Côte d'Ivoire (AEO, 2003).

Although not yet in use, there is also a 125-MW capacity Power Barge[43], called the "Osagyefo Power Barge", which was constructed in Italy in 1995, through

[41]These included *"Combustion Turbine Feasibility Study"* (1990), "*Takoradi Thermal Plant Feasibility Study"* (1992).

[42] In 1999, in line with Ghana Government policy of introducing private sector participation in infrastructural development, VRA was given the mandate to enter into a joint venture with CMS Energy of U.S.A. This joint venture agreement led to the expansion of the Takoradi Thermal Power Plant Station to 550 MW through the addition of 2×110 MW Combustion Turbine plants.

[43] A power barge is a power plant installed on a deck. Meanwhile, the "Osagyefo Power Barge" is lying idle because of the absence of gas.

procurement by the Ghana National Petroleum Corporation (GNPC). It is berthed at Effasu Mangyea in the Western Region of the country.

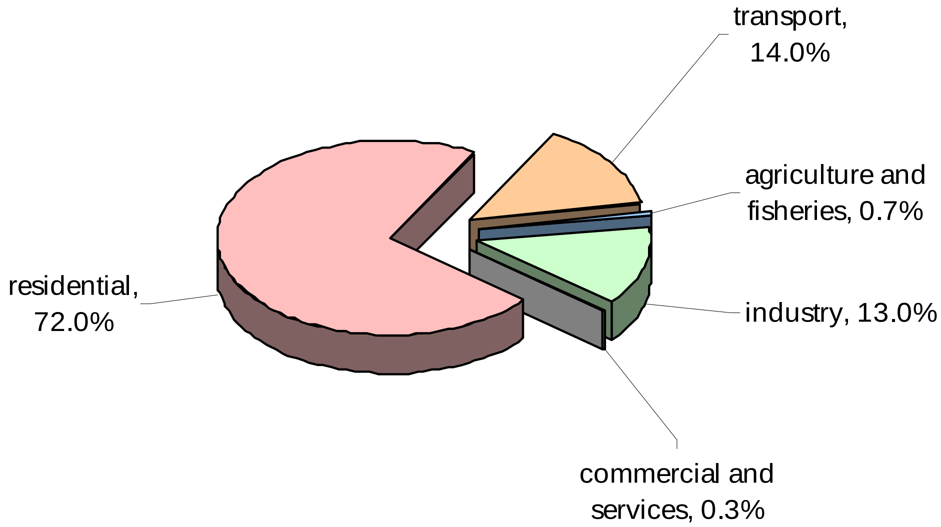
4.5 ENERGY CONSUMPTION PATTERNS IN GHANA

Ghana's annual energy consumption is estimated at 6.6 million tonnes of oil equivalent (toe), with per capita consumption estimated at 360 kilograms of oil equivalent (kgoe) (MOE-GH, 2003). The pattern of energy usage in Ghana is similar to many developing countries in that the bulk of the energy consumed in the country is derived from biomass in the form of firewood and charcoal. According to Amissah-Arthur and Amonoo (2004) "[in Ghana], firewood and charcoal…account for about 59 percent of the total energy consumption, [while] petroleum products and electricity constitute 32 percent and 9 percent respectively" (p.3). Demand for energy in the Ghanaian economy comes from the following sectors - residential[44]; commercial and services; agriculture and fisheries; industry and transport (EC-GH, 2005).

Residential, transport and industry, which are located in the urban areas, dominate energy consumption in Ghana. On the other hand, agricultural activities in the rural areas consume an insignificant amount of the country's energy. EarthTrends (2003) sector data for energy consumption in Ghana in 2003 showed the following pattern - consumptions for residential (72 percent), transport (14 percent) and industry (13 percent); while agriculture/fisheries and commercial/services consume the remaining 1 percent (Figure 4.9).

[44] Rural and urban settlements

Figure 4.9 Total share of sectoral energy consumption in Ghana, 1999 (In thousand metric tonnes of oil equivalent)



Source: Adapted from EarthTrends, 2003.

Currently only 43 percent of Ghana's population have access to electricity (Ghana Population Census, 2002). There is an urban bias with 77 percent of urban households connected, but only 17 percent of rural ones (AEO, 2003). As a result of population growth, urbanisation[45] and economic expansion, demand for all forms of energy in Ghana is steadily growing. According to AEO (2003) "The demand for fuel wood and charcoal is estimated to be increasing at 3 percent per annum; electricity demand is growing at about 7 percent per annum, while consumption of petroleum products is estimated to be growing at an annual 8 percent" (p. 173).

4.5.1 General Characteristics of Rural Energy Use

Energy use in rural areas can be broken down into the household, agricultural and small-scale rural industry sub-sectors and services (WEC/FAO, 1999). Since the

[45] Urbanisation is expected to increase from around 40 percent in 2000 to about 55 percent in 2012 and eventually 60 percent by 2020 (EC-GH, 2005).

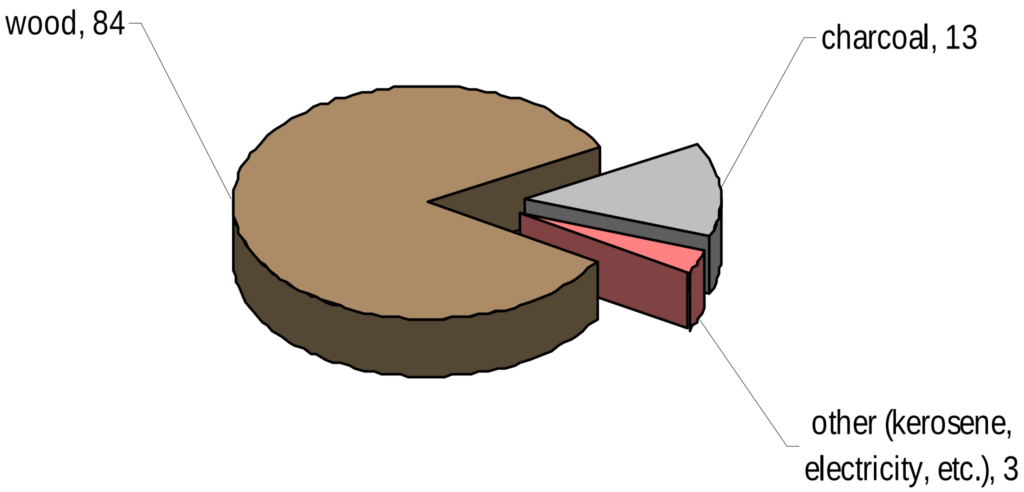
amount of energy use for services (health clinics, schools, street lighting, commerce, transport) is generally quite small in rural areas, it is often included in the rural industries sector.

WEC (1999, pp. 30-31) gives a breakdown of the percentage of energy use in the various sectors of the rural economy for developing countries:

- Households are the major consumers of energy, their share of gross rural energy consumption averages at 85 percent. Most of this is in the form of traditional energy sources used for cooking and heating, which constitutes 80 to 90 percent of the energy used by households.
- Agricultural activities consume from 2 to 8 percent of the total, depending on levels of mechanisation, mainly in the form of commercial energy used to power mechanical equipment.
- Commercial energy, mainly kerosene and electricity where available, is mainly used for lighting, which on average constitutes about 2 to 10 percent of total rural consumption.
- The energy consumption of industries, including both cottage industries and village level enterprises, amounts to less than 10 percent. Woodfuel and agricultural residues constitute the principal sources of supply for these activities.
- Religious festivals, celebrations, burials and other occasional functions may also sometimes consume fuel in rural areas.

In rural Ghana (Figure 4.10), the majority of households (estimated at 84 percent[46]) utilise fuel-wood in its untransformed state for cooking. A further 13 percent depend on charcoal while all other sources, (electricity, kerosene and LPG), together account for less than 3 percent of consumption in their cooking activities (Amissah-Arthur and Amonoo, 2004).

Figure 4.10 Sources of household fuel for cooking in rural Ghana

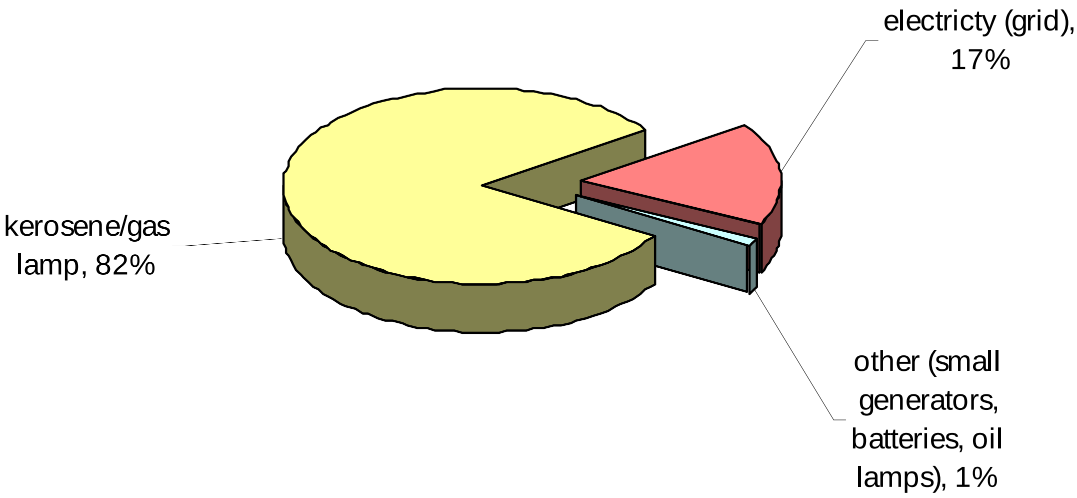


Source: Adapted from Amissah-Arthur and Amonoo, 2004.

For lighting, kerosene lamps are the most popular. According to EC-GH (2005) "about 57 percent of the entire population of Ghana uses kerosene for lighting" (p.4). Figure 4.11 shows the pattern of Ghana's rural household lighting: kerosene/gas lamps (82 percent), grid electricity (17 percent), and others, including diesel/petrol generators, candle, dry cell batteries, and vegetable oil lamps (1 percent) (School of Engineering - KNUST, 2003; Amissah-Arthur and Amonoo, 2004). In Chapter Five, energy use patterns derived from the survey data in the rural areas are presented.

[46] In 2000, the Ghana Living Standards Survey-4 estimates put this figure at 89.2%

Figure 4.11 Sources of household lighting in rural Ghana

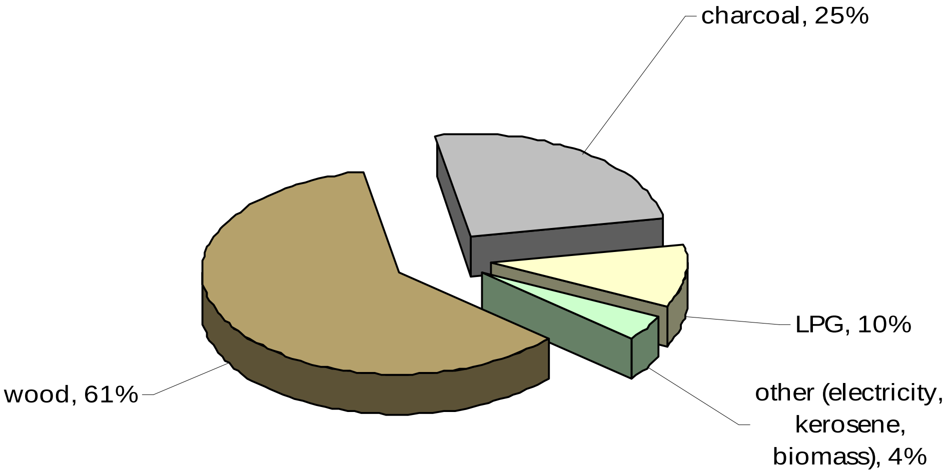


Source: Adapted from Amissah-Arthur and Amonoo, 2004.

4.5.2 Energy Consumption - Urban Ghana

Energy sources in the urban areas of Ghana are more varied than in the rural areas. Biomass (mainly charcoal) still plays a crucial role, especially in cooking, and is the dominant cooking fuel in urban Ghana, (Figure 4.12). According to EC-GH (2005) “about 61 percent of urban households use charcoal as their main fuel for cooking” (p.3). An additional 25 percent use fuel-wood and a further 10 percent use LPG as their main energy resources for cooking (ibid). The other 4 percent meet their cooking energy needs through electricity, kerosene and crop residues (Amissah-Arthur and Amonoo, 2004).

Figure 4.12 Sources of household fuel for cooking in urban Ghana



Source: Adapted from Amissah-Arthur and Amonoo, 2004.

Electricity is more a feature of higher and middle-income households. Whilst 88 percent of urban households use electricity, lighting and refrigeration respectively account for 45 percent and 20 percent of total electricity consumed in urban households (EC-GH, 2005).

4.6 BACKGROUND TO RURAL ELECTRIFICATION AND THE USE OF SOLAR PV IN RURAL ELECTRIFICATION PROGRMAMMES IN GHANA

Rural electrification programmes rolled out in the 1980s. In line with the Economic Recovery Programme (ERP) of the 1980s, the Government of Ghana (GOG) instituted the National Electrification Scheme (NES) in 1989, the principal instrument to extend the reach of grid electricity[47] to all parts of the country, especially the rural areas, over a period of thirty years, from 1990-2020 (Abavana, 2004). An

[47] Grid electricity is popularly called by the masses as 'AKOSOMBO' because it is derived from the Akosombo dam.

implementation plan was drawn up, made up of six 5-year phases[48] spanning the 30-year period.

Under the NES, by 2020 grid electricity was to be extended to all district capitals[49] and all towns and villages with more than 500 people. A complementary undertaking of the NES was the Self-Help Electrification Project (SHEP). Under this SHEP project, communities that are within 20km radius of existing 33 KV or 11KV sub-transmission line can advance their electrification projects, provided they secure all the poles required for the low voltage (LV) network and have a minimum of 30 percent of the houses within the communities wired (Abavana, 2004). As soon as a community meets these conditions, the government is obliged to provide conductors, pole-top arrangements, transformers and other installation costs needed to supply the community. The NES has been funded by grants, and concessionary (soft) loans from agencies such as European Union (EU), Japan International Cooperation Agency (JICA), Danish International Development Agency (DANIDA), World Bank, Swedish International Development Agency (SIDA), Finnish International Development Agency (FINNIDA).

It is clear from this plan that rural electrification was to be provided through the grid. No provision was made for other forms of electricity generation. Other than SHEP, no measures had been drawn up to ensure the electrification of communities that are remote and fall out of the two conditions (i.e. neither within a 20km of 33KV or 11KV line nor having a population of 500 or above).

[48] Phase 1: [1990-1995]; Phase 2: [1996-2000]; Phases 3, 4, 5, 6 [2001-2020]
[49] All the 110 district capitals had been connected to the national grid (Wisdom Ahiataku-Togobo, 2001).

Only in the late 1990s and 2000s do renewable energy sources, such as solar PV and mini-hydro, begin to feature in the Government's rural energy agenda. Although the first plans to use solar PV in Ghana were drawn up in 1989[50], it was not until the 2001 energy policy framework, entitled "*Energy for Poverty and Economic Growth: Policy Framework, Programmes and Projects*" that the idea of mainstreaming PV for rural electrification emerged. According to Abavana (2004) "the decision to use off-grid applications to electrify certain rural communities is new to the NES, which hitherto was grid-biased, and it is premised on the fact that it will virtually be impossible to electrify certain islands on the Volta Lake and remote areas by extending the national grid" (p.5).

It could be argued that preference was given to solar PV rather than the national grid in this policy as the islands communities in the Volta Lake are concerned, because the country has insufficient technology to extend grid lines through the lake. Furthermore, the issue of cost is entrenched in the plans to electrify remote areas and the islands of the Volta Lake with solar PV. The argument is that solar PV systems offer the least-cost option for rural electrification, especially, for the provision of lighting and power for domestic appliances (Abavana, 2004).

4.7 CONCLUSION

This chapter has described key geographical features and the energy landscape of Ghana, covering both the historical and contemporary perspectives. With an estimated

[50] In an interview with senior civil servant '**A**' in June 2005, he notes that "the concept of solar PV in Ghana started as far back as 1989, when Dr. Charles Wereko Brobby doubled as the energy policy advisor to the minister of energy and the Chief executive of the National Energy Board". Senior civil servant '**A**' is at the Ghana Energy Commission.

population of 21.1 million and an annual growth rate of 1.25%, it is clear from the discussion above that the majority of the people (56.2%) reside in the rural areas.
The terrain of the country is generally low, whilst the climate is tropical, with high temperatures for most of the year, in addition to constant breezes and sunshine. Differences in the regional climates of the northern and southern belts of the country have influenced vegetation patterns (i.e. savannah, tropical high forest, coastal scrub and grassland) across the country.

Ghana has an annual GDP growth rate of 5.7 percent. With this growth comes an increased demand for electricity, especially in the rural areas. Despite the national growth rate, the majority of peasant farmers, especially in the northern of the country, are poor. Climatic conditions and the lack of modern farming practices during the dry season are some of the causes of this poverty. Ghana has diverse energy resources, the bulk of which are renewable (biomass, solar, wind, and hydro). While hydro and biomass resources have been exploited to some extent, the same cannot be said of solar and wind.

The total installed electricity generating capacity in Ghana is 1,778 MW, derived mainly from hydro, thermal and diesel power plants. While estimates put the annual energy consumption of the country at 6.6 million tonnes of oil equivalent, only 43 percent of the entire population has access to electricity. Out of this 43 percent, 77 percent are urban dwellers. Only17 percent rural dwellers have access to electricity. While efforts have been made in the past to provide electricity to rural parts of the country, the national grid was for a long time the sole means of doing so. However, from 2001, the government’s plans have included additional delivery platforms, such as PV systems.

CHAPTER FIVE

FACTORS INFLUENCING THE UP-TAKE AND APPLICATION OF SOLAR PHOTOVOLTAIC ENERGY IN RURAL GHANA

5.1 INTRODUCTION

In the previous chapter, the general geography of Ghana, including its geo-physical and demographic characteristics, energy resources and consumption patterns and the rural economies of the three main zones of Ghana were broadly described. Chapter Four therefore gave a broad overview of the rural economy and its climatic conditions, fundamental to the discussion in Chapter Five.

Social construction of technology (SCOT) theory, discussed in Chapter Two, acknowledges that the features of a society play a major role in determining the types of technologies that are adopted, because the social, cultural, economic and technical relations in a society shape its norms and values, which in turn influence the meaning that social groups give to the technologies (Mackenzie and Wajcman, 1985; Pinch and Bijker, 1987). Thus, in order to address objective three of this research, it is essential to explore the background characteristics of the different groups of respondents in the three main case study sites in this research - Kunsu commercial farming community, Wa west and Bunkpurugu/Yunyoo districts.

This chapter therefore provides a critical analysis of the various dimensions of solar PV technology's up-take and application in rural Ghana. It explores the questionnaire data for households and the transcripts of the formal and informal interviews that were collected in the field. The analysis is carried out within the framework of the social construction of technology, which is the theoretical foundation of this research. Results in this chapter show that economic factors form part of the complex web of issues that determine the adoption and non-adoption processes of solar PV, but they are not the sole determinants as has always been demonstrated by solar PV advocates.

Chapter Five is divided into seven main sections, commencing with this introduction. Section 5.2 introduces the social and households' characteristics of respondents in the three case study areas from the field survey. In section 5.3, the patterns of energy consumption in the rural areas are analysed in the three case study sites. Section 5.4 discusses the different ways in which solar PV is used in the case study sites, where solar PV is found. In section 5.5, detailed outlines of the solar PV projects that were undertaken in two of the case study sites (Wa west and Bunkpurugu/Yunyoo districts) are given, to provide a background that will enrich the discussion in section 5.6 and the sustainability issues that are examined in Chapter Six. In particular, section 5.6 highlights the different strands, which shape the adoption or non-adoption of solar PV energy technology in the case study sites. Section 5.7 concludes this chapter.

5.2 SOCIAL STRUCTURE AND HOUSEHOLDS' CHARACTERISTICS IN THE CASE STUDY AREAS

As spelt out in Chapter Three, empirical data were gathered from three main case study areas - Kunsu commercial farming community, Wa West and Bunkpurugu/Yunyoo districts, for this study in Ghana. Only respondents without solar photovoltaic were interviewed in the Kunsu commercial farming community, because of the absence of solar photovoltaic installation there. On the other hand, both respondents with and without solar photovoltaic installations were interviewed in Wa west and Bunkpurugu/Yunyoo districts.

5.2.1 Characteristics of Gender of the Sample

Both categories of respondents showed male dominance in their response to the household questionnaires. Ninety-seven percent (97%) and ninety (90%) of respondents without solar photovoltaic and those with solar PV were males respectively. In total, ninety-four percent (94%) of the 50 respondents to the household questionnaires were males and six percent (6%) were females (Table 5.1).

Table 5.1 Gender characteristics of respondents with solar PV and respondents without solar PV in Bunkpurugu/Yunyoo and Wa West districts and Kunsu commercial farming community.

	without solar PV		with solar PV		total	
GENDER	No.	%	No.	%	No.	%
male	29	97	18	90	47	94
female	1	3	2	10	3	6
total	30	100	20	100	50	100

Source: Fieldwork, 2005.

Getting women to respond to the questionnaires was particularly difficult, because in Ghana, husbands are usually the heads of their families. Consequently, most women were not willing to speak to the interviewer unless permission was sought from their husbands. In addition, the respondents have been skewed towards the male gender, because in the majority of the households with solar photovoltaic installations for example, the husband was the main decision maker in the adoption process (Table 5.2). In this regard, women declined to be interviewed once solar PV issues were mentioned, and instead, asked the interviewers to speak to their husbands.

Table 5.2 Decision-maker in the adoption of solar PV - households with solar PV in Bunkpurugu/Yunyoo and Wa West districts.

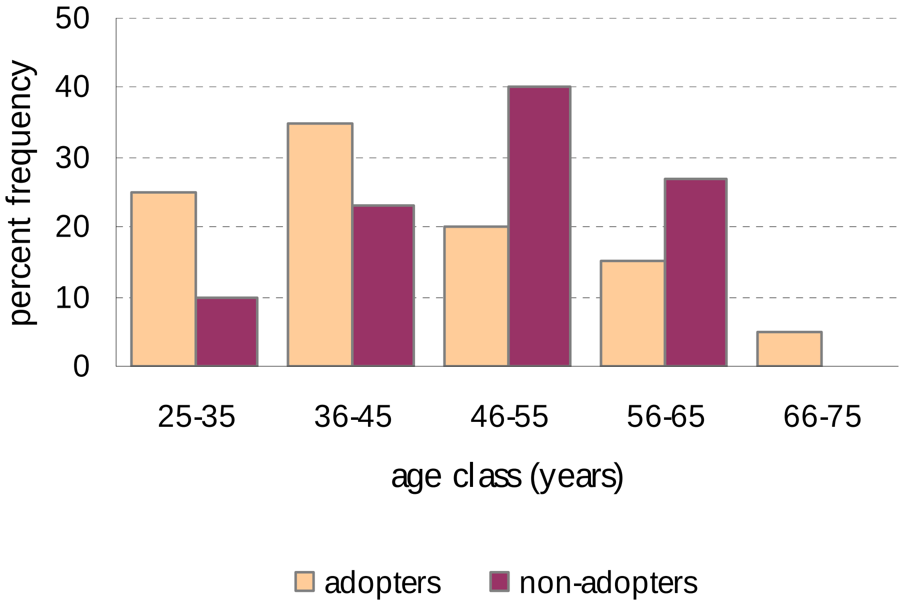
DECISION-MAKER	frequency	%
husband	16	80
whole family	3	15
husband and wife	1	5
total	20	100

Source: Fieldwork, 2005.

5.2.2 Age Characteristics of Sample

The ages of respondents ranged from 25 to 75 years. But the pattern of age distribution in the two categories of respondents (i.e. those with solar and those without solar) differ. The modal age of the 20 respondents with solar photovoltaic technology lies between 36-45 years with 35 percent response rate, whereas the modal age of the 30 respondents without solar photovoltaic technology lies between 46-55 years, with 40 percent response rate (Figure 5.1).

Figure 5.1 Age distribution of respondents with and without solar PV in Wa West and Bunkpurugu/Yunyoo districts



Source: Fieldwork, 2005.

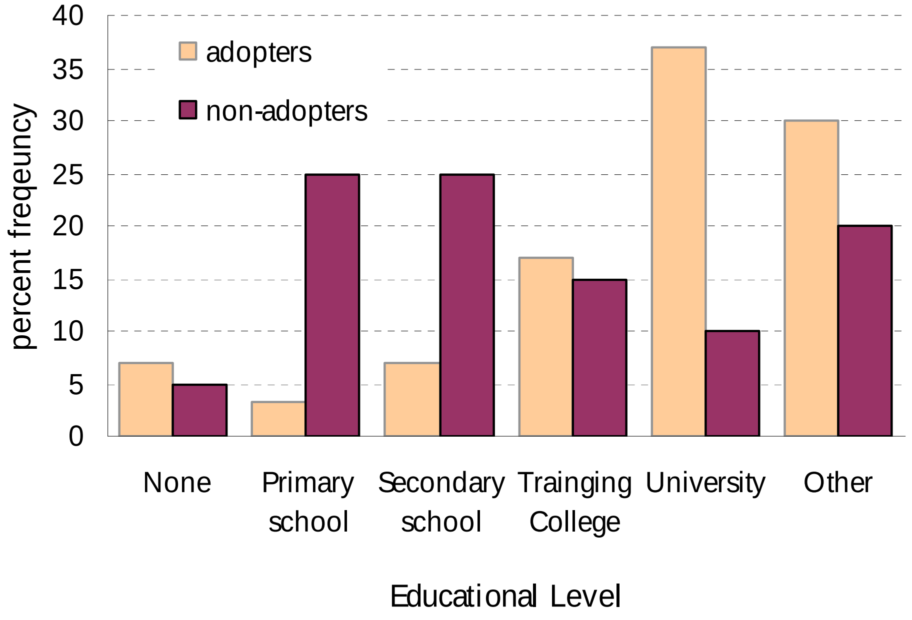
The distinction between the age groups of respondents with solar PV and respondents without solar PV is clear in Figure 5.1. While the majority of respondents with solar PV fall within the younger age brackets (25-35 and 36-45 years) with few respondents in the older age groups, the ages of the respondents without solar PV have been skewed towards the older age categories; 46-55 years and 56-65 years, with very few respondents in the younger age brackets.

The two distribution patterns may be due to age-wealth and age-technology issues. In rural Ghana, the older one becomes the less financial resources one has, (depending on the profession) and vice-versa. For example, in the field of agriculture, many older people in the rural areas who cannot engage in large-scale agricultural activities lack adequate and secure income (Chuks, 2004). The imbalance in resources between the youth and older people will ultimately determine the choices made as we shall see later in parts of this chapter. Moreover, younger people tend to be more adventurous and have greater affinity with new technology, as compared to the more cautious nature of the elderly.

5.2.3 Educational Characteristics of Sample

Educational attainment is a key factor which underlies the understanding of the adoption patterns of solar PV in rural Ghana. Evidence from the questionnaire survey shows a distinct difference with respect to the two categories of respondents (see Figure 5.2).

Figure 5.2 Educational status of respondents with and without solar PV in the case study areas -Kunsu commercial farming community, Wa West and Bunkpurugu/Yunyoo districts



Source: Fieldwork, 2005.

Figure 5.2 clearly shows that the percentage of respondents with solar PV increases with higher education and decreases with no education at all or low level of education. By contrast the percentage of responses from respondents without solar PV decreases with higher education and increases with no education at all or low educational levels.

The different levels of educational status of those with and without PV are closely associated with age (Table 5.3). That is, the educational attainment of respondents without solar PV decreases with an increase in age, while educational attainment of respondents with solar PV increases with a decrease in age. In cross-tabulating age with level of education of respondents without solar PV, it was found that 43 percent of all those who have never been to school or attained only primary education were within the age bracket of 46 to 65 years, with only 7 percent attaining secondary education or above (these include teachers' training college education, university education, Polytechnic). On the other hand, using cross-tabulated results of the age variable and educational status of respondents with solar PV, it was found that 50 percent of them had either attained secondary education or above in the age bracket of 25-45 years, with only 5 percent attaining only primary education or with no education.

Table 5.3 Link between age and educational status of respondents with and without solar PV in Kunsu commercial farming community, Wa West and Bunpkurugu/Yunyoo districts

FREQUENCY	age class (years) adopters			age class (years) non-adopters		
	25-45	46-65	> 66	25-46	46-66	> 67
none or primary	1	5	1	7	13	0
secondary or highe	10	4	0	8	2	0
total	11	9	1	15	15	0

PERCENT	age class (years) adopters			age class (years) non-adopters		
	25-45	46-65	> 66	25-46	46-66	> 67
none or primary	5	20	5	23	40	0
secondary or highe	50	20	0	27	7	0
total	55	40	5	50	47	0

Source: Fieldwork, 2005.

The low level of education among the older respondents could be due to the lack of availability and enthusiasm for education in the past. It could be argued that with the main economic activity being agriculture, parents saw no economic advantage at that time in educating their children, because sending children away to school reduced a family's labour force, without the assurance of an ultimate return.

5.2.4 Leadership Characteristics of Sample

The survey of leadership characteristics of the two different groups of respondents revealed that 75 percent of respondents with solar PV hold civic[51] leadership positions in the community compared to 37 percent for those without solar PV (Table 5.4). It could be argued that the low level of educational attainment by respondents without solar PV is a factor that influences the number of leadership positions they hold. Currently, in Ghana much prestige is given to those who are literate[52] when it comes to leadership issues, because of the need to communicate fluently in English, read official documents and bring in development projects.

The present generation of chiefs in Ghana, for instance, typically come from very good educational and professional backgrounds that differ markedly from the mainly illiterate background of previous chiefs. Accordingly, in Ghana and Nigeria today, there are increasing numbers of professionals and educated people accepting and even looking for chiefly positions (Adjaye and Misawa, 2006). Although fewer queen mothers are as well educated, there is a widespread effort to persuade educated women to take the position of a queen mother and bring education and development into the villages or regions.

[51] These include the village development committee, unit committee, assembly membership and chieftaincy.
[52] For example, the current rule is that all chiefs in the rural areas must be literates.

Table 5.4 Leadership characteristics of respondents with and without solar PV in case study areas - Kunsu commercial farming community, Wa West and Bunkpurugu/Yunyoo Districts

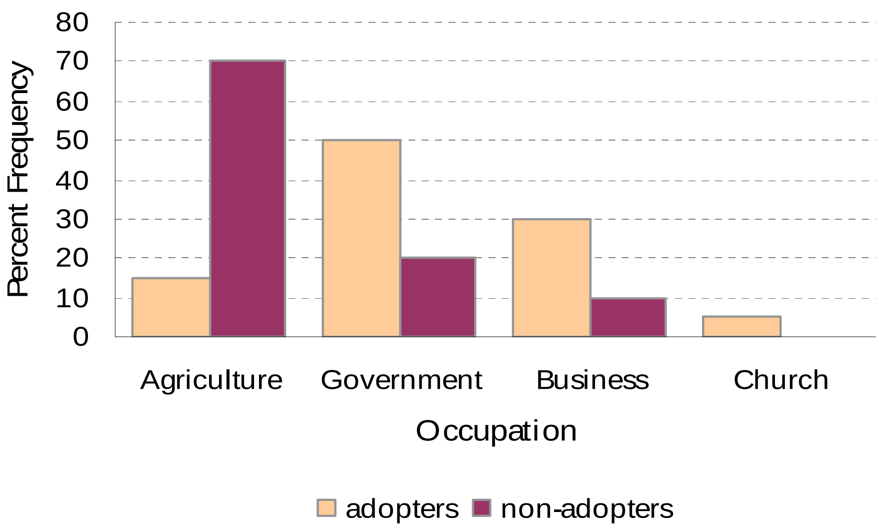
	adopters		non-adopters	
LEADERSHIP POSITION	No.	%	No.	%
None	5	25	19	63
Development Committee memb	6	30	2	7
Unit Committee Member	8	40	7	23
Village Chief	1	5	0	0
Assembly Member	0	0	2	7
Total	20	100	30	100

Source: Fieldwork, 2005.

5.2.5 Characteristics of Occupations of Sample

Survey results from the three case study areas revealed some differences in the occupations of the respondents. With respect to respondents with solar PV in Wa West and Bunkpurugu/Yunyoo districts, approximately 50 percent were government employees, (teachers, nurses or retired teachers); 30 percent in business, 15 percent farmers and 5 percent church leaders (Figure 5.3). Of the 10 government employees, 7 are also part-time subsistence farmers.

Figure 5.3 Occupations of respondents with and without solar PV in Wa West and Bunkpurugu/Yunyoo districts



Source: Fieldwork, 2005.

Employment characteristics of the 20 non-users of PV in Wa west and Bunkpurugu/Yunyoo districts also revealed the following pattern: 70 percent (14) of them were subsistence farmers, 20 percent (4) government employees and 10 percent (2) business men and women. While all the government employees undertake part-time farming, 5 percent (1) also do part-time business. In addition, 29 percent of the full-time subsistence farmers also carry out part-time business activities (Figure 5.3).

On the other hand, 70 percent of the 10 non-PV users in the Kunsu commercial farming community were commercial farmers, 20 percent charcoal burners and 10 percent traders. Meanwhile, 20 percent of these 10 respondents were part-time charcoal burners, with 10 percent each belonging to the commercial farmers and traders.

5.2.6 Summary of the Composite Characteristics of PV users and non-PV Users in the Case Study Areas

In aggregate, it can be argued that from the preceding sub-sections of section 5.2, the composite socio-economic characteristics (age, education, leadership and occupation) of respondents with and without solar PV are very different. The majority of solar PV users are more likely to be young people, well educated, leaders, middle class professionals and traders (who occasionally farm). On the other hand respondents without solar PV are more likely to be characterised by some of the following: old age, poorly educated or with no education at all, no leadership, subsistence farming (with a few involved in commercial farming).

5.3 PATTERNS AND TRENDS OF ENERGY CONSUMPTION IN RURAL AREAS OF GNANA - CASE STUDY AREAS

Survey data helps to reveal the main energy consumption patterns of the three case study areas. In particular, they confirm previous findings about the dominance of biomass in the energy balance, for the provision of cooking energy and the dominance of kerosene for light in rural Ghana as indicated in the previous chapter (section 4.5.1). These consumption patterns are shown in Table 5.5. It should be noted that the three categories in Table 5.5 each sum to more than 100 percent, because of multiple utilisation.

Table 5.5 Main uses of biomass in the three case study sites - Kunsu Farming community, Bunkpurugu/Yunyoo and Wa West districts

USES	adopters Wa west and Binkpurugu/Yunyoo		non-adopters Wa west and Binkpurugu/ Yunyoo		non-adopters Kunsu commercial farming community	
	No.	%	No.	%	No.	%
cooking	20	100	20	100	10	100
heating	9	45	8	40	6	60
lighting	1	5	3	15	3	30
business	11	55	7	35	1	10
rituals	1	5	2	10	1	10

Source: Fieldwork, 2005.

Table 5.5 illustrates the importance of biomass in the households of all the respondents in the three case study areas, irrespective of whether they have solar PV or not. It is clear from the table that while there are differences in terms of percentages between some of the main uses of biomass in households without solar PV and those with solar PV, no differences exist regarding the use of biomass for cooking between them. That is, all respondents, with or without solar PV in the three case study sites

(Kunsu commercial farming community, Wa West and Bunkpurugu/Yunyoo Districts) use biomass for cooking.

It can also be argued that more respondents with solar PV in the Wa West and Bunkpurugu/Yunyoo districts use biomass for business than those without solar PV, because of their 'elitism' in the community. On the other hand, it can be inferred that the number of respondents without solar PV in Kunsu commercial farming area, Wa West and Bunpkurugu/Yunyoo districts who use biomass for lighting, outweigh those with solar PV in the Wa West and Bunkpurugu/Yunyoo districts who use biomass for lighting. This could be attributed to the few lighting sources that non-PV users have as compared to solar PV users.

A summary of the results on the patterns of lighting are presented in Table 5.6 (which consists of all the 30 respondents without solar PV in the three case study areas), and Table 5.7, which covers responses of all the 20 solar PV users.

Table 5.6 Utility of energy sources by respondents without solar PV in the three case study areas (Kunsu commercial Farming Community, Bunkpurugu/Yunyoo and Wa West districts)

	dry-cell batteries		kerosene		shearbutter oil lamp		candle	
USES	No.	%	No.	%	No.	%	No.	%
lighting	30	100	30	100	17	57	8	27
cooking	0	0	3	10	0	0	0	0
radio/tape player	27	90	0	0	0	0	0	0

Source: Fieldwork, 2005.

Tables 5.6 and 5.7 show that kerosene and dry cell batteries are the most significant sources of lighting. Of the 30 respondents (Table 5.6) without solar PV in the three case study areas, all (100%) use kerosene and dry cell batteries for their lighting needs, although this fuel is also used to meet other needs. Sheabutter oil lamps and candles are also used for lighting - 57 and 27 percent respectively by these rural inhabitants.

In Table 5.7 below, despite the use of solar PV (Table 5.8), the responses showed that dry cell batteries and kerosene still play a very important role in the provision of lighting in rural household with solar PV. Among the 20 interviewees with solar PV, while 90 percent still use kerosene for lighting purposes, 30 percent use dry cell batteries for the same reason. This therefore reflects the inadequacy of solar PV potentials to satisfy all the lighting needs of rural households (see section 5.4).

Table 5.7 Utility of energy sources by respondents with solar PV in the two case study areas - Bunkpurugu/Yunyoo and Wa West Districts

	dry-cell batteries		kerosene		shearbutter oil lamp		candle		solar PV	
USES	No.	%	No.	%	No.	%	No.	%	No.	%
lighting	6	30	18	90	0	0	0	0	20	100
cooking	0	0	2	10	0	0	0	0	0	0
radio/tape player	14	70	0	0	0	0	0	0	17	75

Source: Fieldwork, 2005.

5.4 USES AND IMPACT OF SOLAR PHOTOVOLTAIC SYSTEMS WITHIN THREE[53] YEARS OF THEIR INSTALLATION IN THECASE STUDY AREAS

Interviews with key informants (of the PV industry, rural businesses), plus observations and documents, revealed the different ways in which solar PV[54] has been socially constructed, particularly through its use within the first three years of installation. The associated impacts (i.e. the dynamics of winners and losers in the rural society), are discussed in this section. This is approached through the activities of the rural society, including household, social and communal services, off-farm productive uses, religious activities and the political system.

Although the discussion of the various uses of solar PV is taking place under the aforementioned sub-sectors in the rural society, some issues under some of the sectors are not mutually exclusive. Therefore, some of the ways in which the technology is used might be discussed under more than one sector, depending on the context.

5.4.1 Solar PV and Rural Households

Two main applications or households' uses of solar PV can be identified from the survey data: solar PV for lighting, and entertainment (audiovisual) services.

5.4.1.1 Solar PV for Lighting Service

Results from the field data indicate that a major use of solar PV in the household sector within the case study areas of this research is for lighting (Table 5.8). It should be noted that in conducting the fieldwork, the 20 respondents with PV were asked to

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[53] Three years time-frame has been chosen to examine the uses and impact of solar PV in the case study sites, because the systems worked well only within the first three years of their installation in both case study areas. (Personal communication with senior civil servant '**C'** at the EC-GH) on the 04/07/6.

[54] Majority of solar PV systems that have been supplied to these case study sites are the Solar Home Systems (SHS), which are either 50Wp or 100Wp; and the solar battery lighting systems (See Table 5.13).

indicate all the uses of solar PV in their households. Therefore in Table 5.8, uses of SHS total to more than 100 percent, because some respondents indicated more than one use.

Table 5.8 Main uses of solar PV in beneficiary communities in Wa West and Bunkpurugu/Yunyoo districts

USES	Freq.	%
lighting	20	100
entertainment	15	75
business	4	20
cooking	0	0
education	7	35
agriculture	0	0

Source: Fieldwork, 2005.

Although the sample size of this work is small, Table 5.8 shows that 100 percent (20) of the respondents from households with solar PV indicated lighting service as one of the ways PV had been used within the first three years of its installation. It is clear from Table 5.8 that comparatively, solar PV for lighting dominates among all the other uses. The linkages between lighting service from solar PV and the social welfare of beneficiary households is clear: 88 percent of respondents said the solar PV improved their existing lighting system; 75 percent indicated that solar PV led to a decrease in child accidents from kerosene lamps; and 66 percent noted that solar PV brought more self-esteem to their lives. One respondent said:

"*One of the reasons why I adopted solar PV is that I also wanted to experience all the benefits of electricity, which the beneficiaries of the national grid in the urban areas and other parts of the country are enjoying"*.

Although lighting service from the solar PV is the most frequently noted use within the beneficiary households in the case study areas of this research, its positive impact, however, is not broad-based. Some sections of the houses lose out in the supply of light from the solar PV, which culminates in slowing down vital activities of some members of the households (Table 5.9).

Table 5.9 Parts of the house in which PV light is supplied to, in beneficiary communities in Wa West and Bunkpurugu/Yunyoo districts

PARTS OF THE HOUSE	Freq.	%
bedroom	20	100
bedroom + kitchen	1	5
bedroom + living room	13	65
bedroom + courtyard	6	30

Source: Field Survey, 2005.

From Table 5.9, it can be concluded that most respondents prioritised the installation of the solar PV lighting service in the bed rooms, living rooms and courtyards, to the neglect of the kitchen[55] - a locale, dominated by females in most rural homes. Thus, females, who are the main cooks in the households, are effectively marginalised in

[55] In rural areas of Ghana and in most African countries, the duties of the men and women are well defined. The men hardly go into the kitchen, because their duties cover the tilling of the land, hunting, while the domestic chores, especially cooking and others are the preserve of the women.

relation to this PV lighting service distribution. This finding parallels the outcomes of a study in Kenya in 2004 on intra-household energy allocation. In his work in Kenya, Jacobson (2004) found that "intra-household energy allocation dynamics in Kenya solar homes often favour certain uses, such as television viewing and lighting in the sitting room, over others, such as electric lighting in the kitchen" (p.194).

It is therefore clear from these data that the installation and use of a solar PV system in beneficiary communities in parts of the developing world, does not displace other traditionally established modes of lighting. The way decisions are made in the adoption of different energy technologies in the households, and who the decision makers are (see Table 5.2), partly explain this scenario.

In a question to find out the reasons why respondents prioritised the supply of solar PV lighting service in bed rooms and living rooms, whilst the kitchen is overlooked, the following responses were gathered. Of the 20 respondents, 13 (65 percent) said their choice of the lighting service points in the household was influenced by the limited capacity of the installed solar PV system, whilst seven (35 percent) indicated that their prioritisation was due to the fact that light is needed most in the places where the lighting service points were placed (see Table 5.9) and not the kitchen. Some respondents for example said that:

"When cooking during the night, the women use either the torchlight or kerosene lanterns for visibility purposes. Solar PV is for entertainment and bed rooms".

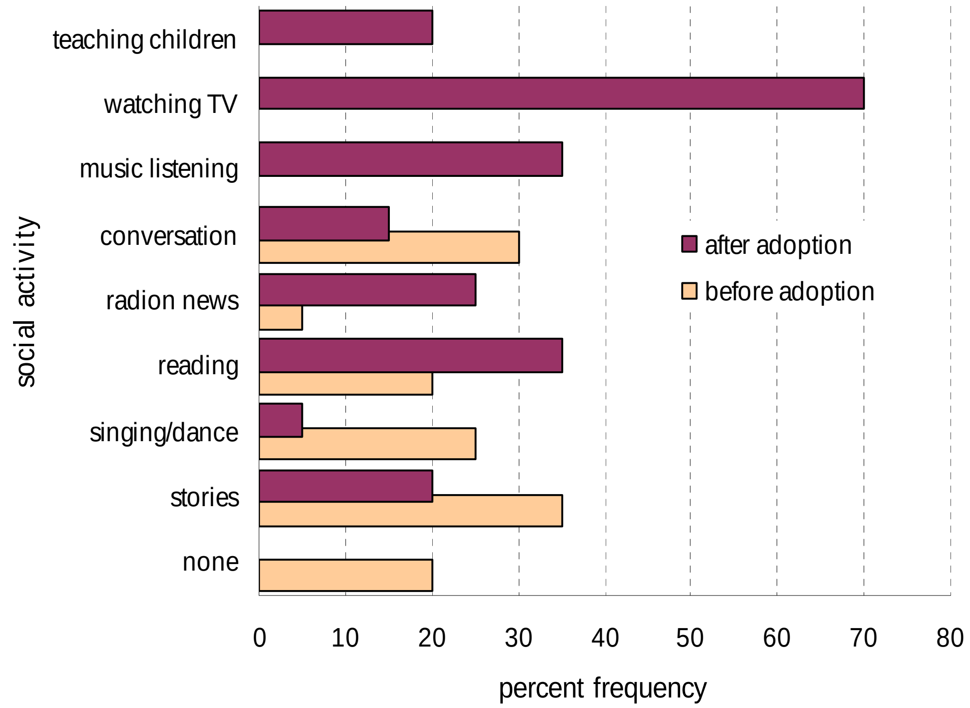
5.4.1.2 Solar PV for Entertainment

Entertainment (TV, radio and tape recorder) is another main use of solar PV within the households in the case study sites that have solar PV. Of the 20 respondents, 75 percent indicated that they used solar PV for entertainment within the first three years after it was installed (see Table 5.8).

The impact of solar PV in the entertainment fabric of rural households in the case study sites is shown in Figure 5.4 below. It is evident from Figure 5.4 that the dominant social activities or entertainment in the households prior to the adoption of solar PV were story telling sessions - (35 percent), conversation - (30 percent) and singing/local dance - (25 percent); while 20 percent engaged in no activities at all. Within the first three years of solar PV adoption, however, the households' entertainment focus changed, whereby TV watching (70 percent), listening to music (35 percent) and listening to radio news (25 percent) take over at the expense of prior activities.

The adoption of solar PV has helped diversified and improved entertainment opportunities for the households, but the emergence of these modern forms of entertainment has a negative impact, particularly in that it seems to undermine traditional and cultural values. The use of solar PV in the rural households may lead to the decline of traditional forms of entertainment including, singing/local dance. Some negative social welfare impacts of audiovisuals service in rural areas, created through the use of solar PV, have been identified by van Campen *et al* (2000) to include: "TV watching is sometimes said to create expectations about (urban) lifestyles, disenchantment with rural life, especially in the young, and thereby contribute to rural-urban migration. …it was also found that some villagers who were beneficiaries of solar battery charging service in Thailand expressed the concern of the new habit of staying up late night watching TV, with a negative impact in terms of decreased amount time devoted sleeping" (p.20).

Figure 5.4 Social activities before and after the adoption of solar PV



Source: Fieldwork, 2005.

5.4.2 Solar PV for Social and Communal Services

Beyond the household use for lighting and entertainment, results of this study showed that solar PV had been used to address various social and communal services, including education, health, water, and street lighting.

5.4.2.1 Solar PV for Education

Education (both formal and informal) in most rural villages in Ghana is now one of the focal points for the communities. Therefore, some respondents viewed solar PV as an amenity that can enhance education in the community. For instance, within the household perspective, before solar PV was adopted, 20 percent of the households listed reading as one of their evening activities. But after the adoption of solar PV, the percentage increased to 35 percent (Figure 5.4). Also, none of the households used to teach children in the evening before solar PV was adopted. However, 20 percent said that teaching children in the evening was one of the social activities in the households after solar PV was adopted (Figure 5.4).

Interviews at rural schools[56] that benefited from solar PV installation in the case study areas showed how solar PV enhances teaching and learning. The benefits of the installed solar PV in one beneficiary community school in Bunkpurugu/Yunyoo district's case study site are outlined below:

"*First of all, solar PV has enhanced effective teaching and learning in school, because the school population is very large, with some classes numbering about 100 pupils, while we have very few staff. So, mostly, teachers are unable to finish their lessons for the day. But because the solar PV is there, they are able to convene classes in the evening for the purposes of finishing the remaining lessons. Secondly, some of the pupils usually organise themselves in the evenings and come to study in the school, because of the availability of the solar light. In addition, the non-formal education group in the village also uses two classrooms from time to time for their evening studies, due to the available solar PV light"* (The Headmaster of Binde Primary School).

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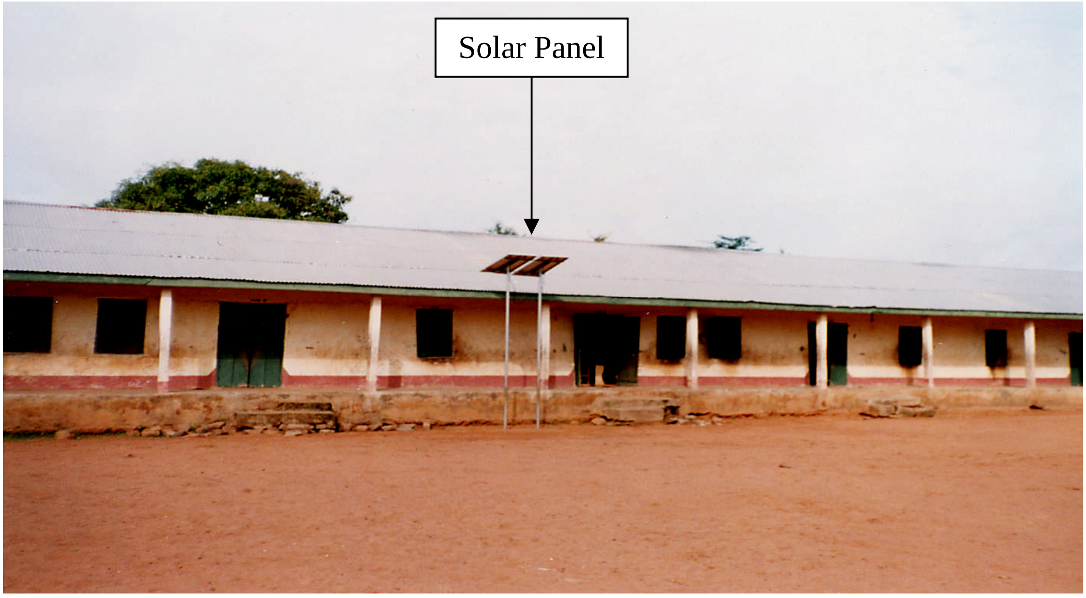
[56] According to solar PV technician **'C'**, four rural elementary schools benefited from solar PV installation in the East Mamprusi district - Binde Primary school, Jimbale Primary, Bimbago and Bunkpurugu Primary schools. However, due to theft cases, the Bimbago and Jimbale systems taken off.

Plate 5.1: Solar PV in Binde primary school



Source: Fieldwork, 2005.

While pupils in Binde primary school now benefit from evening classes and learning by using the solar PV light (see Plate 5.1), teachers in primary schools without solar PV in nearby villages, do not hold evening classes and pupils do not also learn in the evening at the schools' premises. The headmaster of one primary school without solar PV remarked that;

"*Although sometimes we do not finish all our lessons for the day, we do not hold evening classes because there is no light*" (The headmaster of Najong[57] No.2).

The two scenarios described above could have potential different impacts: the schools with solar PV could stimulate more knowledge building among pupils and increased literacy for the illiterate adults; whereas the opposite effect might be felt in rural communities that do not have solar PV in their schools. Ahiataku (2002) for instance notes that "…communities with electricity in Ghana do better in basic school exams than those without electricity" (p.11).

[57] Najong No. 2 is about 6km away from Binde.

5.4.2.2 Solar PV for Health Care

The Binde hospital and the Wechiau health-post (in Bunkpurugu/Yunyoo and Wa West districts respectively) play very important roles in the well-being of the residents. They are the only locally accessible health centres in the two districts and have not been connected to the national grid. The people at the case study sites in Wa west and Bunkpurugu/Yunyoo districts therefore viewed solar PV as addressing a great social need in their communities in the form of improved health facilities.

"Solar PV at the hospital enables us to attend to patients in the night. It is used to run the medical refrigerators, which store vaccines and some other drugs and it also provides energy for the Binde hospital laboratory, where tests are conducted" (A medical assistant, Binde hospital).

The head of the medical team at Wechiau health-post in Wa west district expressed similar views;

"Solar PV lighting facilitates our activities during emergency cases in the night, especially in cases involving complicated child delivery" (The head of the medical of the Wechiau health-post).

Plate 5.2 Solar PV vaccine refrigerator in Binde hospital

Source: Fieldwork, 2005.

As well as these direct social service benefits from solar PV, indirect social benefits are also evident. In the words of the medical assistant at Binde hospital;

"The installation of solar PV in the staff residences also motivates us to stay in the community, because we can derive better lighting from it as well as using it for entertainment" (A medical assistant, Binde hospital).

This response corroborates Bart van Campen *et al's* (2000) findings that "remote, unelectrified rural communities have notorious difficulty to recruit and keep trained medical staff. PV systems providing light, music, TV and communication can be important incentives for professional medical staff, (and also teachers, extensionists) to make life in rural areas more amenable" (p.24).

5.4.2.3 Solar PV for Drinking Water Supply

As a basic necessity, water is often one of the top priorities of every society. According to Van Campen *et al* (2000) "…a reliable supply of clean water can reduce the amount of water-borne diseases; it can contribute to an increase in health, hygiene and convenience, and can help liberate time for other activities, especially for women" (p. 25). In Ghana, 81.2 percent of rural households have no access to pipe-borne water, and mostly depend on streams, rivers and wells (Ahiataku, 2002).

Two villages - Wechiau and Binde in the Wa west and Bunkpurugu/Yunyoo districts respectively, benefited from the installation of solar PV water pumping systems in 2001. These solar PV systems supply the villages with potable water, which is drawn from standing pipes at a number of points. Women especially, felt these solar PV water pumping systems to be highly beneficial. In an informal conversation with a group of three women who were fetching water from a standing water pipe supplied by solar PV system in Wechiau, they expressed the following views that border on the benefits of the solar PV water pumping system:

"Before the solar PV water pump installation, we depended heavily on water from wells, one water hand pump, and rain".

"The water supplied by the solar PV water system is cleaner than what we used to harvest from the rain and fetch from the wells".

"Currently, we do not need to wake up too early to go and queue for potable water at the hand pump site, because there are enough standing pipes at various locations, which supply the water pumped by the solar PV water pumping system".

These views reflect social benefits such as good health, which the community derives from the use of more hygienic water supplied by the solar PV water pump; and more time for women for other activities, due to the less hours they currently spend in fetching water.

Plate 5.3 Solar PV water pump system at Wechiau in Wa West district

Source: Fieldwork, 2005.

5.4.3 Solar PV for off-farm Productive Uses

Field data also reveals that solar PV has brought positive changes to limited off-farm productive activities, which some beneficiaries are engaged in at the case study sites, particularly, small scale commercial businesses and cottage industries.

5.4.3.1 Solar PV for Small Scale Commercial Businesses and Cottage Industries

The most notable small scale commercial businesses to benefit from PV included bars, retail shops, and open coffee/tea selling businesses. To determine the impacts of solar PV on small scale businesses and cottage industries in this research, the following number of rural commercial businesses were interviewed: two bars, one with and one without solar PV; two retail shops, one with and one without solar PV;

and one open coffee/tea selling business. Also four businesses involved in sheanut oil extraction and local beer (i.e. pito) production were interviewed. Table 5.10 summarizes responses relating to changes in closing hours.

Table 5.10 Night closing hours of rural commercial businesses

BUSINESS	pre-PV closing time	post-PV closing time
Bar with PV	21:30-22:00	23:00-24:00
Bar without PV	c. 22:00	c. 22:00
Shop with PV	21:00:-22:00	22:00-23:00
Shop without PV	21:00:-22:00	21:00:-22:00
Coffee/Tea Bar with street PV	c. 22:00	23:00-23:30

Source: Fieldwork, 2005.

The introduction of solar PV has obviously led to changes in the opening hours of businesses in the case study sites (Table 5.10). The bar, the retail shop and the open coffee/tea business with solar PV have prolonged their working hours. In contrast, for the bar and retail shop that have no PV, working hours remained the same.

From the perspective of the owner of the retail shop with solar PV, the improved lighting component of the installed solar PV (compared to the kerosene lantern used in the past) was the reason behind the prolonged working hours. With respect to the bar with solar PV, it was apparent that extended opening hours started after the adoption of solar PV, because of an increase in the number of customers following the introduction of an improved entertainment, powered by solar PV. In an informal conversation with one of the bar attendants, he noted that;

"The majority of us like visiting this bar in the night… because the bar owner usually plays music from his tape for us to dance. For almost all those who like drinking and dancing in this village, this is the bar they come to".

The after-effect of the extended opening hours of these small scale businesses with solar PV could lead to an increase in income generation as compared to those without solar PV. According to the owner of the bar with solar PV;

"Prior to adopting solar PV, my annual sales used to be about 3,000,000 cedis. But after I started using PV, my annual sales level is mostly between 3,000,000 and 4,000,000 cedis".

Some studies have also found a positive correlation between the presence of lighting and entertainment in a rural business and an increase in income generation. For instance, a store in the Dominican Republic experienced a 60 percent increase in daily sales due to the provision of light and radio (Cabraal *et al*, 1996).

While the use of solar PV in the rural commercial businesses might have boosted their returns, the use of solar PV has had no positive impact on cottage industries. The dominant cottage industries in the case study sites are sheanut oil extraction and local beer (pito) breweries. These cottage industries are very important economic activities, which most women carry out to support their households. In both activities, women still need large quantities of woodfuel, as the only viable source of energy. The use of woodfuel has led to the stagnation of these industries, while the current supply and installation of Solar Home Systems (SHSs) are not geared towards the enhancement of the production processes of such cottage industries. Below are some views that were expressed when two local beer brewers and two sheanut oil extractors, all women, were interviewed.

"Production of sheanut oil is declining because it takes a lot of time to collect woodfuel. Right now we have to travel very far before enough woodfuel is collected. As a result, some women have stopped producing sheanut oil and instead, have started trading in the sheanuts" (2 Sheanut oil extractors).

"We need some other types of energy that can be used to brew our local beer (pito) apart from woodfuel. Currently, we can't brew as often as we used to brew, because we need to use a lot of time in search for woodfuel" (2 local beer brewers).

The above views demonstrate that indigenous cottage industries, which form part of the core economic structure of the rural population, especially the poor, have not been enhanced by SHSs. With the exception of cottage industries such as basketry, woodcarving, weaving, and leatherwork (that are little practised in these case study areas), whose activities solar PV illumination can support in the night, it however, does not enhance other cottage industries and agriculture – the main economic activity, because the emphasis of solar PV has been on lighting.

5.4.4 Solar PV for Religious Activities

Religion plays a vital role in the lives of the ordinary people in both urban and rural Ghana. Hence, congregations are generally very willing to improve their places of worship. Analysis of the data from Wa West and Bunkpurugu/Yunyoo districts showed that solar PV has been used for religious purposes:

"Before solar PV was installed in the Binde primary school, there were some churches that used some of the classrooms only during the day on Sundays to worship. However, at the moment some of the churches undertake choir practices and meetings on the school premises in the evening on weekdays, because the solar PV provides light" (The Headteacher, Binde Primary school).

"The congregation of the Najong No.2 Catholic church paid for the installation of the solar PV on the church and pays the monthly fees. We needed the solar PV to enable us to organise our choir practices and prayers in the evenings. Previously, we used to organise our choir practice during the daytime on weekdays as there was no light in the evenings. But the daytime choir practice was always poorly attended, because it overlapped with individual economic activities. Attendance of choir practice has improved now" (Catechist, Najong No.2 Catholic church).

"This mosque has solar PV, because we need better light to serve Allah. When they started supplying solar PV to this community, the leaders of this mosque quickly met with the congregation and expressed the need for it, because it will provide better lighting for us to read the Quran during prayers in the evenings. Solar PV was also important in the mosque, because it was going to provide light for the Arabic instructor to teach our children the Quran (the holy book of Muslims) in the evenings" (The Imam – Wechiau mosque).

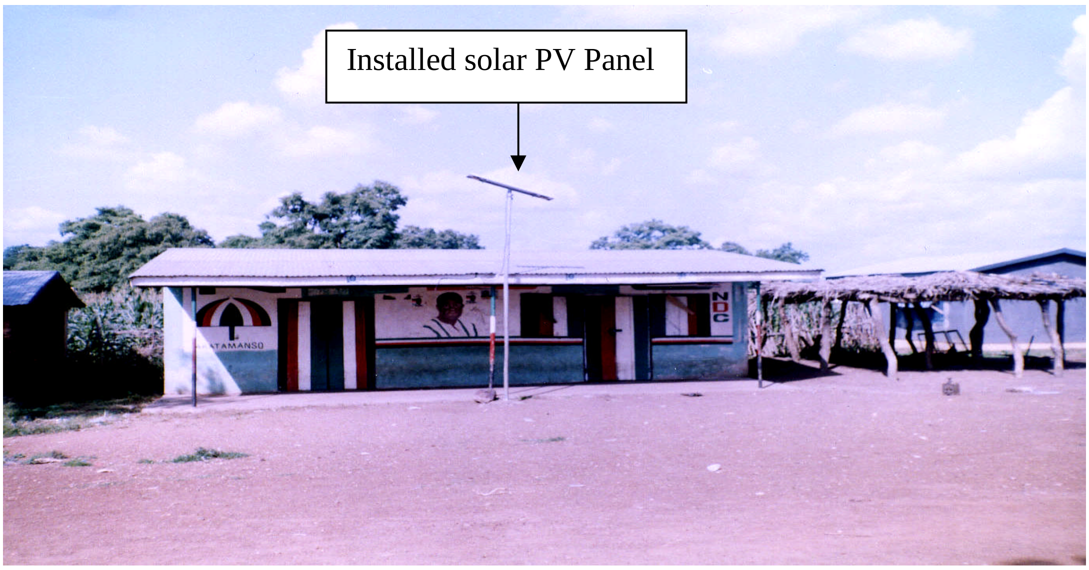
5.4.5 Solar PV for Political 'Vote Capture'

Field data also showed that solar PV has been used politically for 'vote capture' in some villages in the case study areas. The political usage of solar PV in these villages can be conceptualised as being direct and indirect. Democracy in Ghana like most African countries is rudimentary. Hence, the number of votes a parliamentary candidate gets in rural areas does not depend entirely on his/her competence, but sometimes on the ability to demonstrate material wealth.

Vote capture through displays of material wealth - in this instance solar PV, was used in the 2000 and 2004 presidential and parliamentary elections in some rural areas, in order to influence the balance of votes that were cast. In the 2000 elections, the National Democratic Party (NDC) installed a solar PV system in their rural office in Wechiau (Plate 5.4). The main aim of its installation being;

"It was installed to provide light for us to draw campaign plans and also to hold night rallies. No other party in Wechiau could hold night rallies, because they had no light. So for 2000 elections, NDC got majority of the votes because the night rallies helped" (Organiser - NDC Party, Wechiau branch).

Plate 5.4 Branch office of the NDC political party at Wechiau with solar PV



The organiser of the Wechiau NDC party branch clearly thought that solar PV helped the party to capture the majority of votes. A similar pattern of political utilisation of solar PV in the 2004 presidential and parliamentary elections was also noted from the field survey. According to one entrepreneur of solar PV in the northern region,

*"During the last elections (2004), some communities in the northern region that have no electricity, their sitting Members of Parliament (MPs) bought solar lanterns from me and gave them to either the chiefs or their political party leaders in the communities to hold night rallies and campaign for them" (Owner of private solar PV company '**A**').*

5.4.6 Solar PV for Agriculture

From the survey analysis, the use of solar PV for agricultural production in the study areas is non-existent (see Table 5.8), presumably because of the emphasis on lighting at the expense of productive activities. The implication of the non-use of solar PV for agricultural production will be seen in the next section.

5.5 OUTLOOK FOR SOLAR PV PROJECTS IN GHANA, ESPECIALLY, WA WESTAND BUNKPURUGU/YUNYOO DISTRICTS' PROJECTS

Two major solar PV rural electrification projects, mainly demonstrative and evaluative, have been undertaken in Ghana at two different times by the Ministry of Energy (MOE-GH). These are, firstly, the MOE-GH/Spanish Government off-grid solar PV rural electrification project in 1998, and, secondly, the UNDP/GEF and the Government of Ghana Renewable Energy Service Project (RESPRO) in 1999. Wa west District benefited from the former, while Bunkpurugu/Yunyoo District benefited from the latter. A common feature in both projects is that they were funded by donor agencies and came to an end once funds were exhausted. The structural components of these projects are very relevant to our understanding of the adoption or non-adoption behaviour of rural people, as well as the sustainability issues of solar PV in the rural areas.

However, intervening between these two projects, other small scale projects were undertaken across the country, including the Danish International Development Agency/Ministry of Health (DANIDA/MOH) solar refrigeration and lighting projects in some hospitals and clinics, and the REDP/DANIDA solar PV rural electrification project in 2000. Furthermore, prior to 1998, the Canadian International Development Agency/University of Regina/Kwame Nkrumah University of Science and Technology (CIDA/UOR/KNUST) carried out renewable energy project in 1992, while the Technical University of Berlin (TU-Berlin)/KNUST carried out a solar pump project in 1995, both projects on the KNUST campus, to strengthen the capacity and capability of KNUST by way of teaching, on-the-job training, field training .; and to identify a suitable solar powered irrigation pump, respectively. It has been estimated that as of 2002, there had been 4601[58] (the equivalent of 1MWp) PV installations in Ghana, covering different areas of applications (Edjekumhene, 2003) (Table 5.11).

[58] This figure is an approximation of an inventory of all the PV systems that have been installed in the country. However, the majority of these PV systems, especially the home lighting systems, are out of use. In addition, the majority of the water pumping systems, telecommunications, radio transceivers and vaccine refrigeration systems have been installed either by the missionaries, private sector institutions or NGOs.

Table 5.11 Total solar PV installations in Ghana (2002)

APPLICATION	No.
Solar Home System	4,270
Water Pumping	80
Vaccine refrigeration	210
Telecommunications	63
Radio Transceivers	34
Rural telephony	3
Grid-connection	1
Battery Charging Systems	20
Total	4,601

Source: Ghana Ministry of Energy, 2002 (cited in Edjekumhene, 2003).

Table 5.11 shows that at a national level, solar PV installations have mainly been used to provide domestic lighting, with the provision for agricultural application (the mainstay of the rural economy) and cooking (an activity which consumes a lot of rural women time), completely missing out. Compared to lighting, there has been less emphasis on solar PV systems for pumping water for remote areas without access to potable water for themselves and their livestock during the dry season. It can be argued that solar PV for lighting dominates to the neglect of other most important applications such as agriculture (irrigation), because Ghana might have wanted to meet the UNDP/GEF climate change grant's[59] requirement of reducing carbon dioxide emission into the atmosphere; a problem that is thought to be exacerbated by the widespread use of kerosene, the main rural lighting source in developing countries.

[59] The main aim of the UNDP/GEF grant under the climate change focal area is to … "help developing countries and economies in transition to contribute to the overall objective of the United Nations Framework Convention on Climate Change (UNFCCC). It therefore supports projects that reduce or avoid greenhouse gas emissions in the areas of renewable energy, energy efficiency and sustainable transport" (GEF Homepage, 2006).

5.5.1 The Ministry of Energy-Ghana (MOE-GH)/Spanish Government Off-grid Solar Rural Electrification Project

The collaborative solar PV off-grid rural electrification project, which was undertaken in 1998 by the Ministry of Energy (MOE-GH) of Ghana, with solar PV material grant support worth about $2 million from the Spanish Government, was the first major solar PV project to be undertaken in Ghana. Its goal was to assess the social, economic and technical performance of solar PV as an instrument for rural electrification in off-grid communities, by providing demonstration solar PV systems in ten off-grid communities, located further than 20km from the national grid (EC-GH, 2003). These communities were located in the Volta, Eastern, Greater Accra and Upper West regions.

The project had three main foci: (1) community lighting, battery charging centres, and vaccine refrigeration for clinics; (2) street lighting in urban and rural areas; and (3) the installation of panels that have about 54kw power output grid at the Ministry of Energy premises and connected to the grid (EC-GH, 2003). One of the rural communities that benefited from the battery charging centre, street lighting, and solar water pumping systems under this project is Wechiau (one of the case study sites for this research) in Wa west district in the Upper West region.

The framework of implementation and the running of the Wechiau community solar PV rural electrification project was as follows. The first phase of the project began with the installation of a solar PV battery charging centre of 2.1kw to charge individual private batteries on a commercial basis[60]. The Kwame Nkrumah University of Science and Technology (KNUST) was mandated by the MOE-GH to carry out this

[60] Personal communication with senior civil servant **'A'** at the EC-GH, on the 21/07/05.

installation. Having realised that individual private batteries were not enough to make the PV battery charging station commercially viable, the MOE-GH introduced the second phase. In this second phase, the MOE-GH procured 30 battery lighting systems that were manufactured by KNUST, and supplied them to some members of the community. In the third phase, approximately 57 SHSs[61] were installed in some houses in the community.

The supply of the battery lighting systems was administered through a credit scheme. Firstly, interested customers were asked to deposit 50,000 cedis (approximately US$5.50)[62], with the remainder to be spread over a period of four years. When the cost was fully paid, the batteries became their personal property. In the case of the SHSs, the financial model that was used to supply customers was fee-for-service. Customers initially paid 100,000 cedis (US$11) as deposit, prior to installation. Once the solar PV systems were installed, the customers then paid regular monthly tariffs of 15,000 cedis for 50Wp[63] systems and 25,000 cedis for 100Wp[64]. Customers do not own the PV systems at any point in time under the fee-for-service model - they remain the property of the MOE-GH.

The Wechiau community solar PV project was managed by two indigenous groups - the operators of the battery charging centre (2 people) and a solar committee (4-7 people). The operators were recruited and trained by KNUST. Their duties included the charging of batteries commercially and giving charged fees to the solar committee,

[61] The capacities of these SHSs in Wechiau ranged between 50Wp and 100Wp

[62] The cedis, with its symbol - **¢**, is the currency of Ghana. As at 2005 (when the fieldwork for this project was conducted), ¢9,127.42 was the equivalent of US$1.

[63] "50Wp and 100Wp can run about 3 bulbs and a socket to power black and white TV or radio tape; and 5 bulbs and a socket to power black and white TV or radio tape" Senior civil servant **'A'** at the EC-Ghana, on the 21/07/2005.

[64] Personal communication with the old assembly man of Wechiau on the 03/08/05.

and undertaking basic servicing of the community lighting systems[65]. The solar committee was headed by the assemblyman. The duties of this committee were to collect the monthly tariff from the users on behalf of the MOE-GH. A commission of 20 percent on the total amount of tariff collected was always given to the committee (EC-GH, 2003). The committee also had the responsibility of adding the fees accrued from the battery charging station to the 20 percent commission, deposit it at the bank and disbursing it as follows;

- A certain proportion of the amount was to be used for the maintenance of the PV systems - payment of repairs cost, buying of spare parts and also buying of extra batteries.
- Another percentage was to be used to pay the operators at the battery charging centre.

5.5.2 UNDP/GEF and the Government of Ghana's Renewable Energy Services Project (RESPRO)

The second major solar PV rural electrification project is the Renewable Energy Services Project (RESPRO), with an implementation period from 1999 to 2004. It was funded by the Government of Ghana (GOG) and the Global Environment Facility (GEF) through UNDP technical support from the National Renewable Energy Laboratory (NREL) of the United States Department of Energy. RESPRO was therefore established as a special unit of the MOE-GH from 1999 to 2004.

The main aim of RESPRO was to initiate the development of a commercial market for renewable-based electricity services in rural Ghana, with an initial emphasis on solar PV (MOE-GH report GHA/96/G31, 1998). The project was expected to establish

[65] Personal communication with solar PV technician **'A'**, on the 04/08/05.

Africa's first-ever private renewable energy-based rural energy services companies to provide off-grid electricity for households and small-scale industries (EC-GH, 2003). The project's main implementation areas were the East Mamprusi district and the Bunkpurugu/Yunyoo[66] district (one of the study sites) in the Northern region.

RESPRO offered two types of SHSs - 50Wp and 100Wp - that were installed in customers' houses. There were also some community and public installations including a solar PV water pumping system, installation in two schools and street lighting in one community. These were carried out free of charge. However, the main market model for the supply of the SHSs to individual customers was again the fee-for-service. In this project, customers acquired the PV systems by first and foremost filling in a form[67] provided by the project technicians and indicating their choice of either the 50Wp or 100Wp systems. Secondly, they deposited money, which varied depending on the size of the preferred system, prior to installation. "*Prospective clients paid 340,000 cedis deposit for 50Wp system before installation was carried out. Of the 340,000 cedis, 250,000 cedis was the installation fee and the remaining 90,000 cedis was for an advanced tariff for six months. For customers who wanted the 100Wp systems, the deposit was 650,000 cedis prior to installation. 500,000 cedis of this deposit was the installation fee and 150,000 cedis as an advanced tariff for the next six months*"[68] (see Table 5.12). Six months after installation, customers began paying monthly tariffs - 15,000 cedis for a 50Wp system and 25,000 cedis for a

[66] Bunkpurugu and Yunyoo were part of the East Mamprusi district as at the onset of the RESPRO initiative. However, in 2004, a district was created for the Bunkpurugu and Yunyoo surroundings.
[67] There was no signing or thump-printing of contractual documents that detailed the project start and end dates as well as the rights and responsibilities of customers.
[68] Personal communication with solar PV technician **'B'**, on the 06/07/05.

100Wp system. Thus, customers only had the users' rights of the systems, while RESPRO had the property right[69] (the same as the MOE-GH/Spanish project).

Table 5.12 Sizes of SHSs supplied, installation cost and monthly tariffs under RESPRO

SYSTEM SIZE		Installation	Monthly Tariff (after 6 months)
50Wp	installation	¢250000	¢15000
	6 months advance rent	¢90000	
100Wp	installation	¢500000	¢25000
	6 months advance rent	¢150000	

Source: Fieldwork, 2005.

RESPRO was managed by a national co-ordinator, two engineers and six technicians who were responsible for the installation and maintenance of the solar PV systems. RESPRO was structured through a co-ordinating office in Accra; a project office in Tamale, the capital town of Northern region; a field operations office in Nakpanduri[70]; and two satellite offices in Binde and Bunkpurugu. While the project operators charged customers for the installation of the PV systems, repairs and replacement of defective lamps were free. However, when the project ended, not only did these services end, but customers were required to continue to pay the monthly tariff irrespective of whether their systems were functioning or not.

[69] According to solar PV technician **'C'** "whenever a customer defaulted in paying the tariff for three months, his/her PV system was removed". Personal communication with technician **C** on the 25/07/05.
[70] Nakpanduri is the second biggest town after the district capital in East Mamprusi district.

5.6 THE FACTORS SHAPING THE PATTERNS OF ADOPTION AND NON -ADOPTION OF SOLAR PV ENERGY TECHNOLOGY IN THE CASE STUDY SITES

Work on the Social Construction of Technology (SCOT) theory posits that the characteristics of a society play a major role in deciding the types of technologies that are adopted (Mackenzie and Wajcman, 1985; Pinch and Bijker, 1987). In particular, the theory suggests that the social, cultural, economic and technical relations of a society shape its norms and values, in turn influencing the meanings which different social groups assign to various technologies. The analysis in section 5.4 has shown the different ways in which solar PV has been perceived by households and how it has been used in households equipped with it.

Despite the range of meanings that have been assigned to solar PV through its application, the number of people that have adopted or are adopting it in Ghana are few. Responding to a question on whether people like or dislike solar PV, 77 percent of the 30 respondents without solar PV in the three case study sites indicated a dislike for the technology. Only 13 percent said they liked it. In order to understand better the ways in which different groups adopt, fail to adopt and variously utilise solar PV, the following analysis draws on the principles of the SCOT theory to analyse the background characteristics of the surveyed respondents within the three case study sites, focusing particularly on the following dimensions: economic, socio-cultural and behavioural, technical dimension, societal needs and the relative importance of energy for different activities, and political.

5.6.1 The Economic Dimension of the Rural Society

A critical examination of the socio-economic characteristics of respondents with and without solar PV shows that economic circumstances clearly shape the adoption patterns of solar PV, particularly the distribution of wealth. A comparison of the composite socio-economic characteristics (see section 5.3.6) gives further insight into the influence of the economic dimension in the adoption and non-adoption patterns of solar PV. Middle class professionals and business men and women, who earn a regular salary, are more likely to opt for solar PV systems, while the less educated, who are engaged in subsistence farming with irregular income are less likely. Thus, only those with some sort of disposable income could afford the 'luxury' of solar PV. This is evident in Table 5.13, which shows a wealth index of the twenty households with and without solar PV in Wa West and Bunpkurugu/Yunyoo districts.

Table 5.13 Wealth index of households in Wa West and Bunkpurugu/Yunyoo districts

ASSETS	adopters		non-adopters	
Electrical equipment	No.	%	No.	%
Tape player	20	100	13	65
Radio	20	100	16	80
TV	14	70	1	5
Mobile phone	6	30	0	0
Fridge	3	15	0	0
Total score	63 (> 3 per cap.)		30 (c.1 per cap.)	
Mean income (per annum)				
<¢ 5,000,000	0	0	6	30
¢5,000,000-¢10,000,000	6	30	14	70
¢10,000000-¢20000000	11	55	0	0
> ¢20,000000	3	15	0	0
Cattle (no.)				
0	10	50	6	30
1-2	5	25	3	15
3-4	2	10	4	20
5-6	2	10	5	25
> 7	1	0	2	10

Source: Fieldwork, 2005.

Table 5.13 reveals the influence of the economic dimension in the adoption and non-adoption patterns of solar PV, where respondents' educational attainment, occupation and wealth combine to yield a favourable socio-economic context for the adoption of solar PV. The substantial differences of wealth between users and non-users of solar PV are very clear in the table. The majority of solar PV users have higher mean annual incomes than non-users. There is also a great contrast in material assets (i.e. electrical equipment); solar PV users have almost three times as many as non-users. Some 60 percent of households without solar PV in Wa west and Bunkpurugu/Yunyoo districts cited the high cost of solar PV as a reason for non-adoption (Table 5.15). A respondent without solar PV in Bunkpurugu/Yunyoo district remarked that;

"For some of us without regular income, we could not afford the solar PV during the time RESPRO was ongoing not because of the installation cost, but the maintenance cost involved, even though the system will not be my personal property". (See Box 5.1).

Box 5.1 Economic Analysis of the cost of SHS in the two Projects in Ghana

1. Installation Cost:	*50Wp* ¢340,000	*100WP* ¢650,000
2. Value of Recurrent Maintenance cost after the Projects		
A) Lamp replacement *(1*=¢250,000)	¢250,000*3 = ¢750,000	¢250,000*5 ¢1,250,000
B) Battery replacement *(Every 2 years or less)*	¢1,386,613	¢1,386,613
C) Battery water *Replacement cost*	¢146,624	¢146,624
D) Monthly tariff	¢15,000	¢25,000

Source: Fieldwork, 2005.

However, it can be argued that for some of those not adopting the technology, affordability is not always the main issue. For instance, with reference to wealth in terms of the number of cows in a household, as shown in Table 5.13, it is clear that the percentage of households without solar PV that have cows and the number of cows in their possession outweigh that of households with solar PV. Presumably these cattle owners are 'wealthy' and in theory could have afforded to buy solar PV during the time the solar PV projects were underway, (if the number of cows[71] possessed are to be quantified in monetary terms). Moreover, from Table 5.13, about 70 percent of households without solar PV earn an annual mean income of between ¢5,000,000 and ¢10,000,000. Table 5.14 also shows that the annual mean income of respondents in Kunsu commercial community is sufficient to afford SHSs installation. Nonetheless, they have not purchased them. To understand this better we need to continue to explore further the socio-cultural, technical, the priority needs or political dimensions that shape the adoption and non-adoption of solar PV.

Table 5.14 Annual mean income for 2002, 2003, 2004 of Kunsu commercial farming community (Non-PV Users)

Mean income (per annum	No.	%
¢13333333	1	10
¢20000000	2	20
¢23333333	2	20
¢26666667	4	40
¢30000000	1	10
Total	10	100

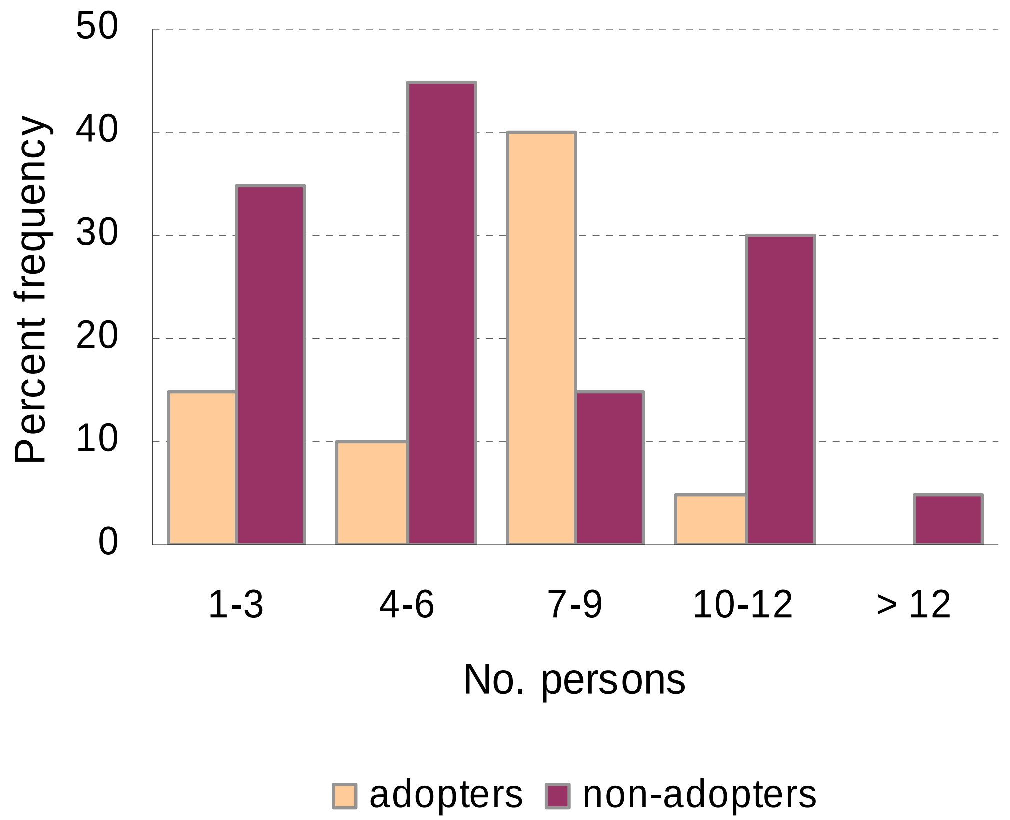
Source: Fieldwork, 2005.

[71] As at 2005, the cost of one cow in Ghana was about ¢3,000,000.

5.6.2 The Socio-cultural and Behavioural Dimension of the Rural Society

As Tables 5.13 and 5.14 reveal, some households without solar PV would seem to have sufficient resources to adopt the SHSs through the two solar projects. However, the analysis indicates that the socio-cultural situations of rural society, particularly household size plays a role in this non-adoption pattern. The size of households is very important as a socio-cultural factor that influences the non-adoption of SHSs by some rural households; because the number of occupants in the household is a key variable in determining the resources available for each member and the quality of life of the family. Figure 5.5 shows the variation in sizes of households of PV users and non-PV users in Wa West and Bunkpurugu/Yunyoo districts.

Figure 5.5 Household sizes in Wa West and Bunkpurugu/Yunyoo districts



Source: Fieldwork, 2005.

Figure 5.5 shows a clear disparity between typical household sizes for those who own SHSs and those without SHSs. The majority of households (80 percent) that adopted SHSs have sizes ranging between 1-6 members, while 70 percent of households without SHSs have sizes[72] between 7-12 members. It would seem that the larger the household size, the more it needs to spend on basic needs and vice versa. The relative large size of households without SHS, coupled with their subsistence agricultural activities, has narrowed their expenditure patterns as compared to small household sizes of the majority of SHS owners, most of whom are professionals. Figure 5.5 also reflects a more 'urban' or modernised 'culture' of professional non-farming households with solar PV (i.e. the decision to adopt solar PV transcends cost-related issue).

Although the sale of one or two cattle[73] could be enough to buy/rent SHS, it is perhaps the case that socio-cultural factors attached to cattle might have prevented the sale of cattle for the purposes of purchasing the technology. In rural Ghana just like most rural areas of Africa, cattle are symbols of social security, prestige, and wealth. In times of great crises, cattle are used in one way or the other to help solve problems; there is also prestige in owning cattle, because cows are symbols of one's wealth and key components of bride prices. As one respondent (with more than 7 cattle, and who has not adopted the SHS) remarked:

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[72] Socio-cultural, religious background, the level of literacy, in one way or the other account for the differences in household sizes, but detailed reasons for differences in household sizes is beyond the scope of this work.

[73] "The people have much wealth more than the cost of the SHS we were supplying, although it might not have been in the form of cash. For instance the man may have more than 10 cattle. May if he sells one cow he can pay for the installation of the SHS. However, these people feel very reluctant to sell their cows…" Senior civil servant **'B'** at the MOE-Ghana. Personal communication with him (06/07/05).

"Eh! Without my cattle, no one will respect me in this village. That is my only wealth" (A cattle owner in Bunkpurugu/Yunyoo district).

Another socio-cultural issue which shapes the non-adoption of solar PV, is the persistent sentiment that the 'Akosombo'[74] (i.e. the National Grid) will be extended to them in the near future. At the mention of electricity in many rural areas in Ghana, Akosombo will be the only point of reference people will make. This is because almost all the district capitals of the country are connected to the grid and are supplied with electricity. Table 5.15 below presents the reasons for the non-use of solar PV by the 10 non-PV users in Kunsu commercial area (where no solar project took place) and the 20 non-PV users in Wa west and Bunkpurugu/Yunyoo districts (where the two solar projects were carried out).

Table 5.15 Reasons for the non-use of SHSs - non-PV users

	non-adopters (Wa west + B/Y Districts)		Kunsu	
REASONS	No.	%	No.	%
Too expensive	12	60	0	0
Not accessible	4	20	10	100
Prefers Grid	16	80	10	100
Lack of PV know-how	13	65	10	100
Unreliable/too complex	11	55	0	0
No knowledge of PV	0	0	10	100

Source: Ghana fieldwork, 2005.

[74] Many people in Ghana refer to the national grid as Akosombo, because it is supplied from the Akosombo dam

From Table 5.15, some responses underscore the socio-cultural aspect of the strong desire for the national grid, a reason cited for the non-adoption of SHSs. Sixteen out of the 20 respondents without PV in Wa west and Bunkpuru/Yunyoo districts indicated that it is the national grid they want and not PV and all 10 respondents in Kunsu commercial farming community indicated likewise. According to one solar PV technician "*some rural people did not adopt the SHSs when the project was ongoing, because of the fear of not getting the national grid once SHS was installed in their houses coupled with the notion that one day the national grid will be supplied to them*"[75]. The view expressed by the solar PV technician **'C'** was corroborated when a respondent without solar PV in Bunkpurugu/Yunyoo district stated that;

"I am prepared to wait for the 'Akosombo' to be supplied to us no matter how long it takes".

On the other hand, the desire for the national grid in the Kunsu farming community could be due to their lack of awareness of the availability of SHS or because they have no access to it, as the statistics reveal in Table 5.15.

Additionally, disharmony among different communities was found to be one of the aspects of the socio-cultural dimension that shape the non-adoption of PV in other rural areas of Ghana besides the case study areas of this project. For a community at loggerheads with another there is a tendency to feel demeaned if SHS is supplied to them, whilst the national grid is supplied to the other, because of the significance and prestige which most rural communities attach to the national grid. A case in point of community disharmony and its influence on the non-adoption of solar PV is the small

[75] Personal communication with solar PV technician **'C'.**

solar project[76] in the Volta River catchment areas. There are two small towns – Kpasa (which had no electricity), and Nkwanta (which was connected to the national grid) in the Volta River catchments. These two communities are inhabited by two different tribes, with a history of mutual hostility. Because of this, solar PV was rejected in Kpasa, because the community felt that solar power was inferior to the national grid in terms of the different services they each provide. The perception was that if the solar PV was accepted, it would have given the Nkwanta people the chance to look down upon them. In order not to feel inferior, the Kpasa people also demanded that their town be connected to the national grid: solar PV was insufficient. This case exemplifies issues of the socio-cultural relations and interpretative flexibility of different social groups (as the SCOT theory posits) and how they shape meaning or perception given to a certain technology.

5.6.3 The Technical Dimension of solar PV

Analysis of the field data raises technical issues surrounding solar PV which shape the non-adoption patterns of SHSs in Wa West and Bunkpurugu/Yunyoo districts. Important issues included technical knowledge (of solar PV systems), technical efficiency and the availability of qualified technicians.

The perceived difficulty of learning to use and understand a particular technology partly determines its acceptance or non-acceptance. As shown in Table 5.15 above, 65 percent and 55 percent of respondents in Wa west and Bunkpurugu/Yunyoo districts respectively attributed their non-use of SHSs to the lack of technical know-how and its complexity. The low level of education of respondents without SHSs in these case

[76] Commentary on this project was given by the senior civil servant **'A'** at the EC-GH through personal communication with him.

study areas reflects their lack of capacity to adapt, operate and maintain solar PV, which in turn influence their decision not to adopt. As two experts pointed out;

"Some ordinary people in the rural areas don't understand how solar PV works and do not like using it" (Energy think-tank **'A'**[77]).

"There is a technical problem in terms of lack of technical expertise among rural populations, and that influences non-adoption of SHSs. Take torchlight for example, it has been rapidly adopted in the rural areas, because they can easily manipulate it and use it as well" (Senior civil servant **'D'**[78]).

Even beyond the lack of technical know-how, the inefficiency of solar PV is another issue that is significant. The short lifespan of some of the installed SHSs components that are expensive to repair, and the inability of SHSs to power demanding appliances such as fridges, fans, creates a great lack of confidence and uncertainty about its efficiency among existing non-adopters. For instance, in Table 5.15 above, 55 percent of the non-PV users in Wa west and Bunkpurugu/Yunyoo districts attributed part of their non-adoption of solar PV to unreliability. This assertion could be due to their observation of the problems, experienced by the 20 solar PV users (see Table 5.16).

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[77] Energy think-tank **'A'** works with African Energy Policy Research Network (AFREPREN/FWD), Kenya.

[78] Personal communication with senior civil servant **'D'** at the EC-GH - August, 2005.

Table 5.16 Problems which SHSs users in Bunkpurugu/Yunyoo and Wa West districts encounter

PROBLEMS	No.	%
Batteries don't last	20	100
No maintainance	17	85
No spare parts	20	100
No technicians	20	100

Source: Fieldwork, 2005.

Related to the problems PV users encounter and their inefficiency is the issue of the number of SHSs still in operation. Out of the 20 solar PV users that were interviewed, nine (45 percent) indicated that their systems were spoilt, while 11 (55 percent) indicated that their systems were still functioning. In his remark, the Wechiau Naa[79] highlighted the inefficiency situation of SHSs in his locality as follows;

"There are only just a few people still using their systems. Most of the systems installed in the houses as well as the street lights, are no longer in use, because the batteries have broken down. We were made to believe that the batteries will last for 10 years. However, some lasted for just two years".

Another technical aspect is the absence of qualified technicians (see Table 5.16). One stakeholder observed that;

[79] Naa is a dagaare word in the language of the people of Upper West region, which means chief. Thus, Wechiau Naa refers to the chief of Wechiau.

"There are very few solar PV technicians in the country who are mostly found in the urban areas. Besides, not all are well versed with the technology, because there are some PV equipments that some of us can't understand. While we can do the right installation, we can't repair them when they break down" (Spokesperson **'A'** from BEST solar Company).

5.6.4 Social Needs and the Relative Importance of Energy for Different Activities in the Rural Society

The needs of different social groups sometimes determine what is present and absent in such societies. Analysis of the field data shows that the different needs of solar PV users and non-PV users in the three case study sites, and the relative importance of energy to different activities, taking into account their diverse backgrounds, are among the mix of factors shaping the adoption and non-adoption patterns of solar PV. The priority needs ranking and the relative importance of energy to different activities differ considerably among the different categories of respondents in the three case study areas as shown in Tables 5.17 to 5.22 below.

In order to reflect their relative importance (i.e. the material things and activities, which energy is needed for in Tables 5.17 to 5.22) to users and non-users of solar PV, a weighting system was devised and used. This weighting system is based on ranked choices, i.e. the number of responses for a particular choice is multiplied by its position in a descending order. The weights are then summed up to reveal the figures that distinguish the priority needs and energy needs of solar PV and non-solar PV users (see bottom half of Tables 5.17 to 5.22). For example, in Table 5.17 and Table 5.18 with nine choices, response of the first choice is multiplied by 9, second choice by 8, third choice by 7 and so on, down to response of the ninth choice, which is multiplied by 1. Table 5.19 has ten choices; hence response of first choice is therefore multiplied by 10 down to response of the tenth choice, which will be multiplied by 1. Tables 5.20 to 5.22 have five rankings each, and follow the same pattern of weighting.

Using the sum of weights of the needs prioritisation of solar PV users and non-PV users in Wa west and Bunkpurugu/Yunyoo districts in Tables 5.17 and 5.18, electricity for lighting was ranked as the second most important needs of solar PV users after food, whereas building of a house was ranked second after food, with electricity eighth by non-PV users. Conversely, electricity was ranked ninth by Kunsu commercial farming community respondents, with the need to expand farmland size or charcoal business ranked second, and building a house first (Table 5.19).

An assessment of the activities in which energy is considered to be very important (see Tables 5.20, 5.21, 5.22) also showed diverse rankings among solar PV users and non-users in the case study sites. Using the sum of weights again, solar PV users in Wa west and Bunkpurugu/Yunyoo districts ranked lighting as the most precious activity for which energy is needed, followed by business and cooking. Non-PV users in the same districts ranked energy for irrigation as the most important activity in which energy is needed, followed by cooking and business. Meanwhile, in the Kunsu commercial farming community, energy for potable water was ranked as most important, followed by energy for cooking and lighting.

Table 5.17 Priority needs ranking (PV users in Wa West and Bunkpurugu/Yunyoo districts)

RANK	food	electricity	education	potable water	house	cattle	open shop	more land	bicycle
1	8	8	4	0	0	0	0	0	0
2	1	5	8	6	0	0	0	0	0
3	5	2	2	6	2	1	0	1	1
4	5	0	2	2	9	1	1	0	0
5	0	2	3	5	5	2	2	1	0
6	1	2	1	0	1	6	3	1	5
7	0	1	0	1	1	3	8	5	1
8	0	0	0	0	2	6	3	7	2
9	0	0	0	0	0	1	3	5	11
Weighted score	149	147	145	130	104	69	61	50	45

Source: Fieldwork, 2005.

Table 5.18 Priority needs ranking (Non-PV users in Wa West and Bunkpurugu/Yunyoo districts)

RANK	food	electricity	education	potable water	house	cattle	open shop	more land	bicycle
1	10	1	0	7	1	1	0	0	0
2	8	0	0	2	9	0	0	0	1
3	1	1	0	5	6	5	1	0	1
4	0	2	2	3	4	5	2	0	1
5	0	2	3	1	0	6	3	0	5
6	0	0	7	1	0	2	5	0	5
7	0	2	6	1	0	0	5	0	5
8	0	9	2	0	0	1	4	1	1
9	0	3	0	0	0	0	0	3	1
Weighted score	167	65	77	144	147	114	77	25	84

Source: Fieldwork, 2005.

Table 5.19 Priority needs ranking (Kunsu commercial farming community – Non-PV users)

RANK	food	electricity	education	potable water	house	cattle	grinding mill	more land	bicycle	tractor
1	0	0	0	0	3	0	0	6	0	1
2	0	0	1	2	1	0	3	1	0	2
3	0	0	0	3	3	0	2	0	1	1
4	0	0	1	1	2	1	2	0	2	1
5	0	0	3	0	1	0	2	0	1	3
6	0	0	2	1	0	2	1	1	3	0
7	0	1	0	3	0	5	0	1	0	0
8	0	0	3	0	0	2	0	1	2	2
9	2	7	0	0	0	0	0	0	1	0
10	8	2	0	0	0	0	0	0	0	0
WEIGHTED SCORES	12	20	53	66	83	43	74	81	51	67

Source: Fieldwork, 2005.

Table 5.20 Different types of activities and the associated relative importance of energy (PV users in Wa West and BunkpuruguYunyoo districts)

RANK	Energy for lighting	Energy for business	Energy for cooking	Energy for entertainment	Energy for irrigation
1	7	6	5	1	2
2	5	5	5	3	2
3	4	5	4	4	3
4	4	3	3	6	4
5	0	1	3	6	9
Weighted score	75	72	66	47	44

Source: Fieldwork, 2005.

Table 5.21 Different types of activities and the associated relative importance of energy (Non-PV users in Wa West and Bunkpurugu/Yunyoo districts)

RANK	Energy for irrigation	Energy for cooking	Energy for business	Energy for lighting	Energy for entertainment
very important	9	5	4	2	0
important	6	7	6	4	0
somewhat important	0	5	4	5	3
less important	3	1	4	6	6
least important	2	2	2	3	11
Weighted score	77	72	66	56	32

Source: Fieldwork, 2005.

Table 5.22 Different types of activities and the associated relative importance of energy (Non-PV users in Kunsu commercial farming community)

RANK	Energy for potable water	Energy for cooking	Energy for lighting	Energy for entertainment	Energy for business
very important	5	4	1	0	0
important	5	5	0	0	0
somewhat important	0	1	5	1	3
less important	0	0	2	6	2
least important	0	0	2	3	5
Weighted score	45	43	26	18	18

Source: Fieldwork, 2005.

We see that the priority needs of those who adopted SHSs differ from those who did not adopt, possibly because of their different socio-economic backgrounds. For instance, because of solar PV non-users' irregular income sources, which is caused by their low levels of education and subsistence agriculture, their needs prioritisation will be different. That is, the priority needs of non-PV users in Wa west and Bunkpurugu/Yunyoo districts focus much more on strengthening their economic standing: shelter and provision of enough food for their households, and not 'luxury' in the form of quality light from solar PV, or entertainment. For example, when a respondent[80] in Bunkpurugu/Yunyoo district, who has a retail shop was asked why he did not buy a SHS, (although he earned about ¢3,000,000 from the store when the RESPRO project was active), he observed that;

"I wanted to expand my business first. Therefore, if I bought the solar PV, I would not have got enough money to do the business and continue to pay the monthly tariff".

However, with high educational attainment leading to good occupations, the professionals in Wa west and Bunkpurugu/Yunyoo districts have regular sources of income and hence their priority needs might shift to leisure and improvement of households' welfare, enhanced by electricity. The needs of migrant commercial farming communities, such as Kunsu, will stem from the reasons for their migration[81] (i.e. the need for productive farming): farm expansion, business and the purchasing of farm implements. In addition, since they do not have access to potable water for a large part of the year, energy to pump water and cooking could also be a priority.

5.6.5 The Political Dimension

The political dimension is also important. The politicisation of solar PV by individuals in authority or those with political ambitions has disillusioned both

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[80] Personal communication with a retail shop owner without SHS in Najon No.2 in Bunkpurugu/Yunyoo district

[81] As mentioned in chapter 3, the majority of the commercial farmers in Kunsu are economic migrants from the northern part of Ghana, where the agricultural activities are barely for subsistence.

adopters and non-adopters of the technology, especially in the two case study sites (Wa West and Bunkpurugu/Yunyoo districts), where the solar projects were undertaken.

Political comments against solar PV as being inferior, but making great promises of hope for the national grid, have partly influenced the non-adoption rates for solar PV in the rural areas of Ghana. In separate interviews with a former employee of the RESPRO and an employee of EC-GH, the use of 'solar PV versus the national grid' discourses for electioneering purposes was said to have dissuaded rural people from adopting solar PV:

"Our politicians have made solar PV look secondary and inferior to the national grid. In the cause of the RESPRO project, subscription became low during the election time, because some aspiring MPs in the Bunkpurugu/Yunyoo district promised the voters that if they voted for them as their MPs they will make sure the national grid is extended to them." (Solar PV technician **'C')**.

"…even whilst you are giving solar PV to a certain constituency, the MP of such a constituency will tell the constituents that the technology is inferior, and add that he/she will ensure that the national grid is supplied to them" (Senior civil servant **'A'** at the EC-GH).

Paradoxically, whilst some politicians supply solar lanterns to their grassroots campaigners to campaign in the night for votes, other politicians discredit the technology and promise the national grid in order to win votes. As will be demonstrated in Chapter six, institutional factors are partly responsible for the ease with which politicians are able to confuse some rural inhabitants about the inferiority of solar PV.

5.7 CONCLUSION

This chapter has critically analysed and discussed the various aspects of solar PV's up-take and application; solar PV projects; and the consumption patterns of energy in the case study areas of this project. The core data used for the chapter were the processed household questionnaires data and transcripts of both formal and informal interviews that were gathered during the field survey. The analysis and discussion of the chapter were conducted within the framework of the Social Construction of Technology (SCOT) theory, starting with the social structure and households characteristics of the respondents in the three case study sites.

The social structure and household characteristics of respondents with solar PV and respondents without solar PV that were analysed included, gender, age, educational attainment, leadership and occupations, which enhanced the understanding of the strands of adoption and non-adoption of solar PV in the case study areas. In general, the empirical analysis found that the gender characteristics of respondents in both categories, i.e. solar PV users and non-solar PV users, were skewed towards males rather than females - a phenomenon that is often argued to be tied to cultural practices. The majority of solar PV users have higher academic qualifications, hold leadership positions and well paid jobs than respondents without PV

Analysis of survey data gathered from the three case study areas on their energy consumption patterns has reinforced the argument of the dominance or the heavy dependency on biomass and kerosene in the energy balance for cooking and lighting respectively, in rural societies of the developing world. Overall, although differences exist in terms of percentages between the main uses of biomass in households with solar PV and households without solar PV, it was found that biomass is used for cooking in all the households that were interviewed, irrespective of their use of solar PV or non-use. Moreover, kerosene and dry cell batteries were found to be playing key roles in the provision of lighting in all respondents' households, notwithstanding their ownership of solar PV or not.

Having examined the general patterns and trends of energy consumption in the case study sites, the different ways in which solar PV has been socially constructed or how it is used, and the associated losers and winners were discussed. Discussion of the ways people identified with solar PV were grouped under households, social and communal services, off-farm productive uses, agriculture, religious activities and the political system. The inference that was drawn from the analysis of these various uses of solar PV was that, whilst its presence impacts or has the potential to impact positively on some activities of rural society, some fundamental rural economic activities including agriculture, supply of potable water, experience no positive impact from the technology.

It was clear from the literature on the characteristics of the rural economies (see chapter 4) that the rural communities in the northern part of Ghana only farm once in a year (sometimes with poor crop yield) because of the single rainfall regime. The main focus of such communities energy needs could therefore be those that will pump water for irrigation farming during the dry season. However, from the analysis, the outlook of the main focus of the two solar PV projects in Wa west and Bunkpurugu/Yunyoo Districts, coupled with the outlook of the total number of solar

PV installations in the respective application areas in Ghana, underscored the neglect of such important rural socio-economic activities as far as the utilisation of PV is concerned. Lighting (which is 'luxury' to the poor rural person) has been the main focus of these PV projects.

In using the background social structure and household characteristics of the three case study sites, in addition to elements of the two solar PV projects that were carried out in Wa west and Bunkpurugu/Yunyoo districts, the dimensions influencing the adoption and non-adoption of solar PV were outlined and analysed. This chapter challenges the literature's emphasis on solar PV cost factors (i.e. solar PV being expensive) being the main barrier to the dissemination of solar PV in the rural areas. As the chapter reveals, the socio-cultural, technical, societal needs and the relative associated importance of energy, and political dimensions, are some of the other important strands shaping the adoption and non-adoption of solar PV in the rural societies of Ghana.

CHAPTER SIX

POLICY INSTRUMENTS/MEASURES, REGULATORY AND INSTITUTIONAL FRAMEWORKS ON SOLAR PV DEVELOPMENT IN GHANA

6.1 INTRODUCTION

In the previous chapter, the general patterns and trends of energy consumption in the three study sites were presented and discussed. In addition, Chapter Five examined critically the different ways in which PV has been used in the study sites and the factors influencing its adoption or non-adoption within the framework of the Social Construction of Technology (SCOT) theory. At the study sites, the barriers limiting the adoption of PV were classified into economic; social-cultural and behavioural; technical; imperfect market/access problems; political dimensions and the varied social and energy needs (See Table 6.1).

Table 6.1 Summary of barriers to PV adoption in the three case study areas in Ghana

BARRIERS CATEGORY	SPECIFIC BARRIERS
ECONOMIC	Cost
SOCIAL, CULTURAL AND BEHAVIOURAL	Large size of households; cultural reasons attached to the non-sale of economic assets; non-acceptance of PV, lack of confidence in PV
TECHNICAL	Lack of PV know-how; lack of skilled PV technicians; unavailability of parts; lack of maintenance; unreliability
IMPERFECT MARKET/ACCESS	Poor awareness; lack of accessibility to PV in rural areas
VARIED SOCIAL AND ENERGY NEEDS	Available PV systems and projects not fulfilling the productive and social needs of rural communities
POLITICAL	False promise on grid; electoral populism; labelling PV as inferior

Source: Field work, 2005.

The focus of Chapter Six is an examination of the interface between these barriers and institutional, policy (international and national) and regulatory frameworks surrounding PV in Ghana. This chapter therefore focuses on a number of key questions:

- What national institutional frameworks and policy measures/programmes of action have been put in place as regards solar PV in Ghana?
- How have these institutional frameworks and policy measures functioned to promote the dissemination of PV to rural Ghana and the participation of the private sector in PV activities? In other words, how effective have these institutional frameworks and policy measures been in overcoming the barriers to PV adoption in rural Ghana?
- What effects have these national institutional frameworks and international policy measures had on the viability of existing PV projects in rural Ghana? (i.e. to what extent were these projects implemented in response to the priority needs of the local people, or were they based on an international donor agenda?)
- What approaches have been used by other countries to promote PV and how different are these from Ghana?

Authors such as Philips and Browne (1999), Hankins (2000) and others have argued that the private sector is critical for PV market development in the developing world. Philips and Browne (1999) for example suggest that "…the PV industry cannot rely on …subsidies to create sustainable markets in developing countries … the private sector will be critical for PV market development" (p. 7-5), whilst Hankins (2000) argues that "…the Government's hand-off approach to the off-grid private sector [in

Kenyan for example] has helped the photovoltaic industry to flourish" (p.98). This chapter, however, challenges these assessments by arguing that although the private sector is important for PV dissemination, the active involvement of government in PV issues is a key element in the dissemination of PV to the majority of the rural poor in the developing world. On its own the private sector will follow the 'market' and address the professional middle class. However, with the government's active involvement in PV the necessary institutional infrastructures, including favourable financial and regulatory environments, clear, open and realistic rural electrification policies for different income groups in the rural areas can be developed and a broader market can emerge. As Sawin (2004) notes "... a sustained renewable energy market can be developed quickly and efficiently if the right combination of policies is adopted" (p.1). In the Ghanaian case, the field survey suggests that there are shortcomings in local, national and international institutional frameworks; and in regulations and policies. The inference that could be drawn apropos PV policy and institutional lapses in Ghana is that effective government institutional, regulatory and policy frameworks are pivotal to overcoming the barriers to PV development in rural areas in the developing world (Figure 6.1).

The chapter is divided into five main sections. Following the introduction, section 6.2 outlines and discusses challenges to the dissemination of PV from a global perspective, and the approaches used by some countries to foster its dissemination. Section 6.3 chronicles the policies, programmes and other institutional measures adopted by Ghana for PV development in the three phases of renewable energy policy in the country. In section 6.4, an evaluation of the effectiveness of these three phases of Ghana's renewable energy policy (in the context of PV development and the sustainability of PV projects) is conducted. The chapter is concluded in section 6.5.

Figure 6.1 Conceptual diagram of effective and ineffective institutional and policy frameworks for energy development at the national and regional/local levels

Pillars of effective institutional and policy frameworks

- ✓ *Well defined energy policy framework*
- ✓ *Strong regulatory institutions*
- ✓ *Efficient legislation*
- ✓ *Well defined and resourced energy departments*
- ✓ *Pro-energy financial institutions*

— *An active indigenous committee with oversight Responsibilities for local energy projects*

— *A regional or district office with the responsibility to monitor the progress of rural energy projects and activities of the indigenous committee*

— *Efficient communication links between the indigenous committee, regional/district office and the projects implementers*

— *Maintenance fund for community projects*

National ——————————————— **Local/ Regional**

- ➢ *Lack of well-defined energy policy*
- ➢ *Poor/unfavourable regulatory framework*
- ➢ *Unevenly resourced energy departments*
- ➢ *Poorly defined energy institutions' functions*
- ➢ *Poor or lack of implementation of energy programmes, policies, regulations*
- ➢ *Lack of financial institutions to support energy activities*
- ➢ *Lack of involvement of stakeholders in decision making*
- ➢ *Abandonment of energy projects*
- ➢ *Poor funding and technical support for equipment maintenance*
- ➢ *Unclear roles for private sector actors*

— *Poorly defined supervisory structures for rural energy projects*

— *Abuse of positions by projects' oversight bodies*

— *Poor co-ordination between projects stakeholders at the local/regional and national levels*

Ineffective Institutional and policy frameworks

Source: Own Construction.

6.2 GLOBAL CHALLENGES TO PV DISSEMINATION AND APPROCAHES TO ITS DISSEMINATION IN SOME CONTRIES

Much has been written on the barriers/challenges to the wide-spread implementation of solar PV and renewable energy. However, a lot of this literature is focused on the developing world, because conventional wisdom perceives PV as the panacea for rural energy needs there (see Chapter One). Barriers to solar PV and other renewable energy penetration have been examined by Oliver and Jackson (1999), Painuly (2001), Cabraal *et al* (1996), Martinot *et al* (2001) and Gueye *et al* (2004).

Painuly (2001) addressed broadly the barriers to renewable energy penetration, including cost-effectiveness, technical issues, and market problems (such as inconsistent pricing structures), institutional, political and regulatory regimes, and social and environmental barriers concerns. He further observes that while some barriers may be country-specific, others may be technology-specific. Writing specifically on the general barriers to solar PV diffusion, Oliver and Jackson (1999) classed these barriers into five. Citing Derrick *et al* (1995) Oliver and Jackson (1999) posited that "the barriers hindering the market development of PV technology can be divided into five types, technological, financial, institutional, regulatory and structural" (p. 381). On the other hand, Gueye *et al* (2004) have argued that three main barriers limit the dissemination of solar PV to rural areas in the developing world. In their discussion of the roles of solar PV in rural development, Gueye *et al* (2004) indicated that "through literature review, interviews and in-country research, we have identified three fundamental constraints to rural PV dissemination in developing countries: financing, capacity building, and quality assurance" (p.7).

Also, in a review of twelve World Bank PV projects in the developing world, Martinot *et al* (2001) gave a broad overview of the impediments to widespread adoption of solar PV. However, unlike other authors that classified PV barriers' dissemination into defined categories, Martinot *et al* (2001) listed these barriers without broad classification to include, "lack of established market; lack of successful business models; lack of business financing and skills; unwillingness of utilities to provide off-grid electricity services; high transactions costs; high first cost and affordability; lack of consumer financing; uncertain technological track record; uncertain or unrealistic grid expansion plans; and other policy constraints like subsidies, tariff structures, and import duties" (p.2). In addition, Cabraal *et al* (1996) examined the barriers to PV dissemination in the developing world, specifically from the affordability perspective. Accordingly "the barriers that constrain the purchase of solar PV include high capital costs, high transactions costs, and market distortions" (Cabraal *et al*, 1996:25).

From the above literature, it can be argued that the points of 'confluence' among these authors are the financing/economic (i.e. cost) and technological barriers to the widespread of PV in the developing world. This scenario shows the emphasis which the majority of authors usually place on cost or lack of affordability as the key barrier limiting the dissemination of PV in the developing world, at the expense of other equally or more challenging barriers. For instance, the literature is largely silent on the varied social and energy needs barriers that were revealed in Chapter Five (see Table 6.1). Whilst economic barriers contribute to the lack of widespread adoption of solar PV in the developing world, this chapter contests the emphasis on it in the literature as the chief reason for poor PV dissemination. It argues that in Ghana at least, it is the ineffectiveness of institutional, policy and regulatory frameworks and the varied social and energy needs that should be regarded as the principal barriers to the dissemination of solar PV, especially in the rural areas (see Table 6.2). The argument is that national institutional, policy, and regulatory frameworks for energy (see Figure 6.1) have a bearing on the successes or the problems within the energy sector.

Table 6.2 Barriers to PV dissemination in Ghana and stakeholders' rankings

Barriers	Category of Respondents and number (Order of importance)[82]					
	PV Businesses and Environmental organisations (N= 5)		Government's energy officials (N=4)		PV non-users in the case study sites (N=30)	
	Rank	No. of Respondents	Rank	No. of Respondents	Rank	No. of Respondents
Economic/ financing	2	4	1	4	2	20
Ineffective Institutional, policy and regulatory frameworks	1	5	4	1	1	27
Social, cultural and behavioural	4	2	4	1	3	15
Technical	3	3	4	2	2	20
Imperfect market	2	4	2	3	4	12
Varied social and energy needs	1	5	1	4	2	20

Source: Fieldwork, 2005.

Table 6.2 summarizes the field study findings of the overall barriers to PV dissemination in Ghana from the national and local perspectives; and the relative importance attached to individual barriers by different stakeholders (i.e. PV businesses, government officials, and rural dwellers). It should be noted that the framework set out in Table 6.1 has been incorporated into Table 6.2. Although the

[82] With respect to the rankings, 1 represents most important based on the highest number of stakeholders' ranking on a particular barrier.

sample used to rank these barriers in Table 6.2 is small, it suggests the importance of ineffective institutional, policy and regulatory frameworks and varied social and energy needs barriers to PV dissemination in rural Ghana. As shown in the table, PV businesses, environmental organisations and PV non-users, ranked ineffective institutional, policy and regulatory frameworks and varied social and energy needs as the most important barriers, followed by economic/financing barriers. On the other hand, Government officials ranked economic/financing and varied social and energy needs highest and ineffective institutional, policy and regulatory frameworks lowest; this is not surprising given their positions.

Many different policy approaches, measures and programmes have been used to offset PV dissemination barriers in several countries in the developed and developing countries in order to promote its dissemination. These include economic or incentive-based instruments[83] (i.e. taxes, subsidies or rebates, tariffs, VAT exemptions, energy fund, financing mechanisms — dealer model, concession model, fee-for-service model); normative or command-and-control measures;[84] and education and information dissemination. Table 6.3 below demonstrates the various policy strategies and measures[85] adopted to promote solar PV dissemination in some selected

[83] Economic or incentive-based instruments are fiscal and other economic incentives and disincentives, which are used to direct the production and consumption activities of households, businesses. The main objective of these instruments is to "motivate a change in behaviour by changing the incentive structure facing consumers and producers" (Panayotou, 1998: 2).

[84] Normative or command-and-control measures of energy policy is where political authorities mandate the desired behaviour in law, and then use whatever enforcement/control mechanism necessary for people to comply with this law. They include targets, standards, prohibitions, limits and licences (UNESCAP, 2006). Some specific examples are Non-Fossil Fuel Obligation (NFFO), Renewables Obligation (RO), Renewable Portfolio Standard (RPS), and Electricity Feed Law (EFL).

[85] It should be noted that these are just some of the PV promotion policy measures of these countries and are not meant to be an exhaustive list.

countries[86]. Indeed, through these approaches solar PV dissemination in these countries has developed more than Ghana.

Table 6.3 Examples of national policy measures and strategies for the promotion of solar PV in some developed and developing countries

COUNTRY	MEASURES FOR SOLAR PV PROMOTION
Germany	High consumer subsidies, national targets for PV utilisation, Electricity Feed Law (EFL), research and development, demonstration
Japan	High consumer subsidies, national targets for PV utilisation, research and development, demonstration
U.S.A	National targets for renewables, including PV through Renewable Portfolio Standard (RPS), high consumer subsidies, rebates, investment tax credits, research and development
South Africa	National targets for PV utilisation, consumer subsidies, ESCO's fee-for-service or utility model with subsidies,
Indonesia	Revolving solar PV Fund, dealer and end-user credit models, consumer subsidies, education and information dissemination in rural areas, no import tariff barriers,
Dominican Republic	National targets for PV utilisation, education and information dissemination in rural areas, no duty on PV modules, ESCO's fee-for-service or utility model,
Philippines	National targets for PV utilisation, import taxes and VAT exemption on PV,
Zambia	Energy service Company's (ESCO) Fee-for-service or utility model
Tanzania	Consumer subsidies, hire purchase model,
India	National targets for PV, dealer and end-user credit models, consumer subsidies,
Argentina	Regulated energy-service-Company (ESCO) concession model, subsidies,

Sources: Cabraal *et al* 1996; Martinot *et al*, 2001; Hankins, 2004; Martinot *et al*, 2005; Solarbuzz, LL. 2006.

One of the most prominent national policy measures for the promotion of solar PV among the selected countries in Table 6.3 above is consumer subsidies. The Japanese and German Governments for instance, "legislated for the use of high subsidies" to

[86] These countries were specifically selected to exemplify the importance of government's involvement in the promotion of PV dissemination, through sound energy policy measures/instruments for PV.

boost solar market development (Solarbuzz, LL. 2006). Through this and other policy measures, these two countries are now the leading PV installers in the world (see Chapter Seven for world solar statistics). Against this backdrop, this chapter challenges the neo-liberal argument by some authors, including Philips and Browne (1999) that subsidies on PV should be eliminated in developing countries so as to increase economically competitive PV programmes. The target group of most of the solar PV programmes in the developing world are the rural poor. Hence, without substantial subsidies, coupled with other policy measures (see Table 6.3), solar PV systems, especially the larger ones with potential economic benefits, could remain out of reach for the majority in the developing world, including Ghana. The chapter now focuses on the different aspects of PV policy, regulatory and institutional measures in Ghana and their effects on PV development.

6.3 CHRONOLOGY OF POLICY AND INSTITUTIONAL MEASURES FOR PV IN THE THREE PHASES OF RENEWABLE ENERGY POLICY IN GHANA

Renewable energy policy development in Ghana can be divided into three phases: 1983 to 1991; 1996 to 2000; and the current policies, 2001 onwards. This section provides a detailed outline of these three phases, with specific emphasis on the various policy and institutional measures that have been initiated for solar PV in the country. The impact of these policies and institutional measures on the development of PV in rural Ghana is assessed in section 6.4.

6.3.1 Renewable Energy Policies from 1983-1991

Before 1983, the national energy policies of Ghana did not cover renewable energy. In 1983, however, the enactment of the Provisional National Defence Council[87] (PNDC) Law 62 began the development of the first national policy on renewable energy technologies (Edjekumhene *et al*, 2001). This law provided the statutory foundations for the establishment and operation of the National Energy Board (NEB[88]). This law remained in force until 1996 as the guiding legislation for the implementation of projects in renewable energy (Akuffo, 1998).

The PNDC Law 62 spelt out the functions of the NEB as follows:

1) Formulation of recommendations on energy policy;
2) Comprehensive planning on how to develop and utilise national energy resources;
3) Carrying out an assessment of the energy resource base of the country;
4) Direct development and demonstration projects in renewable energy in the country;
5) Monitoring the work of public institutions charged with regulatory and management of energy development responsibilities.

6.3.1.1 Policy Measures/Instruments used by NEB for the Implementation of Solar PV Projects and Programmes

To carry out its functions, the NEB created five departments for petroleum planning, electricity planning, renewable energy programmes, energy conservation programmes, and energy information (Edjekumhene *et al*, 2001). A number of projects[89] followed in these departments, including twenty-nine dealing with renewable energy between 1989 and 991 (Akuffo, 1992) (Table 6.1). Two of these

[87] The Provincial National Defence Council (PNDC) was the name of the Ghanaian military government after the People’s National Party's elected government was overthrown by Jerry Rawlings, the former head of the Armed Forces Revolutionary Council.
[88] However, the NEB was disbanded in March 1991 and its personnel and material assets put under the control of the then Ministry of Mines and Energy (MME).
[89] According to Edjekumhene *et al* (2001) “A total of 135 projects and programmes were initiated by NEB between 1989 and 1991…” (p.23).

were solar PV demonstrative projects for villages and nine solar PV research projects (see coloured cells in Table 6.1).

Table 6.4 Renewable energy technologies (RETs) projects initiated by NEB between 1989 and 1991

Projects in 1989	Projects in 1990	Projects in 1991
1.Strategies for improving Charcoal Production in Ghana	1. Strategies for improving Charcoal Production in Ghana	1. Strategies for improving Charcoal Production in Ghana
2. Improved Charcoal Stove Programme	2. Improved Charcoal Stove Programme	2. Improved Charcoal Stove Programme
3. Rural Energy Planning Studies	3. Rural Energy Planning Studies	3. Improved Firewood Stove Project
4. Appolonia Biogas Village Project	4. Appolonia Biogas Village Project	4. Appolonia Biogas Village Project
5. Public Latrine Biogas Project	5. Integrated Biogas Projects	**5**.Monitoring and Evaluating the Performance of solar PVs in Ghana
6. Monitoring and Evaluating the Performance of solar PVs in Ghana	6.Biogas Resource Assessment	**6**. Solar and Wind Energy Resource Assessment
7. Solar and Wind Energy Resource Assessment	7. Establishment of Biogas Laboratory and workshop	**7**. Prospects for solar Water Heating
8. Prospects for Sawdust Briquettes as Renewable Energy source in Ghana	**8**. Monitoring and Evaluation of the Performance of solar PVs in Ghana	**8**. Prospects for Substituting solar Energy for Oil in Large scale Commercial Crop Drying
9. Demonstration of Integrated solar Power for villages	**9**.Demonstration of Integrated solar Power for villages	
	10. Promotion of Sawdust Briquettes as Renewable energy source in Ghana	
	11. Solar and Wind Energy Assessment in Ghana	
	12. Feasibility Study of Substituting solar Energy for Oil in Large scale Commercial Crop Drying	

Source: Akuffo, 1992 (cited in Edjekumhene, 2001).

6.3.2 Renewable Energy Policies from 1996 to 2000 — (The Energy Sector Development Programme (ESDP))

From 1996 to 2000, there was another phase of renewable energy policy in Ghana. The main energy policy, within this period, was the Energy Sector Development Programme (ESDP[90]). Its remit was:

a) to restore improved productivity and efficiency in the procurement, transformation, distribution and use of all energy resources;
b) to reduce the country's vulnerability to short-term disruptions in energy supply;
c) to consolidate and further accelerate the development of woodfuels, hydro-power, petroleum and solar energy; and
d) to secure future power supply through thermal complementation of hydro-based electricity generation.

In line with these strategic objectives, programmes and projects were designed and implemented by the Ministry of Mines and Energy (MME)[91] and other institutions in the following areas:

1) The renewable sector (i.e. the implementation of the Renewable Energy Development Programme (REDP[92]);
2) The National Liquefied Petroleum Gas (LPG) promotion programme; the power (electricity) sub-sector;
3) The petroleum sub-sector; and
4) The energy efficiency and conservation programme.

For the purposes of this thesis, only policy issues, programmes/projects and their implementation measures, as well as institutional frameworks related to the renewable sector, especially solar PV, are addressed.

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[90] Strategic policy objectives of ESDP are under Part II of the ESDP document.
[91] That was the former name for the current Ministry of Energy
[92] The REDP covered only some specific renewable projects that were related to solar energy and biomass (KITE, 2005). REDP was financially supported by DANIDA.

6.3.2.1 Renewable Energy Sector (Solar Energy Policy Measures/Instruments and Programmes)

Under the ESDP, the REDP provided the main policy directions for solar energy activities in Ghana, instituting "…a National Solar Energy Programme (NASEP) to assess, demonstrate and evaluate the technical, economic and social viability of appropriate solar energy technologies" (Kumasi Institute of Technology and Environment (KITE), 2005:18). The solar energy activities that were implemented had the following objectives:

- to evaluate the technical and economic viability of proven solar technologies capable of meeting prioritised socio-economic and developmental needs of the country; and
- to promote the development of solar energy industries that have strong indigenous prospects over the short to medium term future. (Edjekumhene *et al*, 2001).

Solar energy projects, activities and programmes that were implemented under the NASEP included the following:

1) Solar and wind Energy Resource Assessment
2) Evaluation of Solar Photovoltaic systems in Ghana
3) Demonstration of Integrated Power for villages
4) Solar water study
5) Solar crop drying study
6) Off-grid solar PV electrification pilot project
7) Feasibility study of pilot solar thermal plant in Ghana (KITE, 2005).

The main institution, which implemented these projects, programmes and activities of solar energy under the ESDP, was the MME. Economic instruments implemented under this policy regime to promote PV included, Custom duty exemption on solar panels, Value Added Tax (VAT) exemption on a complete PV system (i.e. PV panel and Balance of System (BOS) - battery, wires, charge controller); government funding and an Energy Fund[93] (Edjekumhene *et al*, 2001). These same economic instruments have been introduced under the current renewable energy policies (see section 6.3.3 below)

6.3.3 The Current Renewable Energy Policies (from 2001 …)

Current renewable energy policies of Ghana have been formulated under the 2001 energy policy framework: 'Energy for Poverty Alleviation and Economic Growth: Policy Framework, Programmes and Projects'. The Government's vision was to ensure reliable supply of high quality energy services for all Ghanaian homes, businesses, industries, transport and the export sectors (Abavana, 2004).

In this context, seven policy objectives and associated policy actions were developed to provide the framework for the development and implementation of energy sector programmes and projects in the country, as outlined below:

a) Consolidate and improve existing energy supply system
b) Increase access to high quality energy services
c) Secure future energy supplies
d) Stimulate economic development
e) Minimize environmental impacts of energy supply and consumption
f) Strengthen institutional and human resource capacity and R&D in energy development
g) Special concerns - Renewable Energy Technologies (RETs)
(MOE-GH, 2001b).

[93] A fund established by ACT 541 for the promotion of energy efficiency, natural gas, petroleum products, renewable energy resources, rural electrification and human resource development in Ghana's energy sector. This fund is fed primarily by a proportion of government levy on petroleum products, electricity and natural gas (EC ACT, 1997 (ACT 541)).

For RETs, the policy document spelt out the following policy actions (to accelerate the development and utilisation of renewable energy sources):

- Create a level playing field for renewable energy by removing all fiscal and market barriers.
- Encourage utility companies to adopt renewable energy in their energy supply
- Institute a “RET-Friendly” pricing framework in competitive applications such as grid-connected supply.
- Provide government funding support for non-grid connected RETs for economic and social activities (such as schools, health centres, provision of potable drinking water).
- Support technological development and cost reduction through pilot demonstration projects and local manufacture of RETs (MOE-GH, 2001b).

6.3.3.1 Regulatory and Institutional Framework

Under the current energy policy of Ghana, RETs’ regulation comes under two public institutions — the Ministry of Energy (MOE-GH) and the Energy Commission (EC-GH).

Functions of the Ministry of Energy (MOE-GH)

The MOE-GH provides the overall policy direction for energy in the country. This involves “…formulating, implementing, monitoring and evaluating energy sector policies in Ghana, and also supervising the operations and activities of the following energy sector institutions” (MOE-GH Meet The Press, 2005:2):

- Volta River Authority (VRA)
- Electricity Company of Ghana (ECG)
- Tema Oil Refinery (TOR)
- Bulk Oil Storage and Transportation Limited (BOST)
- Ghana National Petroleum Corporation (GNPC)
- Energy Foundation (EF)
- Ghana Oil Company Limited (GOIL)
- Ghana Cylinder Manufacturing Company (GCMC)
- National Petroleum Authority (NPA)

- Energy Commission (EC-GH)

Functions of the Energy Commission (EC-GH)

The Energy Commission Act, 1997 (Act 541) established the Energy Commission (EC-GH). The EC-GH is required by law to regulate, manage and develop the utilisation of energy resources in Ghana; to provide the legal, regulatory and supervisory framework for all providers of energy in the country: specifically by the granting of licenses and establishing standards for the transmission, wholesale, supply, distribution and sale of electricity and natural gas; refining, storage, bulk distribution, marketing and sale of petroleum products and related matters. The EC-GH is also tasked with managing the Energy Fund[94].

In sum, these three phases represent an evolution and different trajectories in renewable energy policy in the country, not least on the institutions and policy measures. Different government institutions have taken charge of solar PV projects and programmes in each phase: 1983 to 1991, NEB; 1996 to 2000, MME; 2001 onwards, MOE-GH and EC-GH. Policy measures used to implement solar PV projects and programmes under phase one were demonstration, research and education. In phase two, besides the use of demonstration, research and educational measures in solar PV projects and programmes, economic instruments (custom duty exemption on PV panels and VAT exemption on complete PV system) were also implemented. Policy measures in phase three included the use of economic instruments (custom duty exemption on PV panels and VAT exemption on complete PV system); and envisioned measures such as the removal of fiscal and market

[94] The Energy Fund is established under Section 41 of the EC-GH Act (ACT 541) and fed primarily by a proportion of Government levy on petroleum products, electricity and natural gas. Monies generated through the Fund are supposed to be used inter alia for the promotion of projects for the development of and utilisation of renewable energy resources and rural electrification (EC-GH ACT, 1997).

barriers (to attract private sector participation in RETs development); increased government funding for RETs. As demonstrated in section 6.4, the characteristics of these phases are part of the factors that have shaped the level of solar PV development in Ghana.

6.4 EVALUATING THE THREE PHASES OF GHANA RENEWABLE ENERGY POLICY ON THE DEVELOPMENT AND SUSTAINABILITY OF SOLAR PV AND SOLAR PV PROJECTS IN RURAL GHANA

As indicated in section 6.2, besides the influence of socio-cultural and economic factors on the adoption and utilisation of a particular technology, effective policies and vibrant institutional frameworks are key factors, which promote a technology's development. In this light, this section assesses critically the three phases of renewable energy policies, regulatory and institutional frameworks of Ghana, in order to determine their adequacy for the development of solar PV (i.e. the ability to overcome barriers to PV dissemination) and sustainability of PV projects in rural areas. This evaluation looks at the three regimes of renewable policies in the energy sector of Ghana en bloc, and not under separate sub-headings.

While two decades of incorporating renewable energy into the mainstream energy planning in Ghana may define the policy environment, the appropriateness and implementation of these policies is another issue. Analysis of the country's performance regarding renewable energy policy, institutional and regulatory frameworks for the past two decades reveals the lack of far-reaching provisions for the promotion of solar PV market and PV adoption among PV businesses and both rural and urban populations. According to Painuly and Fenhann (2002) the "… existing renewable policy framework [in Ghana] is not potent enough to ensure the commercialisation and widespread utilisation of RETs" (p.21). From the field interviews and documentary analyses, a number of issues can be identified in these policies, regulatory and institutional frameworks on PV adoption in the rural areas of Ghana.

Table 6.5 summarises the limitations of the institutional frameworks and policies for solar PV promotion in Ghana, and are discussed in the following sections. Elements in Table 6.5 correspond with features of the general institutional and policy ineffectiveness for energy development at the national and regional/local levels, as outlined earlier on in Figure 6.1.

Table 6.5 Key features of the institutional and policy frameworks for PV at the national and regional/local levels in Ghana

National Level	**Regional/local Level**
➢ Absence of well-defined policies — No targets for PV —Government's conflict of interest between grid and PV —Absence of coherent provision for PV education and information dissemination —Uneven policy measures for PV and grid ➢ Weak regulatory framework ➢ Poor institutional arrangement for PV at the energy sector — No dedicated institution solely for PV — Discharge of inappropriate functions by energy institutions ➢ Poor or lack of implementation of PV Programmes, policies and strategies —Reactive energy sector, because of the over-dependency on donor aid —Absence of financial institutions to support PV activities ➢ Lack of conformity of national and international PV policies or agenda with energy needs of rural people ➢ Abandonment of PV projects	➲ Poorly defined supervisory structures for rural energy projects ➲Absence of indigenous plans/ programmes to sustain rural PV projects ➲Poor discharge of functions by projects oversight committees at the level (leadership failure) ➲ Absence of efficient co-ordination between PV projects implementers and oversight committees at the level

Source: Fieldwork, 2005.

6.4.1 Lack of Clear-cut Policies on Areas of PV Deployment

A major feature of renewable energy policies that have had a bearing on solar PV in Ghana within the past two decades has been the absence of clear-cut policies on specific rural areas of PV deployment — a consequence of this situation being the conflict of interest in the national grid extension and the execution of PV projects. Rhetorical goals and policies on renewables are not enough to enhance the growth of solar PV energy technologies. PV development is rather boosted when specific places are targeted and supported by convincing implementation. According to Martinot *et al* (2000) "without the government demarcating an identified niche for solar PVs in its policies, rural consumers are enticed by the promise of electricity provision through the grid, adversely affecting demand for solar PV…" (p.10). When asked if there are government policies on specific areas of PV deployment in Ghana, one key informant at the EC-GH said;

> *"That is what we are trying to develop at the moment in the rural electrification programme".*[95]

However, a contrary view was expressed by another solar PV stakeholder as follows:

> *"The government has not demarcated and is not demarcating specific places for the sole supply of PV. A case in point is the RESPRO project. The initial understanding was that PV was the only energy source to be supplied to the beneficiary communities. But this was compromised, when the grid was supplied to these communities".*[96]

Indeed, it has been mentioned in the current energy policy framework of the country that "there are some remote rural communities that cannot be connected to the grid in the next 5 to 10 years … [hence]… the Ministry of Energy (MOE-GH) in partnership

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[95] Personal communication with senior civil servant **'A' –** August 2005.

[96] Personal communication with solar PV technician **'C' -** July 2005.

with the utility companies and the private sector will initiate a programme to provide these communities with solar PV systems" (MOE-GH, 2005:5). However, it could be argued that this very provision is vague and weak. First of all, unlike policies for the national grid that specify the number of communities and the specific communities to be supplied with the grid in a year, this provision lacks clarity regarding the annual number of remote rural communities and the specific remote communities to be supplied with PV. In other words, the policy is devoid of national targets, compared with other countries that have high PV dissemination rates, as shown in Table 6.3. Secondly, the provision is weak because of the government's conflict of interest between the national grid extension and the execution of solar PV's projects.

This conflict of interest became clear in the two study areas (i.e. Bunpkurugu/Yunyoo and Wa West districts). These two districts, especially the district capitals, were the only ones in the country that were not connected to the national grid before the solar PV projects started in 1998. Hence, when they were supplied with solar PV, the action was seen as the beginning for the sole utilisation and promotion of PV in rural areas without the national grid.

However, the fieldwork in 2005 revealed that plans had been put in place for the extension of the national grid (see Plate 6.1) to these two districts. This action demonstrates the conflict of interest[97], and also reveals the insubstantial nature of the Government's policy for PV development and deployment in the rural areas. According to Tse (2000), Ghana's energy policy environment "…heavily favours extension of the grid even to areas where it is not economically justified" (p.14).

[97] According to Ahiataku-Togobo (2002) "Political influence on grid extension is a challenge to PV development [in Ghana]. Electorates are promised grid power in exchange for votes" (p.25).

When asked as to why the government has such a conflict of interest between PV and the national grid, a key informant at the EC-GH noted that;

> *"The introduction of the national grid alongside solar PV in the rural areas should be seen as a complementary initiative to meet their energy needs and not a conflict of interest on the part of the government".*[98]

However, the following views from a former employee of RESPRO reveal a more complex reality, further illustrating the effects of the government's lack of consistency in its policy regarding areas of PV deployment and grid extension:

> *"…a lot of people in the rural areas now regard solar PV as a transition source of electricity delivery and are not willing to adopt PV, because of the extension of the grid to communities that already have solar PV or that could have been supplied with PV. For instance, at the inception of the RESPRO project, some communities were targeted to be supplied with PV, but out of the blue, the grid was extended to these communities. After the RESPRO project, Bunkpurugu town and villages along the road, which were supplied with PV are about to be connected to the grid".*[99]

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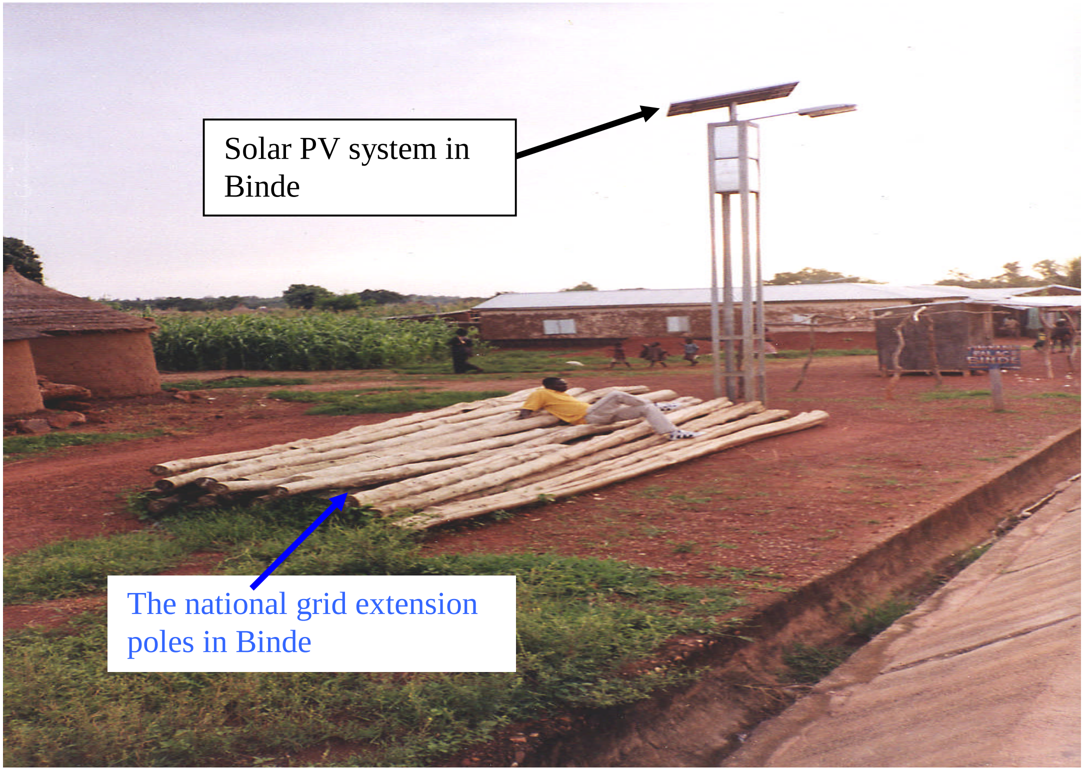
[98] Personal communication with senior civil servant **'C' —** June 2005.
[99] Personal communication with solar PV technician **'C' —** July 2005.

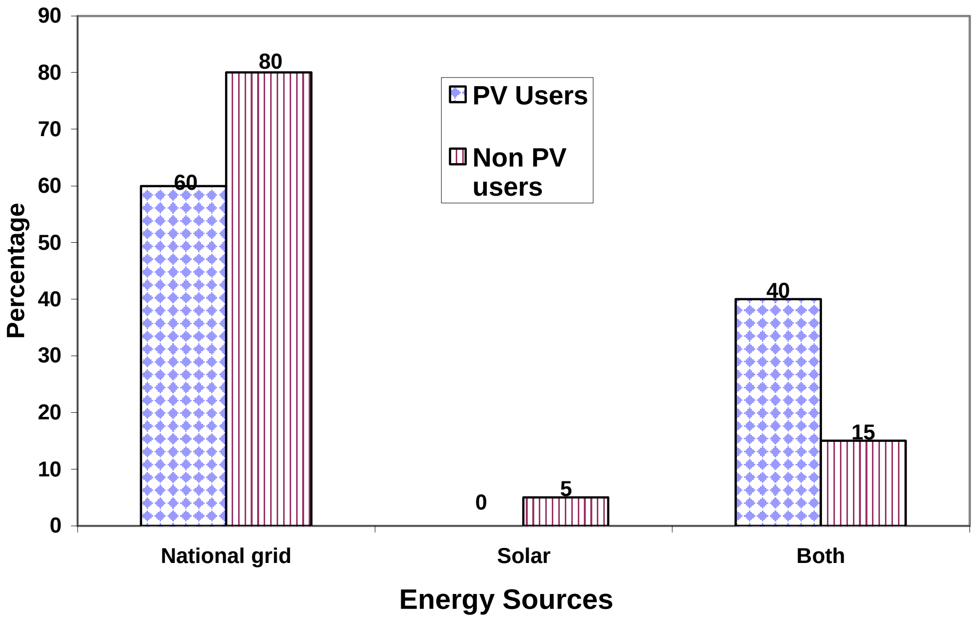
Plate 6.1 Distribution of electricity extension poles in Binde (a beneficiary Community of the RESPRO in Bunpkurugu/Yunyoo district) for the supply of the national grid



Source: Fieldwork, 2005.

The prospects of a decrease in PV adoption in both Bunpkurugu/Yunyoo and Wa West districts because of the impending extension of the national grid became evident during interviews with the 20 non-PV users and 20 PV users. The majority of both categories of interviewees expressed their desire to switch to the national grid (Figure 6.2). However, Figure 6.2 shows a relatively small percentage of PV users and non-PV users indicating their preference for both solar PV and the national grid.

Figure 6.2 Relative preference for solar PV and national grid - PV users and non users in Bunkpurugu/Yunyoo and Wa West Districts



From the discussion of this identified energy policy lapse on PV in the country, it can be inferred that the political will for PV activities in the country is lacking. It can therefore be argued that this energy policy lapse has some influence on the political, socio-cultural and behavioural barriers to PV adoption in rural Ghana. For instance, this lapse might have been part of the causes of the lack of confidence in PV and its non-acceptance by some rural people, because they saw signs of grid extension (see Plate 6.1 above). It might have also been the reason why political candidates describe PV as inferior for rural people and in turn promise falsely about extending the grid to them if they vote appropriately (see Chapter five). Interviews in the study sites have shown how this dissuades people from accepting PV.

6.4.2 Absence of a Coherent Provision for PV Education and Information Dissemination

As demonstrated in Table 6.3 above, together, education and information dissemination are vital energy policy measures that can enhance the adoption and utilisation of specific energy sources. The level of acceptance of a particular technology depends not only on its price and the socio-economic background of a group of people (as shown in Chapter Five), but also on their knowledge[100] of the technology; its potential, availability and related policy support. Strong policy measures on education and information dissemination could be one of the keys to achieving a high level of awareness on the technology's potential and availability. Thus, it is very important to assess the extent to which these policy measures have been promoted in the context of PV technology in Ghana.

A critical analysis of past and present renewable energy policies, especially, solar PV in this thesis, has shown that these policies lack consistent provisions for PV education and information dissemination. From field evidence it seems that the rural population and even a proportion of the urban population[101] in Ghana are unaware of PV systems, including information on functionality, cost, benefits, accessibility and potentials. In their discussion of renewable energy technologies in Ghana, Edjekumhene *et al* (2001) allude to the fact that education and information policy measures were used to promote PV development under the NEB and ESDP, but argued that these measures were short-lived and geographically restricted.

Empirical evidence from the fieldwork showed that education and information dissemination policy measures on solar PV in these two renewable energy policy regimes (as well as the current policy regime), took place in only the few households

[100] In the words of Hankins (2004) for example, "…PV markets grow in an organic manner. Consumer demand grows once awareness is built up…" (p.34).

[101] According to solar PV technician **'D'** "the majority of urban population also lack solar PV awareness because of the extensive supply of the national grid in urban areas". Personal communication with him — July 2005.

that benefited from PV projects[102]— non-beneficiary households were not included. Once the projects finished, education and information dissemination also ended. The conclusion is that Ghana's renewable energy policies, especially, education and information dissemination measures on PV have been incoherent, and lacking long-term and broad-based foci. The result is a general lack of awareness of the technology and a low level of adoption.

In an interview with three solar PV businesses, the unanimous view was that education and information dissemination measures were very limited, particularly in the rural areas:

> *"As far as I can tell there is not much PV education and information dissemination in this country [Ghana]. The Ministry of Energy has not done much, likewise the Energy Commission. Most people in the rural areas who can even afford to buy PV are not aware of what it can do".* (Spokesperson **'C'** from Solar Light Company).

> *"I will rate the education on solar PV in the country [Ghana] at 25%. For instance in the case of the RESPRO, they undertook installation without much education. To me, it will be good if solar PV is added to the country's formal and informal educational curricula. This will enable both adults and children to start becoming aware of the functions and uses of solar PV".* (Spokesperson **'A'** from BEST solar Company).

> *"There is no good policy on PV education and dissemination in this country and this has resulted in poor education on the technology. The reality is that every time one is reading the newspapers or*

[102] "We did not carry out mass education on solar PV while we were implementing the RESPRO. We chose only a few households in the communities, carried out education on how PV is used by word of mouth and started with the installation" (Solar PV technician **'C'**).

> *listening to the radio about energy projects in the country, they are usually referring to the Volta River Authority (VRA) and very little talk about building up solar energy education programmes".* (Solar PV technician **'D'** from Solar Utilisation Network Company).

The views above did not differ much from those expressed by eight stakeholders (see Table 6.6). Note that the above three interviewees are included in the eight stakeholders in Table 6.6. As Table 6.6 reveals, while 46 percent of the 50 solar PV users and non-users (in the three case study sites) strongly disagree that there is adequate public education on PV, four percent and fourteen percent strongly agree and agree respectively.

Meanwhile, two officials at the MOE-GH and EC-GH expressed different opinions. While one insists that there has been adequate public education on PV, the other demurred:

> *"There has been good public education and information dissemination on PV in Ghana by way of demonstration projects in a number of villages and towns in northern Ghana and parts of the Volta region"* (Senior civil servant **'B'** at MOE-GH).

> *"I don't think we have done enough education on PV"* (Senior civil servant **'C'** at EC-GH).

These different views are possible indicators of the weakness of education and information dissemination on PV in Ghana.

Table 6.6: Levels of agreement among rural interviewees and stakeholders about government policy and institutional frameworks on PV in rural Ghana

	Aggregate Ranking Responses from PV users and non-users of PV in Kunsu, Wa West and Bunpkurugu/Yunyoo Districts					**PV Stakeholders[103]**				
Levels of Agreement/Statements	**Strongly Agree**	**Agree**	**Neither Agree nor Disagree**	**Disagree**	**Strongly Disagree**	**Strongly Agree**	**Agree**	**Neither Agree nor Disagree**	**Disagree**	**Strongly Disagree**
There is adequate public education on PV	2 (4%)	7 (14%)	5 (10%)	13 (26%)	23 (46%)	***0***	***0***	***1***	***2***	***5***
The government has greatly promoted PV to the rural areas	1 (2%)	10 (20%)	2 (4%)	17 (34%)	20 (40%)	***0***	***1***	***0***	***4***	***3***
There is a strong regulatory policy that governs PV suppliers and protect end-users of PV	0	0	5 (10%)	13 (26%)	32 (64%)	***0***	***0***	***3***	***2***	***3***
There are national incentives that enhance PV adoption	1 (2%)	5 (10%)	3 (6%)	20 (40%)	21 (42%)	***0***	***0***	***0***	***0***	***8***
The rural PV projects have been properly implemented	2 (2%)	5 (10%)	8 (16%)	10 (20%)	25 (50%)	***0***	***0***	***2***	***3***	***3***

Source: Fieldwork, 2005.

[103] Eight stakeholders were involved in this ranking. These included two personnel from Friends of the Earth, three personnel from private PV companies, one technician from the PV battery charging station in Wechiau, and two former technicians of the RESPRO project.

6.4.3 Uneven Policy Measures for Solar PV and the National Grid

Balanced policy measures/instruments for different energy sources in a particular economy are indispensable for their development and vice versa. In the words of Tse (2000) "for policy measures to be effective, they must be broadly fashioned to provide fair access for a range of energy sources" (p.14). From the data analysis in this thesis, one major feature that was revealed on the three renewable energy policy regimes of Ghana is the unevenness in the measures/instruments used to implement solar PV and the national grid.

Tariff, subsidy, energy fund and government budgetary provisions in these policy frameworks are some of the economic instruments that have been used for grid and solar PV implementation. As Chapter Two shows Government subsidy for energy sources enhances the affordability for the poor, while an even tariff system gives each an equal chance. Table 6.3 above, shows that consumer subsidies for solar PV has been one of the main economic instruments used to boost PV demands in Germany, Japan, U.S.A, South Africa, Tanzania, India and Argentina. However, In Ghana it can be argued that the Government's financial incentive structure (e.g. tariffs, energy fund) has always favoured the national grid more than solar PV.

Since the inception of the National Electrification Scheme (NES) in 1989, the government has been responsible for the capital cost of the national grid extension; whilst the energy cost is passed onto the consumer by means of the concept of cross-subsidization (i.e. higher usage consumers who are considered rich, subsidize the lower consumers who are considered poor). In contrast, the capital cost of PV installation in the rural areas is borne by consumers, without subsidy on tariff[104]. As Abavana (2004) points out; "While the introduction of renewable energy, especially PV, to the National Electrification Scheme is a welcome relief to proponents of renewable energy, presently government electrification policy tends to discriminate against the latter. For instance, it has been established that in certain remote communities, providing PV systems will be the most cost-effective way of electrification. However, while government bears almost 95% of the cost of grid extension, solar PV electrification projects are being piloted on the fee-for-service basis with an emphasis on cost recovery. Worse of all, the monthly tariff paid by users of PV systems tends to be relatively higher than what is paid by lifeline consumers using up 50kWh of grid electricity" (p.5).

The impact of the higher tariff on solar PV compared to the subsidized tariff on the national grid helps to explain why many rural consumers opt for the grid instead of solar PV. In an interview with a former employee of RESPRO for example, he noted the following:

> *"…when one assesses the tariff that grid consumers in Nankpanduri[105] are paying compared to what the solar PV users in Bimbago are paying, people don't feel attracted to solar PV anymore. For instance, someone using a 100watts PV system in Bimbago can't use it for colour TV, ironing, fan, fridge, still pays about 25,000 cedis (i.e. $3) per month. Meanwhile a national grid consumer in Nankpanduri, who can use the grid to power all these electrical equipments, pays lesser tariff. This is making solar unattractive".[106]*

[104] Tariff under the RESPRO was 8-10 times grid power (Ahiataku-Togobo, 2001).
[105] Nankpanduri and Bimbago communities are just about 20km from each other under Bunpkurugu/Yunyoo district.
[106] Personal communication with solar PV technician **'C'** – July 2005.

Government funding for the national grid and solar PV is also very uneven. As shown in Table 6.7 below, while the government's yearly investment in the national grid is on the rise, the support for solar PV is not increasing over time. Since 1998, much has not been spent on solar PV, contrary to Government's renewable policy (in 2001) of providing more funding support for solar PV and other RETs.

Table 6.7 Comparison of government funding between the national grid and solar PV in Ghana in the past ten years

YEARS	National Grid (Akosombo)	YEARS	Solar PV
1996	↑ US$130m to extend the grid under phase 3 of the Self Help Electrification Program (SHEP) ↓	**1996**	-
1997		**1997**	-
1998		**1998**	US$2 MOE-Ghana/ Spanish government
1999		**1999**	↑ US$3.131m to implement RESPRO (GEF $2.5m & MOE-Ghana $500,000) ↓
2000		**2000**	
2001	↑ US$105m[107] to extend the grid under phase 4 of the SHEP ↓	**2001**	
2002		**2002**	
2003		**2003**	
2004		**2004**	
2005		**2005**	-
2006		**2006**	-

Source: EC-GH, 2003; MOE-GH, 2001a; MOE-GH, 1998; MOFEP-GH, 2006; Ahiataku-Togobo, 2001; Personal communication with senior civil servant '**A**' at EC-GH, 2005.

Table 6.7 demonstrates that while the government keeps on sourcing bilateral and multilateral funds in the forms of grants, concessionary loans, soft loans, to implement the Self Help Electrification Programme (SHEP) under the National Electrification Scheme (NES) (see Chapter Four), much of solar PV funding depends on sporadic donor support, with little direct government support in cash or kind. For instance, of the US$3.131m spent on the RESPRO project, the government of Ghana only

[107] This amount is part of the total amount US$350m required to implement the whole of SHEP-4.

contributed US$500,000 in cash and kind (RESPRO Report GHA/96/G31, 2000). In the same vein, the government only contributed in kind (i.e. the supply of PV systems' installers) to the joint MOE-GH/Spanish government PV programme[108]. The bias in favour of government support for the national grid at the expense of solar PV possibly explains why there has not been any PV funding in the country since 2005, as Table 6.7 reveals.

Similarly, the effectiveness of the Energy Fund in promoting PV dissemination in the country can be questioned. For example, Table 6.8 below shows the patterns of expenditure from this fund within the technical wing of the Ministry of Mines and Energy (MME-GH) for a three-year period.[109] Although the years in which the expenditure patterns of this fund took place are very few (Table 6.8), the data help explain the differences in government financing schemes for various sources of energy supply in the country.

As evident from the table, the apportionment of monies from the fund is heavily skewed towards electricity planning (i.e. National Electrification Scheme (NES)), which is more concerned with grid extension. Up to about seventy-two percent (15 billion cedis or US$ 16,492,07m[110]) of disbursement from this fund went into NES in 1996, whilst 16 billion cedis (US$ 16,91689m) and 24 billion cedis (US$ 25,375,34m) were allotted from this fund in 1997 and 1998 respectively for NES. As Table 6.7 demonstrates, these figures far exceed the allotments for the development of renewable energy, to which solar PV belongs. Even a comparison with figures for the promotion and development of petroleum or energy conservation, still leaves the

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[108] Personal communication with senior civil servant **'A'**, at EC-GH, June, 2005.
[109] Information was not available for other years after 1998.
[110] Current exchange rate is US$1 to 9,458 cedis http://ghanaweb.com/ [Accessed: 30/01/07].

renewable energy relatively under-financed. The conclusion that could be drawn from the patterns of allocation of the Energy Fund as per the three years under discussion is that there has been substantial support for the NES relative to renewable energy.

Table 6.8 Patterns of expenditure from the energy fund within the technical wing of the Ministry of Mines and Energy in 1996, 1997, 1998

	1996		1997		1998	
DETAILS OF EXPENDITURE	**Recurrent (¢m)**	**Dev't (¢m)**	**Recurrent (¢m)**	**Dev't (¢m)**	**Recurrent (¢m)**	**Dev't (¢m)**
1. Project monitoring and management	26.4		28.09		30.39	
2. Corporate planning & finance	33.6		41.5		38.0	
3. Petroleum (including LPG)	14.0	4,089	14.03		27.325	5,313
4. Renewable energy	55.86	339	80.05	339	116.41	
5. Energy information centre	31.98		26.51		45.45	
6. Energy conservation	26.56	1,532	79.76	1,532	252.17	783
7. Resource & environmental planning	13.96		22.83	150	33.99	
8. Electricity Planning (i.e.NES)	13.0	15,598.2		16,695		24,080
TOTAL	**215.36**	**21,558.2**	**292.77**	**18,716**	**543.74**	**30,176**

Source: Technical Wing, Ministry of Mines and Energy, 1999 (cited in Edjekumhene *et al*, 2001).

6.4.4 Institutional Problems

There has never been a dedicated national institution solely for the development and promotion of solar PV and other RETs in Ghana. As discussed earlier on, the MOE-GH and the EC are the two institutions involved in solar PV and other RETs, currently. However, just like the NEB and MME-GH in 1983 and 1996 respectively, these two institutions undertake other activities, which take a higher priority

(Ahiataku-Togobo, 2005). The effects of lack of dedicated institutions for PV include, poor planning and implementation of PV programmes and policies. According to a senior spokesperson at the EC-GH;

> *"While ECG and VRA are the institutions which implement the hydro and thermal electricity generation and transmission programmes; and TOR and GOIL implement petroleum programmes; solar PV has no direct institution that solely promotes and implements its activities"* (Senior civil servant **'A'**).

In a discussion with senior civil servant **'B'** at MOE-GH, he was of the opinion that there is an institution at the MOE solely for PV activities. According to him;

> *"RESPRO is the main government institutional set-up to disseminate PV in the country, and is based currently in northern Ghana".*

On the other hand, a former employee of the Renewable Energy Services Programme (RESPRO) expressed the view that an institution for PV development only existed briefly in the country. In an interview, he noted that:

> *"From the inception of the RESPRO, we were made aware that after the completion of the project, it will still continue to function as the sole government institution responsible for the provision of off-grid electrification services in the country. However, after three years of operation, RESPRO became non-functional, because of lack of financial support. All the eight technical staff that carried out the PV installations and repairs in the course of the RESPRO were laid off"* (solar PV technician **'C')**.

From these mixed views, it can be argued that there is a relationship between the low adoption of PV, sustainability issues of PV projects and institutional failures. The views of the solar PV technician **'C'** reveal signs of institutional failure, including the absence of a consistent and dedicated institution for PV activities; the inadequacy of government financial support; and the lack of human capacity building (i.e. the technical personnel) and retention for PV activities. These weaknesses contribute to the problems of lack of skilled personnel, lack of maintenance, lack of know-how, poor awareness and unreliability (see Table 6.1). For instance, PV customer satisfaction depends on durable systems and efficient maintenance, which are functions of available and reliable technical personnel. One stakeholder of solar PV in Wechiau indicated that;

> *"Due to lack of maintenance, about 90% of solar households systems in Wechiau are not functioning at the moment. Out of the 10 solar PV street lighting systems, only 2 are functioning".*[111]

At the national level, inadequate level of co-ordination among MOE-GH and EC-GH seems to be another institutional weakness that militates against the promotion of solar PV in Ghana. Although the Acts establishing these two institutions clearly spell out their functions, there seems to be an institutional weakness in the form of an overlap of functions — a situation that could hamper energy development. For instance, as pointed out in section 6.3.3.1 above, the MOE-GH provides the overall policy direction for energy in Ghana in addition to supervising the operation of EC-GH and other energy institutions. At the same time, some of the functions of the EC-GH in section 2 of the EC Act, 1997 are that "the EC-GH … recommend national energy policies; advise the Minister of Energy on national policies" (p.6). Also, within both institutions there are different arrangements in its renewable energy divisions. Whilst senior civil servant **'B'** at the MOE-GH noted the existence of harmony

[111] Personal communication with solar PV technician **'A'** – June 2005.

between the two institutions, a junior worker at the EC-GH expressed the following view in an interview;

> "*There is some duplication of functions between the EC and MOE in some departments, but it is very difficult to comment*".

Another problem is the discharge of inappropriate functions or poor implementation of projects. As outlined in section 6.3.3.1 above, MOE-GH and EC-GH are both energy policy making institutions for the energy sector and not energy project implementing institutions. Besides the VRA, ECG, TOR, which have the technical expertise to implement energy projects and programmes, the MOE-GH and the EC-GH lack the technical capability to design and implement energy projects. It can therefore be argued that the implementation of the solar PV projects in the Wa West and Bunpkurugu/Yunyoo districts by the MOE-GH, both represent poor discharge of functions. The MOE-GH's lack of technical expertise in energy projects implementation, in addition to its status as a government institution, has resulted in implementation and management problems for these solar PV projects. An official in the renewable energy division of the EC-GH noted;

> "*The problems of PV projects implemented by MOE-GH are that staff members of MOE are more into policy issues and not the implementation of projects that involve the collection of money*".[112]

The PV project in Wa West District illustrates this well. On completion, this project was co-managed by the operators of the solar battery charging centre and a solar committee, and supervised by the MOE-GH from Accra. In an interview with the Wechiau chief, his elders and the current assembly member of Wechiau to the District Assembly, it became apparent that the project had suffered from poor supervision by

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[112] Personal communication with senior civil servant **'C'** Renewable Division, EC-GH – August 2005.

its implementers (i.e. MOE-GH), abuse of positions by solar committee members, poor coordination between the MOE-GH and the solar committee, poor after-installation services, absence of project sustainability plans and abandonment. These civil leaders of Wechiau summed up the factors that led to the problems of this MOE's PV project in Wechiau as follows:

> *"The visits of the MOE-GH to this project had been very irregular — sometimes once in two months or three months or no visits at all. In addition, the solar committee with the former assembly member of Wechiau as its chairman, misappropriated the PV tariff they collected, the fees accrued from the battery charging station and used not to pay the battery charging operators. Consequently, the battery charging operators stopped carrying out basic services to the community lighting systems and stopped giving the accrued fees from the battery charging centre to the solar committee. Similarly, PV users also stopped paying tariffs to the committee, because their PV systems were not being serviced when they break down. This first committee was dissolved and another one formed. However, it could not function properly".*[113]

Through interviews, it was clear that the project was no longer managed by anybody — the solar committee had been dissolved and personnel from the MOE-GH had also stopped visiting Wechiau. According to the solar battery operator in Wechiau;

> *"No PV user pays tariffs at the moment; no solar committee; the MOE-GH personnel have stopped visiting this project for about two years now, and we the solar battery operators will not account the fees we collect to anyone until we get our outstanding pay".*

[113] Personal communication with the current assembly member of Wechiau, the Wechiau naa (chief) and his elders.

The former assembly member of Wechiau, who also doubled as the former chairman of the solar committee refuted the assertion by the civil leaders of the village that the former solar committee misappropriated the PV tariff and fees that were collected. He noted that:

> *"Although the tariff and fees from the PV project were to be used to buy extra spare parts, repairs and to pay the workmanship of the electricians, in one of the MOE-GH officers' visit to Wechiau, they asked me to redraw all the PV generated money that I deposited at the bank for them. Meanwhile, because people in the village did not like me and others in the committee, they accused us of financial misappropriation".*

On the other hand, in a discussion with senior civil servant **'A'**[114] at the EC-GH concerning the MOE-GH's PV project in Wechiau, he intimated that;

> *"High operational cost limited the monitoring team in Accra from visiting the Wechiau PV project. Moreover, this was a donor project and the implementation period had elapsed. However, the project is going alright, because although I have not been there since 2000, information I gather from people who visit there is that the project is running well.*

The conflicting nature of these viewpoints raises more questions about the MOE-GH's technical, managerial (i.e. leadership) and human resource capabilities to implement and sustain PV projects in the country. Moreover, these views point to the poor institutional arrangements, poor policy framework and financing concern. It also reaffirms the government's reactive approach to PV activities rather than proactive, because of its dependency on donors. In addition, it showcases the absence of

[114] Senior civil servant **'A'** was the head of the MOE's PV implementation team in Wechiau.

government and indigenous sustainable[115] plans to support these donor projects after their operational phases.

6.4.5 Inadequacy of New Policy Instruments/Measures for Solar PV

Analysis of the fieldwork interviews and documents also revealed that the structure of the past and present renewable energy policy frameworks of Ghana have been devoid of potent innovative instruments/measures for the promotion of solar PV, especially in the rural areas. Unlike other countries (Table 6.3), which have seen the growth of their PV industries and an increase in the rate of PV adoption through innovative financing mechanisms, the analysis reveals that these innovative instruments/measures have been limited in scope in Ghana. From the three renewable energy policy regimes presented above, it is evident that the Energy Service Company (ESCO) concession, the lease/hire purchase, and the ESCO fee-for-service or utility models as discussed in Chapter Two, have not been deployed adequately and effectively for solar PV projects in the country. According to KITE (2005) "the country has no financial mechanism for supporting entrepreneurs… [and] … lack of financing schemes to support the poor to access energy services…" (p.30). However, a former employee of RESPRO argued that the fee-for-service model has had a wide application in PV projects in Ghana as he notes:

> *"Fee-for-service model has been used in the implementation of all the MOE's PV projects that have been undertaken so far, including the Wechiau project, RESPRO".*

[115] For instance in Wechiau, only 2 street lighting systems out of the 10 installed were functioning as at 2005. In an interview with the headmaster of the Binde primary school, it was also noted that no sustainable measure existed for the school PV system.

Notwithstanding the application of the fee-for-service in these donor PV projects, the question still remains regarding how effective this fee-for-service model under the authority of the MOE-GH has been in promoting PV dissemination in rural Ghana. As discussed in Chapter Two, the fee-for-service model works best when it is implemented by an ESCO and not an energy policy making institution.

From the analysis, it has also been revealed that the absence of broad and clear tax and exemption policy instruments for solar PV in these policy frameworks are also problematic. For example, in the 1998 energy policy, the Government of Ghana removed import duties and sales tax on solar generating systems in order to encourage their import and use. The provisions in that policy measure included the following;

> *"Solar panels do not attract import duty except the Balance of System (BOS). The complete PV system will also be exempted from Value Added Tax (VAT) if the components of the BOS are imported together. However, the importer will pay VAT on the BOS components if they are imported separately"*.[116]

While the Government hoped that the 1998 tax exemptions would stimulate the importation and use of PV, other stakeholders, especially private PV businesses, noted the opposite. For instance, Tse (2000) noted that "the wording of the exemptions was unclear, and the Customs Excise and Preventive Service (CEPS) has often been unable to assign a Harmonized System (HS) Code to imported solar energy equipment…an installation company that imports various components for assembly would…pay duties and taxes on all components except the modules themselves. On

[116] Personal communication with senior civil servant **'C'** at the EC-GH.

the other hand a company that imports complete kits including lights and appliances will enjoy the exemption because the crate is labelled 'Solar Generation System'" (p.12). Another key stakeholder further pointed out that;

"There is lack of clarity regarding what constitutes a solar generating system. For example, solar cookers are not classified as solar generating systems, and are therefore not exempted from import duties".[117]

Furthermore, policy on renewable energy in Ghana has lacked substantive and integrated programmes for solar PV. Within all the three renewable policy regimes, solar PV activities have all been named as demonstration projects, although their technical and physical viability had already been established in the first two renewable policy regimes. The absence of substantive projects in these policy regimes could be due to the government/MOE-GH's reactive approach to PV supply. Besides the absence of substantive PV programmes, the focus of PV projects and activities in these policy frameworks has been one directional - the supply of Solar Home Systems. There has not been any provision for the promotion of integrated solar PV projects, including solar PV systems for irrigation activities for rural areas that experience single rainfall seasons each year. As Bart van Campen *et al* (2000) pointed out "…the success of PV programmes is significantly enhanced when an integrated strategy is followed" (p. V). The unidirectional nature of PV projects raises questions in respect of the conformity between the agenda of the international donors of PV and the energy needs of the rural people. As pointed out in the literature, the majority of donor PV projects have been implemented against the backdrop of the need to reduce greenhouse gas emission. This agenda possibly runs contrary to issues such as food

[117] Spokesperson **'B'** from Solar Utilisation Network Company.

security, accessibility to potable water, high economic returns, which are more important to poor people in rural Ghana.

6.4.6 Problems of the Regulatory Framework

Problems relating to the regulatory framework for solar PV activities in Ghana were also identified in this study. After critically examining all the three energy policy frameworks' documents on renewable energy, it emerges that there has been inadequate definition of PV end-user protection measures, such as national PV companies' codes of practice, national PV technical standards; as well as the absence of certification, testing and enforcement institutions for PV. In an interview to find out what user protection measures the country has enforced, senior civil servant **'B'** at the MOE-GH division, gave his response as follows;

> *"We do not have standards, testing and certification for solar PV, but we will develop some. So until we develop and gazette these standards and other codes of practice, people are just bringing in solar PV systems they can afford".*[118]

This lack of standards and other end-user protection measures has led to poor perceptions (e.g. unreliability barrier) among urban and rural people regarding PV, which in turn have affected the adoption level of PV in Ghana. In other words, such a regulatory lapse could be closely associated with the poor perceptions that people develop regarding PV. As shown in Table 6.5 for instance, of the 50 respondents in the three case study areas, 64 percent strongly disagreed that there is a strong regulatory policy in the country that governs PV suppliers and protects PV end-users. One key stakeholder of PV also observed that;

[118] Personal communication with senior civil servant **'B'** at the MOE-GH – July 2005.

"Some people got discouraged with solar PV because of the type of PV systems that were imported. Due to the absence of prescribed standards for PV, there were a lot of importations by the sector during the energy crisis in 1998, the majority of them being labelled as excellent. However, a lot of people got discouraged about using PV again when they discovered that their systems were inefficient and could not last for long, contrary to what they were told".[119]

Some stakeholders were also of the opinion that the regulatory framework was susceptible to more problems when applied to PV service providers. One of the mandates of the EC-GH under section 2 of the EC-GH Act (Act 541) is to "…grant licences …to public utilities for the transmission, wholesale supply, distribution, refining, storage, bulk transportation, and sale of electricity, petroleum products and natural gas" (p.6). However, some private PV businesses view the processes of obtaining a licence to operate a solar PV business as being unclear and rather unwieldy. For example, in an interview, the manager of solar PV Company **'C'** described the conditions required to obtain a licence for PV business as follows;

"It takes many months to get all the documentations required to obtain a licence to operate solar PV Company. The application processes require an environmental impact assessment, environmental report and all sorts of paper works. And as far as the environmental impact assessment is concerned, the application is assessed using the same conditions used for the environmental impact assessment of an aluminium plant. In fact, It is unclear regarding the reason why a PV company is licensed using the same requirement for licensing a petroleum company when they are totally different. These requirements are difficult to understand".[120]

An official at the EC-GH, however, expressed the following views:

[119] A research person at FOE-GH – August 2005.
[120] Personal communication with spokesperson **'C'** from Solar Light Company – September 2005.

> *"We try our best to grant licences to people intending to operate PV business as early as we can. However, sometimes applications delay because of insufficient documents. We sometimes require applicants to carry out environmental impact assessment, because some applicants trade in other commodities in addition to PV in the same premises".*[121]

Unclear regulations for licensing private companies to sell PV can lead to less private sector involvement, especially small enterprises. Some of the factors inter alia, which could have contributed to the minimal involvement of private companies in PV activities in Ghana are the unclear and stringent regulations on licensing.

6.5 CONCLUSION

This chapter has examined the interfaces between the barriers to PV dissemination in rural Ghana and the country's energy policy measures, institutional and regulatory frameworks on PV energy. In other words, the chapter discussed the main characteristics of these renewable policy measures/instruments, institutional and regulatory frameworks and their effectiveness in overcoming the barriers to adoption and utilisation in the rural areas, and the sustainability of solar PV projects. The chapter was predicated on the fact that effective government institutional, policy and regulatory frameworks are the pivots to overcoming the barriers to PV development in rural areas in the developing world and vice versa. As such, the chapter counteracts the neo-liberal view expressed by some authors that subsidies on PV need to be eliminated in developing countries so as to increase economically competitive PV programmes. Making reference to selected countries' energy policy on PV, the chapter has detailed the importance of subsidies to the growth of their PV industry and how indispensable this is to other countries, including Ghana.

[121] Personal communication with senior civil servant **'A'** at EC-GH - June, 2005.

From the field data analysis, it was clear that the three energy policy regimes for Ghana that had provisions for renewable energy development and utilisation are the 1983 to 1991 energy policy framework, the 1996 to 2000 energy policy framework and the current policy, (2001 on). In the context of solar PV, government policy and institutional measures such as research and development, demonstrative projects, education, fee-for-service delivery, energy fund, that can enhance PV dissemination, have been developed and implemented in some of these policy regimes. However, the analysis has revealed that there are still a lot of questions on the efficiency of these institutional, policy and regulatory measures/instruments to overcoming the barriers to the adoption and utilisation of PV in rural Ghana and sustaining PV projects.

The national government of Ghana seems to have a conflict of interest between the national grid and PV supply. Consequently, government policy to create a level playing field for solar PV and national grid is still lacking. As the analysis revealed, there is more government expenditure, notably a favourable tariff system through subsidy for the national grid than solar PV. This therefore raises questions on the government's full commitment or political will to establishing and implementing clear policies for areas of PV and grid extension. The analysis also revealed issues of the non-existence of innovative policy instruments and PV market models; weak educational measures; institutional and regulatory frameworks' inefficiencies, including the overlap in functions between the MOE-GH and EC-GH, discharge of inappropriate functions, and the absence of consumer protection measures. In addition, although an Energy Fund has been set up at the EC-GH, solar PV and other RETs have been underfinanced from this fund.

Overall, these policies, institutional and regulatory lapses have cumulatively affected the sustainability of solar PV projects in the rural areas. Similarly, at the study sites of this research, these lapses form part and parcel of the factors that help explain the high level of unwillingness to adopt solar PV, with many people preferring the grid to PV. Generally, the analysis in the chapter illustrates the importance of effective government policy, regulatory and institutional frameworks in PV dissemination process. Hence, it can be concluded that the stage of PV market development in Ghana is linked to its unique internal processes — social, economic, political, institutional and regulatory issues. The next chapter, which is a comparative study between Ghana, Kenya and Zimbabwe, gives more insight to understanding such processes responsible for the levels of PV market development in different countries.

CHAPTER SEVEN

A COMPARISON OF SOLAR PV DEVELOPMENT TRAJECTORIES IN GHANA, KENYA AND ZIMBABWE

7.1 INTRODUCTION

Chapter Six examined the main characteristics of Ghana's renewable policy measures/instruments, institutional and regulatory frameworks vis-à-vis their functionality in addressing the barriers to PV adoption and utilisation in rural areas, and the sustainability of PV projects. This revealed the interrelatedness of Ghana's renewable policy, regulation, and institutional frameworks and the less encouraging patterns of PV dissemination and sustainability in the rural areas of the country.

Using empirical evidence from fieldwork in both Kenya and Ghana and extensive historical literature, Chapter Seven provides a comparative analysis of the different solar PV development trajectories in Kenya, Zimbabwe[122] and Ghana. The chapter seeks to answer the following key questions: what drivers or interactive historical and contemporary factors account for or help to explain the disparities in the dissemination rates of solar PV in these three countries? In other words, why has Ghana lagged behind in the dissemination and utilisation of PV, whilst its dissemination in countries such as Kenya and Zimbabwe as well as South Africa has boomed? What lessons can be learnt from this comparative study? Can these lessons shape policy to enhance PV dissemination process in Ghana?

[122] It should be noted that while the chapter explores the development trajectories of PV in Kenya and Ghana from the past to present time, in the case of Zimbabwe the comparative analysis focuses on the years PV dissemination started up to the early 2000s. This is because there is paucity of data on the technology in Zimbabwe after early 2000s due to the current political situation.

Kenya and Zimbabwe were chosen for this three-country analysis, because they are among the largest solar PV markets in Africa (Hankins, 2000, Duke *et al*, 2002, Jacobson, 2004). In particular, the Kenyan solar PV market has been viewed by many authors (including Duke *et al*, 2002, Otieno, 2004, Global Energy Network Institute (GENI), 2006) as an archetypal success story for solar PV market in the developing world. In contrast, Ghana appears to be one of the least developed solar PV markets in Africa (Table 7.1). Moreover, these three countries are located in different sub-regions in Africa — Kenya in East Africa, Zimbabwe in Southern Africa and Ghana in West Africa, all with contrasting socio-economic, political, historical circumstances, as shown below (section 7.2) — although all three countries have comparable favourable climates for solar PV application.

Table 7.1 Estimated number of solar PV systems disseminated in African countries

COUNTRY	ESTIMATED NUMBER OF SOLAR PV DISSEMINATED
Burundi	1,800
Djibouti	941
Malawi	900
Eritrea	2,000
Uganda	3,000
Ghana	4,601
Ethiopia	5,000
Botswana	8,000
Zimbabwe	85,000
Kenya	150,000
South Africa	150,000

Source: Karekezi, 2002b; Edjekumhene, 2003; Karekezi and Kithyoma, 2005.

Using the framework of the Social Construction of Technology (SCOT) theory, the existing historical background differences of these countries are examined to find out their influence in the dissemination process of solar PV in each case. Examining the historical perspectives of these countries within this theoretical framing is very important, because it reveals the importance of international, national and local processes and their linkages with solar PV dissemination. For instance, Jacobson (2004) argues that "…historically rooted similarities and differences among countries play a central role in determining the possibilities for a solar market development in each context" (p. 131). Examples of solar PV perspectives in other developing countries are used throughout the chapter to corroborate its contextualisation.

From the global perspective, Germany is currently the highest solar PV market installer in the world with a share of 57 percent, followed by Japan (20 percent), United States (7 percent), the rest of Europe (6 percent), and the rest of the world (10 percent) (Marketbuzz™, 2006). Africa's share of this global PV market is less than five percent (Hankins, 2004). Some driving forces account for the different growth rates of PV markets in the industrialized countries. In Germany and Japan for example, both governments have legislated for high subsidies which have stimulated the development of their domestic PV markets. Consequently, solar PV industries in Germany and Japan have strong distribution and dealer networks with well-trained installers and better customer support capabilities relative to other industrialised countries (Solarbuzz LL, 2006).

Similarly, the levels of solar PV diffusion differ among developing countries, which could be attributable to a host of factors. Kenya, Mexico, South Africa, Zimbabwe, India, and the Dominican Republic for instance, have high rates of PV dissemination[123] (Acker and Kammen, 1996; Kammen, 1996), whilst Malawi,

[123] It should be noted that high level of dissemination in these countries does not mean all the systems have been sustainable or still operational. As demonstrated in the Ghana case in chapter 5 and 6 and in other studies by a host of authors — Acker and Kammen, 1996; Bacon, 1998; Duke *et al*, 2002; Mulugetta et al, 2000, a lot of installed PV systems in developing countries have gone into disuse because of technical problems. However, the preponderant centrepiece in this chapter is to unpack

Zambia, Ethiopia and Ghana on the other hand have relatively low rates. For instance, although South Africa is currently among the category of developing countries with a high PV diffusion rate, its PV dissemination rate was slower than Kenya in the 1990s, especially 1994, because of dissimilar drivers in the two countries' PV markets (Margolis *et al*, 1996). Therefore, the analysis in this chapter will help to explore the possible drivers that have influenced the differing levels of PV market development and dissemination in Ghana, Kenya and Zimbabwe.

Chapter Seven is divided into four main sections, starting with this introductory section. In section 7.2, the geographic and economic profiles of each of the three countries, their energy generation mix and the historical accounts of solar PV development are discussed. The main drivers that have influenced the disparity in solar PV diffusion in these countries are teased out and juxtaposed in section 7.3, while section 7.4 highlights the main issues that have emerged from this comparative study by way of concluding the chapter.

7.2 SOLAR PV DEVELOPMENT IN KENYA, ZIMBABWE AND GHANA

7.2.1.1 Geographic and Socio-economic Profiles of Kenya

Located in eastern Africa, Kenya straddles the equator, which bisects it into two nearly equal parts lying between 4.5° N and 4.5° S, and borders the Indian Ocean between Somalia and Tanzania. The total area of the country is 582,650km^2 with approximately 34.7 million people, and an annual population growth rate of 2.57 percent (CIA World Factbook - Kenya, 2007). The majority of the population (approximately 79 percent) in Kenya, live in the rural areas; the population density of

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'whys' and 'hows' there are such high levels of solar PV diffusion in some countries in Africa (using Kenya and Zimbabwe) and low diffusion rates in others (using Ghana).

the country reaches over 300 per square km in some areas and as low as 5 per square km in others (Agumba and Osawa, 2000, Hankins, 2001, CIA World Factbook - Kenya, 2007).

The GDP of Kenya was $17.39 billion in 2006 with a growth rate of 5.8 percent, whilst per capita GDP was $1,100 (CIA World Factbook - Kenya, 2007). Classified as a low-income country by the World Bank, about 50 percent of the population was below the poverty line in the year 2000. The major sectors in the economy are agriculture (16.3 percent); industry (18.8 percent); and services (65.1 percent) (Table 7.2).

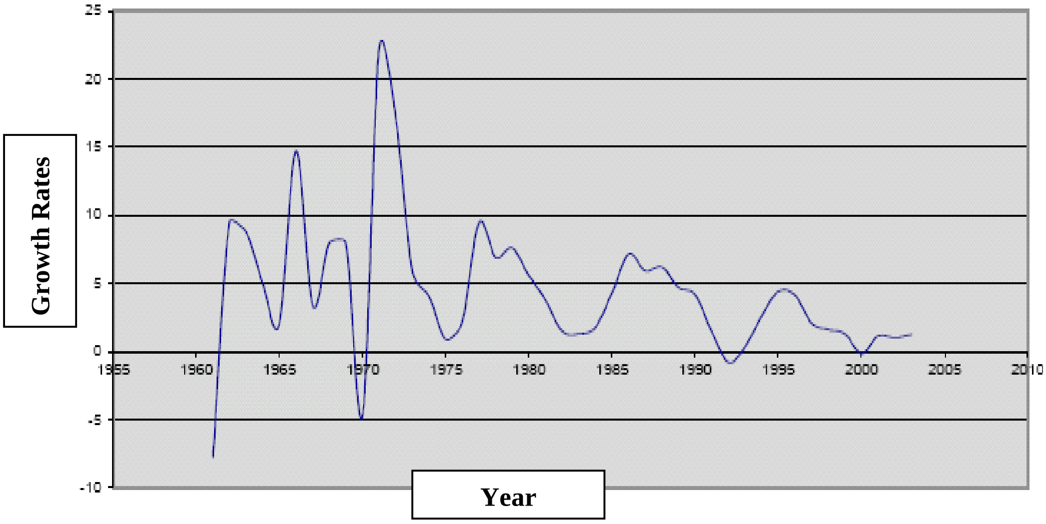
Table 7.2 Summary of current demographic and economic indicators of Kenya

Population	34.7m (2006 est.)
GDP – Real Growth Rate	5.5% (2006 est.)
GDP Per capita	Purchasing Power Parity – $1,100 (2005 est.)
GDP – Composition by sector	Agriculture: 16.3% Industry: 18.8% Services:65.1% (2004 est.)
Labour force – by occupation	Agriculture: 75% Industry and services: 25% (2003 est.)
Population below Poverty line	50% (2000 est.)
Currency	Kenyan shilling (KES)
Exchange Rate	Kenyan shillings per US dollar – 75.554 (2005), 79.174 (2004), 75.936 (2003), 78.749 (2002).

Source: CIA World Factbook - Kenya, 2007.

From a historical perspective, after independence in 1963, Kenya had ten years (1963 to 1973) of steady and rapid economic growth in a stable political environment. This steady economic growth was realised through the promotion of public investment, encouragement of smallholder agricultural production, and incentives for private (often foreign) industrial investment (Acker and Kammen, 1996; Bureau of Africa Affairs, 2007a). During this ten-year period, the Kenyan GDP grew at an annual average of 6.6 percent, while agricultural production grew by 4.7 percent annually, stimulated by redistributing estates, diffusing new crop strains, and opening new areas to cultivation (Bureau of Africa Affairs, 2007a).

Figure 7.1 Kenya: changes in GDP growth rates since 1960



Source: Dunne and Asaly, 2005.

The post-independence economic growth was interrupted by the first and second oil shocks[124] of 1973-1974 and 1979 respectively. However, Kenya rebounded back from both oil shocks and recorded a strong annual economic growth (about 10 percent) by the end of the 1970s and about 6.2 percent from the mid-1980s through to the early 1990s (see Figure 7.1 above). Currently, tea and coffee are the third largest foreign exchange earning sector in Kenya after tourism and flowers (Bureau of Africa Affairs, 2007a).

[124] Kenya imports all of its oil and is therefore vulnerable to fluctuations in petroleum prices.

7.2.1.2 The Electricity Generation Mix of Kenya

The total electricity production of Kenya, using 2005 data estimates, is 4.34 TWh (International Atomic Energy Agency (IAEA), 2006a). The sources of the electricity generation mix of the country comprise hydroelectric plants, thermal plants and other plants (i.e. biomass, wood and waste, wind, geothermal, solar) (IAEA, 2006a). The relative percentages of electricity production from these electricity generation sources using the 2003[125] electricity data are as follows: hydroelectricity 74 percent; thermal electricity 17.8 percent; and other sources (biomass, wood and waste, wind, geothermal, solar) 7.9 percent (IAEA, 2006a). In the latter source of electricity production, geothermal electricity generating capacity constitutes five percent, while biomass, wood and waste, wind and solar electricity generating capacities constitute the remaining 2.9 percent (World Energy Council (WEC), 2001).

Since 1974, the government of Kenya has embarked on a Rural Electrification Programme (REP), principally based on the national grid extension strategy for the uplift of the quality of life among the rural people (Margolis *et al*, 1996; BCEOM,[126] Energy Alternatives Africa Ltd (EAA) and FONDEM[127] Consortia, 2001). Data from 2000 to 2004 show that only about 15 percent of the entire population (and about four percent of the over twenty-seven million rural population) have access to electricity from the grid (Hankins, 2000; BCEOM EAA FONDEM Consortia, 2001; Energy for Sustainable Development (ESD), 2003; Keiffenheim, 2004; UN Millennium Project, 2004). New rural grid connections in the country are only approximately 5000 persons per year (IEA-PVPS T9-07, 2003).

[125] The latest energy data figures on Kenya are dated to 2003.
[126] BCEOM is a French semi-public company. Its full meaning is: Bureau Central d'Etudes pour les Equipements d'Outre-Mer.
[127] FONDEM is a French non-governmental organisation. Its full meaning is: Fondation Energies pour le Monde.

On the other hand, more than 150,000 units of solar PV systems (i.e. more than 2.5 MWp) have been installed in Kenya since 1990, predominantly through the private PV sector especially in the rural areas, and with approximately 20,000 new systems being installed annually (Duke *et al*, 2002; ESD, 2003). The BCEOM EAA FONDEM Consortia's study (2001) indicated that "…about three percent of rural Kenya currently uses PV systems…" (p.16). Based on these figures, it could be concluded that the utilisation of solar PV in rural Kenya is comparable with or even better than the national grid. As the IEA PVPS T9-07 (2003) observed "the number of homes being electrified annually with PV in the rural areas [in Kenya] exceeds that being electrified through grid extension by the electrical utility" (p.83).

7.2.1.3 Historical Perspective of Solar PV Development and Dissemination in Kenya

Solar PV systems were first used in Kenya in the late 1970s for government funded projects in telecommunications (Duke *et al*, 2002; Acker and Kammen, 1996). The sales and use of the technology in Kenya, however, grew significantly in the 1980s. This period witnessed international donor funding for solar photovoltaic projects for a range of applications, including power for health clinics, water pumps in arid areas, schools, electric fences in wildlife reserves, Christian mission compounds; and the emergence of the private PV market (Musinga *et al*, 1997; Duke and Kammen, 2002). Prior to 1984, little attention was given to direct sales of PV to rural Kenyans. Several solar import companies' shops were only located in Nairobi to meet the donor driven demand. "The conventional wisdom at the time was that rural residents did not have enough money to buy solar PV systems" (Acker and Kammen, 2002:481, citing Hankins, 1992).

In 1984, Harold Burris, an ex-Peace Corps volunteer from the United States of America, set up a small business (the first ever PV business shop outside the capital of Nairobi) in a coffee growing region near Mount Kenya.[128] While international PV companies in Nairobi were focusing on donor markets, Burris sought ways that PV could cost-effectively be taken up by households and businesses in the neighbouring village (Hankins, 2001b). The success of Burris' enterprise marked the dawn of the private[129] PV market in rural Kenya, which has since been on the ascent. According to ESD (2003) "…Kenya…has reached the mature market stage [of commercial PV market development]…" (p.7). Authors such as Hankins (2001b), Agumba and Osawa (2000) and others have classified the development of the PV market in Kenya into four stages:

- **1981-1983: The early stages of PV development**

This stage was triggered by the 1981 United Nations Environment Programme's (UNEP) conference on renewable energy, held in Nairobi. The conference brought solar energy into sharp focus among the private sector, donors, NGOs, experts and consumers, because of the oil price shocks of the seventies (Hankins, 2001b). This period was therefore characterised by multinational use of larger PV systems in large-scale telecommunications, and demonstration in water pumping, vaccine refrigeration and off-grid school lighting projects; the establishment of at least three PV companies selling PV modules in Nairobi; and Nairobi was the East Africa regional centre from

[128] Burris had initially set up a solar business called "Kidogo Systems" in the town of Machakos in 1982 ("Kidogo" means "small" in the Swahili language). In 1984 he renamed the business "Solar Shamba" and moved it to the town of Embu in the coffee growing belt around Mt. Kenya ("Shamba" means "small farm" in Swahili). This move to a more lucrative market marked the beginning of successful cash market direct sales of solar PV systems to rural customers in Kenya (Acker and Kammen, 1996; Jacobson, 2004).
[129] "The private market's genesis [of solar PV] may be roughly dated as 1984" (Acker and Kammen, 1996:87).

which PV systems were purchased (Acker and Kammen, 1996; Hankins, 2001b). In effect, this period was characterised by donor aid and government funded systems.

- **1984 - 1989: PV market development**

The commercial PV market began from this stage and developed steadily (Acker and Kammen, 1996; Agumba and Osawa, 2000). According to Hankins (2001b) "Between 1984 and 1989, a market developed for the solar home system concept. "Solar Shamba", Betto Solar and a few other players pulled together the solar home system package idea, and immediately a number of larger players got involved in mass producing and marketing the product" (p. 3). General growth in PV sales was around 5-10 percent per annum for this period (Agumba and Osawa, 2000).

Typical systems sold to rural families during this period, especially from 1984 to1988 used crystalline modules of about 40Wp (Acker and Kammen, 1996). According to Agumba and Osawa (2000) "Over 90 percent of the modules sold from 1984 to 1988 were crystalline" (p.2). However, in 1989 small low cost photovoltaic amorphous silicon (a-Si) modules entered the Kenyan PV market (Duke *et al*, 2002). In addition, the PV industry at this time also started to use a lot of balance of system of components such as fluorescent lamps and holders, batteries, inverters charge controllers, , from local manufacturers (Hankins, 2001b).

- **1990 -1997: Bigger players and smaller systems**

From the early and mid 1990s the PV market grew steadily, especially after 1994, it grew at a rate of over 25 percent per annum (Hankins, 2001b). The characteristics of this period include the engagement of bigger players in the PV business, such as supplier companies, in the dissemination of PV to the rural areas. The 10Wp and 14Wp a-Si PV modules that entered the market in 1989 were widely adopted within this period, with sales exceeding that of crystalline PV in terms of total kilowatts (EAA, 1999). In addition, while the relative percentage of complete system sales went on the decline, the number of over-the-counter, customer-installed systems [or what is sometimes called the ‘do-it-yourself systems] increased during this period (Agumba and Osawa, 2000).

- **1998 onwards: Low-cost imports and development of finance systems.**

From 1998 onwards also marked another phase of PV development and dissemination in Kenya. As at 1998, the Kenyan PV market reached about three percent of the total population (Hankins, 2001b). The PV market in Kenya from 1998 to date has been dominated by the small amorphous silicon PV systems, with the average system size being less than 25Wp. Duke *et al* (2002) observed that “Most solar home systems in rural Kenya are now based on a 12Wp or 14Wp a-Si modules…” (p. 481). This period is also characterised by the introduction of consumer financing systems including hire purchase for solar PV.

7.2.2.1 Geographic and Socio-economic Profiles of Zimbabwe

Zimbabwe is located in Southern Africa between 20° 00 S and 30° 00 E (CIA World Factbook - Zimbabwe, 2007). It is bordered by South Africa to the South, Botswana to the West, Mozambique to the East and Zambia to the North. With a total land area of 390,580 km^2 Zimbabwe has a total population of about 12.3 million as at 2006. Just like Kenya, the majority of the population live in the rural areas. While about 68 to 70 percent of the Zimbabwean population live in the rural areas, 32 percent live in the urban areas (Mapako, 2002; IEA-PVPS T9-07, 2003). The population density averages 32.64 persons per square kilometre (CIA World Factbook - Zimbabwe, 2007), with most densely populated rural areas approaching 180 persons per square kilometre (Mapako, 2002).

From 2006 statistical estimates, Zimbabwe has a GDP (Purchasing Power Parity (PPP)) of about $25.05 billion, a per capita GDP of $2000 and a negative growth rate of -4.4 percent (CIA World Factbook - Zimbabwe, 2007). About 80 percent of the population are below the poverty line, while the main sectors in the economy comprise services, industry and agriculture (see Table 7.3). Principal export items are mineral products, such as gold and nickel, and farm products such as tobacco and cotton (IEA-PVPS T9-07, 2003). Agricultural industry used to consist of the commercial plantations run by large-scale farms before the land reform efforts in 2000. Zimbabwe has an important percentage of the world's known reserves of metallurgical-grade chromites and other commercial mineral deposits including coal, platinum, asbestos, copper and iron ore (Bureau of Africa Affairs, 2007b).

Table 7.3 Summary of current demographic and economic indicators of Zimbabwe

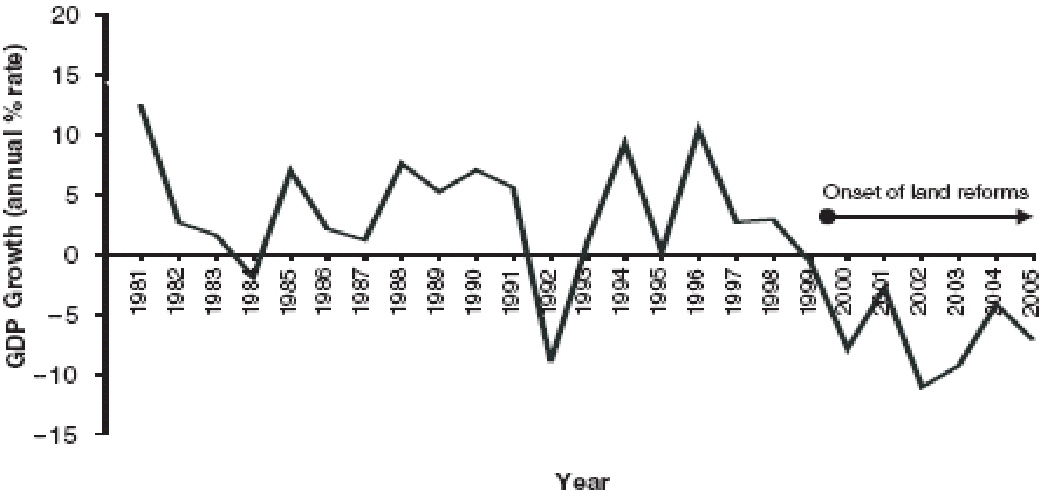
Population	12.3m (2006 est.)
GDP – Real Growth Rate	-4.4% (2006 est.)
GDP Per capita	Purchasing Power Parity – $2,000 (2006 est.)
GDP – Composition by sector	Agriculture: 17.7% Industry: 22.9% Services:59.4% (2006 est.)
Labour force – by occupation	Agriculture: 66% Industry: 10% Services: 24% (1996 est.)
Population below Poverty line	80% (2004 est.)
Currency	Zimbabwean dollar (ZWD)
Exchange Rate	Zimbabwean dollars per US dollar – 4,303.28 (2005), 5,068.66 (2004), 697.424 (2003), 55.036 (2002).

Source: CIA World Factbook - Zimbabwe, 2007.

Zimbabwe has had a chequered economic history before and after independence. In the early 1970s, the economy experienced a modest boom, while it slumped between 1974 and 1978 (Bureau of Africa Affairs, 2007b). However, between 1979 and 1981, Zimbabwe experienced a brisk economic recovery, with the annual real GDP growth rate exceeding 20 percent. The pattern of economic growth in the remainder of the 1980s to the early part of the 1990s was replete with fluctuations. The annual real GDP growth rate declined in 1982, 1983, and 1984; increased in 1985; slumped to zero in 1986; registered three percent in 1987 and averaged about five percent in 1988 through 1991 (Bureau of Africa Affairs, 2007b; Richardson, 2006). According to Richardson (2006) "Economic growth [of Zimbabwe] from 1980 to 1989 averaged a robust 5.2 percent in real terms…" (p. 2).

Similarly, real GDP growth rate of Zimbabwe in the remainder of the 1990s has also been characterised by fluctuations. It plummeted in 1992 and 1993 to about -6 percent and zero respectively, rose to about 7 percent in 1994, zero in 1995, 10 percent in 1996 and averaged about 3.7 percent and 2.5 percent in 1997 and 1998, respectively (Richardson, 2006) (Figure 7.2). However, from 1999 to date, Zimbabwe has been recording negative growth rates.

Figure 7.2 Zimbabwe: Changes in GDP Growth rates, 1981-2005



Source: Adapted from Richardson, 2006.

7.2.2.2 The Electricity Generation Mix of Zimbabwe

The total electricity production of Zimbabwe, using 2003 data estimates is 8.88TWh (IAEA, 2006b). In Zimbabwe, electricity is supplied mainly from a mix of hydroelectric and coal-fired thermal power plants (UNDP/World Bank ESMAP[130] Report 228/00, 2000; IEA-PVPS T9-07, 2003). With reference to the 2003 electricity generation figures of Zimbabwe compiled by the IAEA (2006b), hydroelectric plants produce 49.2 percent of the country's electricity, while thermal plants produce 50.8 percent. Although Zimbabwe has no nuclear plants that produce electricity, it should be noted that the above data failed to measure the cumulative percentage of electricity supplied from solar PV. Extrapolations from Painuly and Fenhann's work in 2002, however, showed that Zimbabwe has an installed capacity of over 1MW of solar PV as at 1998 (Painuly and Fenhann, 2002).

[130] ESMAP refers to 'Energy Sector Management Assistance Programme'.

In Zimbabwe, about thirty to thirty-five percent of the total national number of households (about 2,510,410) is connected to the electricity grid (Mapako, 2002; IEA-PVPS T9-07, 2003). However, while over seventy percent of urban households are electrified through the grid, only five percent of the rural households are grid-electrified (Afrane-Okese and Mapako, 2003). In 1997, the government of Zimbabwe initiated its first post-independence ten-year rural electrification programme (Mapako, 2004).

With an annual insolation of over 2000kWh/m^2 (conducive for solar PV application), Zimbabwe has about 85 000 solar PV household systems installed (Afrane-Okese and Mapako, 2003). According to the UNDP/World Bank ESMAP Report 228/00, (2000) “The Zimbabwe Electricity Supply Authority (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, utilise PV electricity” (p.10). Prior to the year 2000, the annual increase growth of solar PV in Zimbabwe was estimated at three percent (Southern Centre for Energy and Environment (SCEE), 2001).

7.2.2.3 Historical Perspective of Solar PV Development and Dissemination in Zimbabwe

Like Kenya, the solar PV market in Zimbabwe has been considered by authors and research reports (e.g. UNDP/World Bank ESMAP Report 228/00, 2000) as being robust and mature. Solar PV systems have been in domestic and commercial use in Zimbabwe since the 1960s[131] and 1970s (Bacon, 1998; Mapako and Afrane-Okese, 2002). However, the technology began to attract more attention in the 1980s (Mulugetta *et al*, 2000; UNFCCC, 1998). In the 1980s, solar PV systems were

[131] Bacon (1998) observed that “A small-scale PV industry has existed in Zimbabwe since the 1960s” (p.258), while Mapako and Afrane-Okese (2002) indicated that “…The [PV] market [in Zimbabwe] was active since the early 1970s…” (p.2).

installed in rural households, small businesses, schools and health service centres. Citing Energy Bulletin (1991), Mulugetta *et al* (2000) observe that "Between the mid-1980s and early 1990s, there were about 2400 households in rural Zimbabwe that had solar PV systems" (p.1).

In Zimbabwe, the production of PV systems began in 1988 (UNDP/World Bank ESMAP Report 228/00, 2000). Solar PV cells were purchased on the international market and assembled into panels. By late 1998, about 73 companies were involved in various aspects of solar PV systems market in Zimbabwe, including among others four local lights producing companies, two companies that undertook various stages of solar refrigerator production and four local battery companies that serviced the local market (ibid).

The dissemination of early solar PV systems in Zimbabwe was mostly through the private sector with a few donor-funded systems. According to Mulugetta *et al* (2000) "…the most likely clients were urban workers, buying systems for relatives in rural areas or rural-based civil servants who had some reserve of disposable income" (p.1069). At that time, there was no government strategy on solar PV systems with almost all of the support coming from donor organisations and their assistance to governmental organisations and the private sector (ibid). Consequently, the purchase of solar PV systems was limited to the ability to pay the market price. As Mulugetta *et al* (2000) further noted "Those who could not pay the lump sum outright or provide some guarantee of full payment were effectively excluded from having access to the technology. Thus, the solar companies largely targeted the affluent rural dwellers or urban residents with second homes in rural areas" (p.1069). Donor related solar PV activities that were undertaken in the 1990s in Zimbabwe are as follows.

From 1993 to 1998, the Global Environment Facility (GEF) in conjunction with the United Nations Development Programme (UNDP) and the government of Zimbabwe carried out a solar PV project in Zimbabwe, using three modes of dissemination — private, utility and Non-Governmental Organisation (NGO) delivery. This project installed about 12 000 solar PV systems (Mapako and Afrane-Okese, 2002). Between 1997 and 1998, the Japan International Cooperation Agency (JICA) funded a project that installed some solar PV systems in the country through the Energy Services Company (ESCO) dissemination approach. Additionally, in 1999 the Chinese government donated a number of solar PV systems with televisions and a communal water pump to some communities in the country (Mapako and Afrane-Okese, 2003). Taken together, these projects installed about 20 000 systems out of the total installed (85 000) PV systems in the country (Mapako and Afrane-Okese, 2002).

7.2.3.1 Geographic and Socio-economic Profiles of Ghana

In a brief overview,[132] Ghana is located between latitude 4° and 15° N with a land total land area of 238,540 km^2. Ghana has a population of approximately 22.4 million (CIA World Factbook - Ghana, 2007). Of the total population, fifty-four percent lives in the rural areas, while population density in the country varies from 897 per km^2 in the southern part of country, especially Greater Accra Region to 31 per km^2 in the north, especially the Northern Region (World Health Organisation (WHO), 2006). Table 7.4 below is a summary of population and economic indicators of the country.

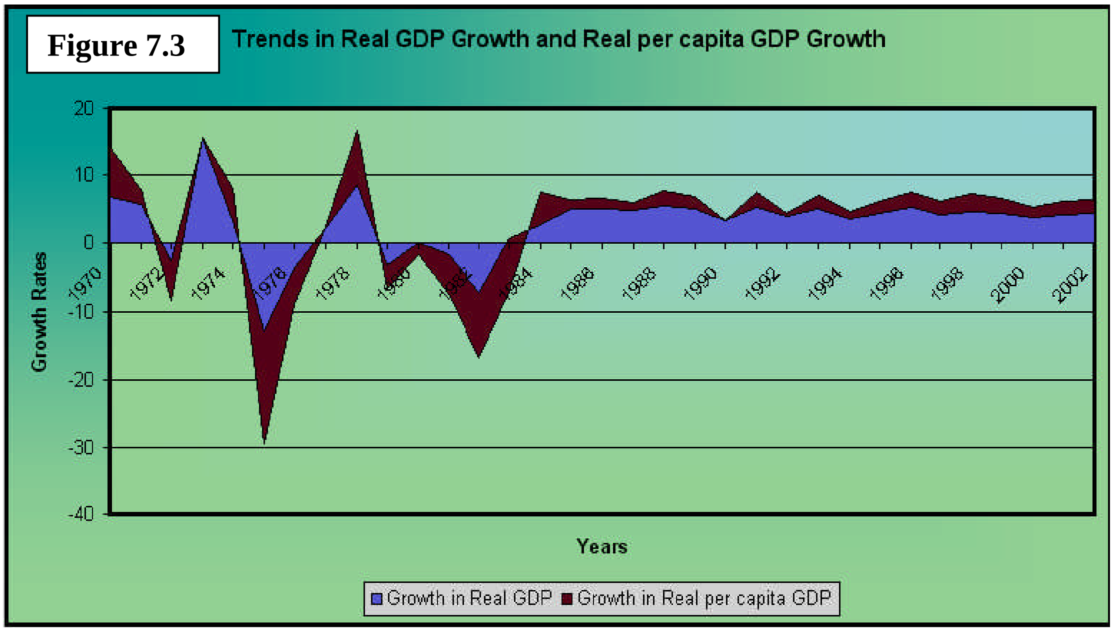
[132] Refer to Chapter Four for extensive discussion on current trends of geographic and socio-economic profiles of Ghana. However, the political and economic histories of Ghana are reviewed herein.

Table 7.4 Summary of current demographic and economic indicators of Ghana

Population	22.4m (2006 est.)
GDP - Real Growth rate	5.7% (2006 est.)
GDP - Per capita	Purchasing Power Parity -$2,600 (2006 est.)
GDP - Composition by sector	Agriculture:37.3% Industry: 25.3% Sevices:37.5% (2006 est.)
Labour force - by occupation	Agriculture: 60% Industry: 15% Services: 25% (1999 est.)
Population below poverty line	31.4% (1990-2003 est.)
Currency	Cedi (GHC)
Exchange rates	Ghanaian cedis (¢) per US dollar - [9,164.66 (2006)], [9,127.42 (2005)], [9,004.6 (2004)], [8,677.4(2003)], [7,932.7 (2002)], [7,170.8(2001)]

Source: CIA World Factbook - Ghana, 2007; UNDP, 2006.

The economic growth record of Ghana has been one of unevenness since it attained independence in 1957. With a reasonably high GDP real growth in the 1950s and early 1960s, the Ghanaian economy began to experience a slowdown in GDP growth in 1964. According to Aryeetey and Fosu (2003) “Growth was turbulent during much of the period after the mid-1960s and only began to stabilise after 1984. In 1966, 1972, 1975-1976, 1979, 1980-1984, the growth rate was negative” (p.4). The lowest growth rate of -14 percent was experienced in 1975, while the highest peak rate reaching 9 percent was experienced in 1970 and 1978 (see Figure 7.3) (ibid).



Source: Adapted from Aryeetey and Fosu, 2003.

However, as demonstrated by Figure 7.3 above, the economy recovered from its negative growth rate of about -5 percent in 1983 to a large positive rate of 8 percent in 1984. Since then (i.e. 1984), Ghana has had favourable growth, with relatively little variance (Aryeetey and Fosu, 2003). Currently, real GDP growth rate of the country is 5.7 percent (Table 7.4).

7.2.3.2 The Electricity Generation Mix of Ghana

Some highlights[133] of the electricity generation mix of Ghana are as follows. The total electricity production is 5.36 TWh (IAEA, 2006c), using 2003 estimates. Eighty-four percent is produced by hydroelectric plants, while sixteen percent is generated by thermal plants (ibid). About 4,601 solar PV systems have been installed in Ghana (Edjekumhene, 2003). In 1989, Ghana instituted a thirty-year National Electrification Scheme that started from 1990. Currently, forty-three percent of the population have access to the national grid, with seventy-seven percent and seventeen percent of the urban and rural households having access to electricity respectively (AEO, 2003).

[133] Refer to chapter four for a detailed examination of the electricity generation mix of Ghana.

7.2.3.3 Historical Perspective of Solar PV Development and Dissemination in Ghana

The history of solar PV development and dissemination in Ghana dates back to the 1990s. By 1991 only 337 solar PV systems with varying applications had been installed, but this number increased steadily to 3,490 by 2000 (Tse, 2000) (see Table 7.5). However, as indicated above, the total number of installed solar PV systems in Ghana is now 4,601. About twelve active solar PV companies and retailers were involved in the installation and sale of solar PV systems in early 1999, i.e. shortly after the country experienced an electricity crisis in 1997 (Tse, 1999). All these companies were either located in Accra or Kumasi (i.e. the two most developed cities in the country), but none in the rural areas or the other regions. However, "By the middle of 2000, fewer than half of these companies were actively involved in the industry" (Tse, 2000:5).

Extrapolations from the 2005 fieldwork interviews[134] with PV stakeholders as well as documentary evidence sources (e.g. Solarbuzz™, 2005a), suggest that only about seven companies and retailers currently sell solar PV components alongside other electrical equipments or goods in the country. They are all concentrated in the cities, six in Accra and one in Tamale.

[134] Personal communication with spokesperson '**A'** from BEST Solar Company and spokesperson **'C'** from Solar Light Company in Ghana - July 2005.

Table 7.5 Status of solar photovoltaic dissemination in Ghana

NUMBER OF SYSTEMS INSTALLED (CUMULATIVE)				
Application	**1991**	**1994**	**1998**	**2000 (est.)**
Lighting	25	67	1,500	2,200
Water Pumping	5	n/a	50	80
Vaccine Refrigeration	68	56	180	210
Telecommunications	214	500	800	900
Other	25	77	n/a	100
Total	**337**	**700**	**2,530**	**3,490**
PEAK WATTS OF SYSTEMS INSTALLED (CUMULATIVE)				
Application	**1991**	**1994**	**1998**	**2000**
Lighting	12 kW	18 kW	100 kW	120 kW
Water Pumping	3 kW	n/a	20 kW	25 kW
Vaccine Refrigeration	32 kW	14 kW	40 kW	48 kW
Telecommunications	102 kW	292 kW	350 kW	450 kW
Other	11 kW	26 kW	n/a	50 kW
Total	**160 kW**	**350 kW**	**510 kW**	**693 kW**

Source: Adapted from Tse, 2000.

Table 7.6 below is a summary of a range of socio-economic indicators (past and present), as well as the general electricity and solar PV status of the three countries outlined above.

Table 7.6 Summary of aspects of past and present socio-economic and energy (electricity and solar PV) in Kenya, Zimbabwe, Ghana

	KENYA	ZIMBABWE	GHANA
1) Population	34.7m	12.3m	22.4m
% Rural	79%	68%	54%
% Urban	21%	32%	46%
2) Total Electricity Production	4.34 TWh	8.88 TWh	5.36TWh
% Hydroelectric Plants	74%	49.2%	84%
% Thermal Plants	17.8%	50.8%	16%
% Solar and other plants	7.9%	0.0%	0.0%
3) Percentage of national access to grid electricity	15%	32%	43%
% Urban	20%	70%	77%
% Rural	4%	5%	17%
4) Number of Installed PV Systems	150 000	85 000	4 601
Year/Period of solar PV inception	1970s	1960s and 1970s	1990s
5) Past Economic Growth Rate Trends			
Early 1970s - Mid 1980s	Steady growth with a few intermittent declines	Steady growth with a few intermittent declines	Continual economic decline
Mid 1980s - Mid 1990s	Steady economic growth	Steady growth with intermittent declines	Steady growth
Mid 1990s - Early 2000s	Steady growth with intermittent declines	Initial steady growth in the mid-1990s and massive and continual decline from 1999 onwards	Steady growth

Source: Own construction, 2007.

7.3 COMPARATIVE ANALYSIS OF THE DIFFERENT DEVELOPMENT AND DISSEMINATION PATHS OF SOLAR PV IN KENYA, ZIMBABWE, GHANA

Table 7.6 above shows that while Kenya and Zimbabwe have much in common, there are considerable differences between them and Ghana. Compared to Ghana, Kenya and Zimbabwe have experienced a rapid growth in solar PV dissemination since the 1960s/1970s. For Ghana, the solar PV industry started becoming active in the 1990s. The focus of this section is to uncover the drivers that underpin the solar PV dissemination disparities amongst these countries.

Understanding of the disparate dissemination levels of this technology in the three countries needs to be situated in a combination of contextually specific historical processes and factors in the respective countries. Table 7.7 below synthesises the identified historical forces and drivers that help explain the three-country solar PV dissemination disparities. As the table indicates, these drivers can be broadly classified into direct and indirect categories. In addition, each driver can be classified as being internationally or nationally oriented, depending on their geographic scales of operation. It should be noted that none of these drivers, taken alone or a combination of two, is adequate to offer understanding of the different dissemination levels of solar PV in the three countries. Rather, it is the combined effect of all these drivers that is very important for understanding the different solar PV dissemination trajectories in the three countries under consideration. Each of the drivers, firstly the direct drivers, is critically examined below.

Table 7.7 Classification of the drivers underpinning the different rates of PV development and dissemination in Kenya, Zimbabwe and Ghana

DIRECT DRIVERS	INDIRECT DRIVERS
Role of international funding	
Government policy direction on energy - Policies on grid vis-à-vis PV -Rate of grid extension	Disparate political historical landscapes of the three countries
Market approaches/access dynamics - Targeting the rural affluent group √ Entrepreneurial spirit of solar PV businesses -Awareness creation -Adoption of favourable financing schemes	
Technical Capacity building on solar PV -Sizes of PV systems sold -Estimated number of solar PV companies and technicians -Estimated number of other PV institutions	
Disparate historical economic forces, especially in the rural areas	
GEOGRAPHIC SCALES OF DRIVERS	
International Drivers	**National/Local Drivers**
International funding	Government policy direction on energy
	Market approaches/access dynamics
	Technical capacity building on solar PV
	Disparate economic and political historical landscapes

Source: Own Construction, 2007.

7.3.1 Role of International Funding/Donor Support

One of the historical factors that helps explain the high levels of solar PV dissemination in Kenya and Zimbabwe as compared to Ghana is the different levels of influence exerted by western donors (e.g. international government agencies and NGOs, bilateral aid, and church organisations) in solar PV issues in these countries. One area of donor agencies' influence in solar PV issues is investment. Their investment in solar PV would have either contributed to wider dissemination and increase in awareness of the technology or low dissemination and low awareness.

Kenya, Zimbabwe and Ghana illustrate the effect of different levels of donor investment.

With respect to Kenya, it cannot be overemphasised that donor investment in solar PV has been a great catalyst to the growth of the technology's market. Donor agencies' investment in solar PV has been substantial, especially from the 1970s to the middle of the 1980s, which eventually triggered the private market development. According to Acker and Kammen (1996) "…the 'donor market' — mostly large-scale photovoltaic projects funded by donor agencies — was for a number of years the only PV market in Kenya…Not only did their funding create a demand for PV that allowed the private market subsequently to develop, but the donor agencies supported workshops, training and demonstration projects as well" (p.87). The donor market continues to drive the PV market in Kenya, with projects for school lighting, water pumping and vaccine refrigeration comprising just some of applications (ibid). In the 1970s and 1980s, Kenya had a comparative advantage over other African countries in the light of donor investment in solar PV, because Nairobi (the capital of Kenya) played the role as the regional "hub" for the donor driven solar industry in East Africa. According to Jacobson (2004) "… in the late 1970s and early 1980s, solar sales were sufficiently limited … such that some of the main solar suppliers elected to set up a single regional office to serve markets in several countries. In East Africa, Nairobi, Kenya served as the "hub" for the regional solar PV supply chain" (p.131). This therefore created the initial solar PV supply chain in Kenya. Currently, the donor segment of the Kenyan PV market accounts for about one-quarter of annual equipment sales while the private market for the solar home systems (SHS) accounts for the remaining three-quarters, and predominantly located in the rural areas (BCEOM EAA FONDEM Consortia, 2001; ESD, 2003).

Figures are not available to indicate the relative amount of donor agencies' extensive investment in solar PV in the 1970s and 1980s in Kenya. This could be due to the nature of the donor support — the direct supply and installation of solar PV systems, instead of the provision of funds to the government to procure and install them. However, international funding figures available for the 1990s possibly gives an insight into how skewed such investments have been in favour of Kenya as compared to countries like Ghana. In 1998 for example, the International Finance Corporation (IFC), the private lending arm of the World Bank Group (WBG) allocated $5 million to Kenya through the Photovoltaic Market Transformation Initiative[135] (PVMTI), to encourage the market development for solar PV for a period of ten years (1998-2008). Even this single injection of finance exceeds the total international funding for solar PV in Ghana for the whole of the 1990s.

Similarly, the influence of international funding for solar PV activities in Zimbabwe arguably offers an explanation for the relatively high dissemination level of solar PV as compared to Ghana. As pointed out in section 7.2.2.3 above and depicted in Table 7.8 below, Zimbabwe experienced considerable international donor funding for solar PV in the 1990s. Prominent among these donor funding sources were the UNDP-GEF solar PV programme, with a total expenditure of US$7 million, and the JICA solar PV programme with a total funding of US$ 10 million (see Table 7.8). Like Kenya, the overall past international donor investment for solar PV in Zimbabwe surpasses that of Ghana.

[135] "The Photovoltaic Market Transformation Initiative (PVMTI) is a strategic intervention to accelerate the sustainable commercialisation and financial viability of PV technology in the developing world. It is based on the premise that private sector project design and financing on commercial basis will stimulate more sustainable ventures than government or donor financed PV procurements" (IFC, 1998:1).

Table 7.8 International donor funding for solar PV deployment in Zimbabwe

Donor	Year	Area of Support	Total amount
UNDP-GEF	1993-1998	Solar PV programme	US$7million
JICA	1997-1999	Installation of clusters of PV systems	US$10 million
GTZ	1992-1994	Solar water pumping	US$6.5 million
Chinese government	1999	110 solar PV household systems and a water pump	-
Italian government		Lighting of rural schools and clinics	US$ 92 thousand

Source: Adapted from Davidson and Mwakasonda, 2003.

In comparison with Kenya and Zimbabwe, past international donor funding on solar PV in Ghana is relatively lower. As discussed earlier on in chapter five, international donor sponsored projects on solar PV in Ghana also began in the 1990s like Zimbabwe, firstly with the Spanish government/MOE-GH's project in 1998 and the UNDP/GEF/Ghana government Renewable Energy Service Project (RESPRO) in 1999. As indicated in chapter six, while the former project was worth about US$2 million, the latter was funded for US$2.5 million. The sum of these two major projects (i.e. US$4.5 million), is evidently lower than the one-off IFC funding alone in Kenya or the UNDP-GEF funding alone in Zimbabwe. The relatively high amount of international donor investment in solar PV in countries such as India, Morocco, China, South Africa and Botswana in the 1990s, with their corresponding high solar PV installations corroborates the catalytic role of international donor funding to the high dissemination of solar PV. India had US$15 million IFC funding in 1998; Morocco, US$5 million IFC funding in 1998; China, US$20 million UNDP/GEF funding in 1995; South Africa, 27 million EUR PV funding from the Dutch government and European Commission in 1995; and Botswana, US$3.3 million funding from the GEF in 1999 (IEA-PVPS T9-07, 2003; Project Brief - Botswana, 1999). However, countries with comparatively less amount of international donor funding including, Uganda (US$1.756 million UNDP/GEF funding in 1995) and Benin (US$1.135 million UNDP/GEF funding in 1995), (Hedon Household Energy Network, 2004) have been shown to have low solar PV installations.

7.3.2 Government Policy Direction on Energy

A direct driver that arguably contributes to shaping the disparate levels of solar PV dissemination in Kenya, Zimbabwe and Ghana is the different make-ups as well as the foci of the energy policies in these countries. Holistic national policies on the grid and solar PV for rural areas in the three countries are of great interest in the present analysis of this thesis. As will be highlighted in this sub-section, the characteristics of each of these countries' energy policies a propos grid and solar PV have directly shaped the energy consumption patterns and behaviour of energy end-users in the rural areas.

Kenya:

Since independence in 1963, Kenya's national electrification policies have been based largely on the supply of electricity from the grid. The 1974 Rural Electrification Programme (REP)[136] was based on the extension of the national grid. However, after more than three decades, only four percent of rural households had access to the grid, while about 150,000 solar PV household systems (SHS) had been installed (in over 3 percent of rural households (Hankins, 2001b)), mainly through the private-purchase system (see Table 7.6). The current annual number of homes electrified privately with PV in rural Kenya exceeds those being electrified through the grid (IEA-PVPS T9-07, 2003).

[136] The REP has been jointly operated by the Kenya government and the Kenya Power and Lighting Company (KPLC) - a parastatal agency that is 51% owned by the Kenyan government.

A major characteristic of the Kenyan REP that goes some way to explain the high adoption rate of solar PV household systems in rural Kenya, has been the slow pace of the grid extension to rural areas, thereby creating dissatisfaction. In an interview with stakeholder "**E**" in 2004, he pointed out that:

> *"Most people in rural areas in Kenya rely on solar PV to power their electrical equipments, because the government has not honoured its rural electrification promises"*[137]

Results of studies in Kenya (see Acker and Kammen, 1996, Jacobson, 2004, BCEOM EAA FONDEM Consortia, 2001) support the argument that the slow pace of the grid extension is one of the major drivers for the growth of the solar PV household systems' market in rural areas. Acker and Kammen (1996) observed that "For most rural consumers, prospects of grid electrification are dim…For the Kenyan Government, rural electrification is of secondary importance when compared to urban electrification" (p.89). To connect to the grid, rural consumers needed to overcome three main hurdles: high cost; multiple organisational barriers that thwarted the formation of groups of like-minded neighbours who can afford to pay; and bureaucratic/political lethargy, which slowed the approval from the Kenya Power and Lighting Company (KPLC) and worse of all the actual connections (ibid). The EAA FONDEM Consortia's (2001) report also noted that;

> "Decreased opportunity for access to the grid (KPLC/MOE Rural REP) stimulates the PV sector. Privatisation of power, load-shedding and increased costs of running KPLC lines contribute to the decision by rural people to buy PV. In the KENPREP study, over 65% of the 1000 plus

[137] Stakeholder "**E**" is a solar PV technician for the Solarnet organisation in Nairobi, Kenya as well as solar PV systems retailer in Mai-mahiu.

> households interviewed were within 1 km of the grid…still most did not think they would be connected to the grid. In the World Bank 410 household survey study, most people lived within 2 km of the grid but purchased PV anyway" (p.39).

Similarly, Jacobson (2004) contends that "…the emergence and growth of the solar market was strongly tied to the slow pace of grid based rural electrification" (p.134). Historically, the Kenyan REP has focused most of its energies on delivering electricity to small towns, market centres and rural industries such as coffee and tea processing, while comparatively household electrification has been a low priority (ibid). Accordingly, the allocation of the REP funds was "politicised" and non-transparent[138], as only households fortunate enough to be located in politically favoured areas were well placed to benefit from REP subsidy, much more so than their counterparts in other less connected regions. Consequently, "…many rural Kenyans have long since given up hope of receiving a grid connection any time soon" (Jacobson, 2004: 139).

Furthermore, aspects of past Kenyan government policies, especially duties and tariffs on solar PV, also help to explain the country's high adoption rate of the technology compared to Ghana. The Kenyan government policies on solar PV taxes in the 1980s, 1990s and from 2000 onwards resulted in substantial reductions in solar PV household systems prices thereby increasing affordability. From 1986 to 1991, the Kenyan government removed all import duties on solar modules, which were then reintroduced in 1992 (Jacobson, 2004). Nonetheless, in 1996 import duties on solar PV modules were reduced from 53 percent to 27 percent, while all duties have been

[138] In the view of EAA (2003) "The [Kenya] Rural Electrification Fund (REF) lacks transparency and accountability …and has failed in its main aim" (P.1).

removed on all solar PV equipments since 2000 till date (Duke *et al,* 2002; Magambo, 2004) (see Table 7.9). According to EAA FONDEM Consortia (2001) the removal of duties on solar PV modules "…stimulated sales of PV and resulted in market growth of over 20 percent per year from 1991 onward" (p.40). Based on the above outlined policies on solar PV import taxes, which the Kenyan government implemented in the past, one can counteract the view held by authors (such as Hankins, 2000) that, the Kenyan government had a hands-off approach to the off-grid private sector. As discussed in Chapter Six, both government and the private sector have a role to play in the wider dissemination of PV technology. Hence, the changing tax policy on import duty of solar modules in Kenya is a case in point of how important the government role is.

Table 7.9 Cumulative tax rate for solar modules in Kenya for selected years

	Cumulative Tax Rate (Import duty and VAT/Sales Tax)				
Item	**1986**	**1992**	**1996**	**2000**	**2002**
Solar Modules (Without diodes)	0%	53%	27%	0%	0%
Solar Modules (With diodes)	0%	53%	27%	0%	0%

Source: Adapted from Duke *et al,* 2002; Jacobson, 2004; Magambo, 2004.

Zimbabwe

The focus of past rural electrification policies in Zimbabwe paralleled those of Kenya. With extensive coal reserves, the emphasis of Zimbabwe's rural electrification policies after independence was on the extension of the existing national grid — an example being the 1997 ten-year rural electrification programme (see section 7.2.2.2 above). However, as evident from Table 7.5 above, by 2003 only five percent of rural households had access to electricity from the national grid; with almost the same percentage (i.e. 4.6 percent) of rural households privately adopting solar PV household systems (UNDP/World Bank ESMAP Report 228/00, 2000). Like Kenya, it could be argued that the main focus of the Zimbabwean Rural Electrification Programme and the pace at which the Zimbabwe national grid is extended to the rural areas are part of the processes that shape the high adoption pattern of solar PV by rural households. For instance, the main objective of the 1997 rural electrification programme was not to cover households. As IEA-PVPS T9-07 (2003) points out "In its effort to promote rural electrification, the [Zimbabwean] government initiated a ten-year programme in 1997, under which local economic centres, including District Service Centres (DSCs) and Rural Service Centres (RSCs), are electrified by existing grid extension. No special programmes are planned for households" (p.32). This could have therefore led many rural people with disposable income to start purchasing the 'do-it-yourself' solar kits. This involves clients buying a set of system components and setting them up independently (Mapako and Afrane-Okese, 2002).

In addition, other features of Zimbabwe's energy policies (especially in the 1990s) that might have accounted for the high dissemination rates of household solar PV systems are the waivers on taxes and import duties. For example, during the GEF/UNDP solar PV project (i.e. 1993-1998), all solar PV components imported under the project were duty-free[139]. This might have led to a reduction in prices and eventually enhanced end-users affordability. As Mapako (2002) reveals "Over the five-year period, over 9000 45-watt systems were delivered under subsidised conditions…in the form of duty waiver on imported components and a low interest rate of 15% per annum for clients purchasing systems under the [GEF/UNDP] project" (p.21).

[139] However, all other solar PV importations attracted duties during the GEF/UNDP project's period and post-GEF/UNDP project phase (UNDP/World Bank ESMAP Report 228/00, 2000).

Ghana

The rural energy policy focus of Ghana in the past (see Chapter Six) was akin to those of Kenya and Zimbabwe, as discussed above. In other words, like most African states, the approach to rural electrification in these countries was based on the national grid. However, while Kenya and Zimbabwe have considerable low levels of rural electrification through the grid, the level of grid extension to the rural areas in Ghana is relatively higher — 17 percent (see Table 7.6 above). This is an indication that the aspect of implementation in the grid-based rural electrification programme in Ghana, although not excellent, is more efficient than that of Kenya and Zimbabwe. As was revealed in Chapter Six, the government of Ghana has been spending a considerable amount of money on the national grid. It can therefore be argued that the level of grid extension to the rural areas in Ghana is one of the key drivers to the low dissemination of solar PV systems compared to Kenya and Zimbabwe. As has been noted in Chapter Five, some rural interviewees in Ghana indicated their preparedness to *wait for the Akosombo (i.e. national grid) no matter how long it takes.* This could be because they had seen evidence of the grid extension[140] and partly, because of the political promises (mostly false ones) of grid extension made to rural people in order to capture votes.

Other aspects of Ghanaian government energy policy that might have played a role in the low dissemination of solar PV in rural Ghana as compared to Kenya and Zimbabwe are the import duties on solar components and the high tariffs on solar PV systems vis-à-vis the national grid. In the first place, whilst grid users in Ghana benefit from tariff subsidy, solar PV users do not (see chapter six), which arguably

[140] Currently, all the 120 district capitals of Ghana have been connected to the grid. Thus, a lot of extension poles have passed through many villages before reaching the district capitals. Upon seeing the extension poles, many rural people are therefore full of the expectation of grid extension.

drives a lot of people to crave for the national grid. Secondly, while Kenya and Zimbabwe have waived all import duties on solar PV systems at some time in the past, leading to a reduction in solar PV prices, this has not happened in Ghana. As Chapter Six revealed, the measures implemented by the Ghana government in 1998 to remove import duties on solar PV systems have been ineffective, because of lack of clarity.

7.3.3 Market Approaches/access Dynamics

The diverse market approaches/access dynamics used to disseminate solar PV in Kenya, Zimbabwe and Ghana by both private and public sectors in the past, can also be argued to be some of the direct drivers to the high dissemination levels of solar PV household systems in the former two countries and the low dissemination level in the latter country. While Kenya and Zimbabwe share similarities in the various market approaches/access dynamics to the development of solar PV market, especially the private businesses, Ghana's approaches are different, as discussed below.

7.3.3.1 Targeting the rural Affluent Social Group

One of the market approaches used by private businesses in Kenya and Zimbabwe to disseminate solar PV to rural areas at the early stages of its development and later on, was through targeting affluent rural communities without electricity or affluent people in urban areas with rural homes. As Jacobson (2004) points out "…in each of these countries a catalyst group demonstrated the possibility of commercially viable private sector sales of solar systems directly to a segment of the rural off-grid population (i.e. the relatively better off) …with relatively high success rates in terms of customer satisfaction…"(p.36). The successes of these catalytic or pioneer *social groups,* which took place without donor assistance boosted other private businesses' entry into the solar PV rural market.

The market for solar PV in rural Kenya started in 1984, through the establishment of the "Solar Shamba" by Harold Burris at Embu town in the south of Mount Kenya (see Section 7.2.1.3). Firstly, Burris trained a group of about a dozen local technicians to market and install PV lighting systems, encouraging them to seek customers among the high-income households on the southern and eastern sides of Mount Kenya, which harbour the rich white coffee and tea farms (Acker and Kammen, 1996; Hankins, 2001). Burris' successes attracted other local entrepreneurial groups and individuals to join the rural PV market (Duke *et al*, 2002*).* For instance, many rural-based artisans formed business agreements with urban solar companies in Nairobi, in order to join the rural market (Agumba and Osawa, 2000). The influx of local businesses in the solar PV rural market after Burris' successes could be attributed to the entrepreneurial spirit of local businesses in Kenya. For instance, in an interview, stakeholder "**E**" pointed out that;

> *"People in Kenya are very aggressive and are not afraid to take risks. Everybody wants to be part of the first cohort of people to sell or to use any new technology that is in the market. The mobile phone is just one example".*

Indeed, currently there are many PV businesses in the Kenyan market, as shown in section 7.3.4 below. Although the Zimbabwean rural private PV businesses is not as developed as Kenya, nonetheless, the market approach of targeting well-off individuals within the rural areas was used (and perhaps continues to be used now) to market solar PV systems in rural Zimbabwe at the early developmental stage of the technology. In the 1980s according to Mulugetta *et al* (2000) "…solar companies largely targeted the affluent rural dwellers or urban dwellers with second homes in rural areas" (p.1069). This also manifests the entrepreneurial spirit of solar PV companies in Zimbabwe at the time. The high disseminations of solar PV in Botswana and South Africa could also be attributable to this market approach by the private businesses social group, as they share similar characteristics in the rural areas (i.e. the existence of many rich white farmers) with Zimbabwe and Kenya. This approach was also used in the Dominican Republic and Sri Lanka in the 1980s that culminated in success stories for the private market on solar PV. The affluent people (the first to adopt solar PV) in these countries, are what Rogers (1995) describes as innovators in his theory of diffusion of innovations (see Chapter Two).

In contrast with Kenya and Zimbabwe, solar PV companies in Ghana have not adopted this approach of targeting affluent rural dwellers, although they do exist (e.g. civil servants, commercial farmers) and can buy solar PV. The few PV businesses in the country — all of which were established in the 1990s and 2000s, are almost all located in the capital city of Accra with the exception of one, which is also located in the capital city of Northern region — Tamale. These private businesses have rarely promoted solar PV technology in rural areas — a possible indication of the absence of entrepreneurial spirit. The absence of a rural focus on the part of these PV businesses in the country can be discerned from the views of spokesperson **'C'** from Solar Light Company:

> *"The solar PV businesses that are currently operating were all established in the 1990s and 2000s, especially 1998, when the country experienced power crisis. Thus, we entered the market to meet the urban electricity demand as a result of this crisis. However, when the power*

crisis was over, many solar PV businesses went out of the market. Those currently operating are very small, do not deal exclusively with PV, because the PV market is not encouraging. We have also not ventured into the rural areas, because of financial risks".

7.3.3.2 Awareness Creation

Another marketing tool that might have created the differences in solar PV dissemination levels in the three countries is awareness creation[141]. According to Hankins (2004) "…PV markets grow in an organic manner. Consumer demand grows once awareness is built up…" (p.34). While the level of awareness creation or education on solar PV is low in Ghana as Chapter Six revealed, it has been very high in Kenya and Zimbabwe. With respect to Kenya for instance, Hankins (2000) observed that "by 1999, 3-4 percent of rural population [in Kenya] had acquired a photovoltaic system, and at least 70 percent knew what such a system was" (p. 95). Approaches that have been used to create this high level of solar PV awareness in rural Kenya included: demonstrations in schools and houses to educate potential clients; direct marketing at district agricultural shows; visits to consumer homes by sales agents and technicians; education of consumers and sales agents through educational seminars; advertisement in newspapers, and encouraging early adopters to tell others about the utility of the technology (Acker and Kammen, 1996; Hankins, 2001b; Duke *et al,* 2002).

Mainly by inference (given the recent political context), it can be argued that the high level of solar PV awareness in rural Zimbabwe has also been created through similar approaches since these are some of the most effective approaches that can be used to reach and convince the affluent segment of the rural population. Besides these

[141] It should be noted that awareness creation and targeting of affluent people are complementary.

approaches, the GEF solar project also heightened awareness of solar PV in rural Zimbabwe. According to Mulugetta *et al* (2000) "… the [Zimbabwean] GEF Solar project … enhanced national public awareness of the benefits of PV electricity …due, in no small measure, to the publicity that was undertaken …to popularise the technology across the country…" (p.1074).

7.3.3.3 Adoption of Favourable Financing Schemes

The adoption of favourable financing schemes in Kenya and Zimbabwe would seem to have enhanced the high level of PV adoption. Some private solar PV businesses in Kenya have used consumer financing schemes such as a Hire Purchase (HP) credit system. The HP credit system has been helping workers in both rural and urban areas in Kenya to purchase solar PV systems on credit and pay the debt on a monthly basis through direct debit. By 2001, about five major HP firms were supplying PV solar household systems to the Kenyan market, with sales making up well over ten percent of the solar PV market (Hankins, 2001b). Also of note is the Kenyan consumer micro-credit scheme, which was introduced in 1998 by the PVMTI to broaden solar PV access to rural Kenyans through commercial and cooperative bank micro-lending programmes. This programme, which is still ongoing, has led to the installations of hundreds of systems (Jacobson, 2004). With respect to Zimbabwe, the 1997 Japan International Corporation Agency (JICA) project also utilised the Energy Service Company (ESCO) approach to disseminate the PV systems (Mapako, 2002). This project was successful as a result of the ESCO innovative delivery scheme. In addition, the Zimbabwe GEF project used a revolving fund financing scheme that helped increase the accessibility of PV systems to many consumers in both rural and urban areas.[142] According to UNFCC (1998) "The major driving force for the achievement of the Zimbabwe GEF is the revolving fund, managed by the Agricultural Finance Corporation (AFC), which provided low-interest loans to potential PV owners" (p.14). In contrast, in Ghana the few existing solar PV businesses continue to rely only on cash sales module — there are no innovative financing schemes. The government has also faltered on donor PV projects, because of the poor implementation of the fee-for-service module (see Chapter Six).

7.3.4 Technical Capacity Building on Solar PV

The diversity of technical capacity building issues on solar PV is another variable that feeds into the disparate levels of solar PV adoption in Kenya, Zimbabwe and Ghana. The line of reasoning in this section is that the better developed the technical capacity for solar PV in a country is, the higher the level of solar PV adoption and vice versa. Key elements of technical capacity building on solar PV, in the context of the present analysis are:

- the various sizes of the PV systems that have been sold or are being sold in the three countries;
- the estimated total number of companies and technicians involved in the solar PV industry; and
- the number of subsidiary institutions supporting the PV industry in each country.

The different sizes of solar PV systems being sold in the market in the three countries is one of the technical capacity building elements that might have partially accounted for the high levels of solar PV adoption in Kenya and Zimbabwe, and the low

[142] The basic tenet of revolving fund is that an organisation gets a reserve of money to set up the operational structures and to lend to borrowers at an agreed interest rate. Thus, in the GEF/UNDP project, this reserve money was given to the AFC.

adoption level in Ghana. While the PV markets in Kenya and Zimbabwe seem to have a range of low and high wattage sizes of PV modules that can satisfy different income levels, the reverse is the case in Ghana, where only high wattage PV systems are available. These, presumably, can only be afforded by the high income social group. Unlike Kenya and Zimbabwe, where PV systems components can be bought piece at a time, in Ghana PV businesses only sell the entire package to consumers (See Appendix 4 for PV SHS price packages in Ghana).

For example, in the Kenyan solar PV market, the low cost 12 Wp amorphous silicon module[143] (a-Si) solar PV system is the smallest PV module system and is found in many shops. The biggest module is over 60 Wp. Findings in the BCEOM, EAA and FONDEM Consortia's (2001) study on Kenya PV market indicates that small size solar PV systems (i.e. from 12 Wp to 40 Wp) constitute 70 percent of the market, 45 percent of which belongs to the 12 Wp a-Si module. Indeed, authors such as Duke *et al* (2002), Hankins (2001) argue that most PV SHSs in rural Kenya are based on the 12 Wp a-Si module systems due to their availability at a relatively low cost and the opportunity to buy PV systems components piece by piece[144] at a time. The situation is similar in Zimbabwe where a range of PV system module sizes is available, spread fairly evenly from 12 Wp to 60 Wp (UNDP/World Bank ESMAP Report 228/00, 2000). As Davidson and Mwakasonda (2003) also noted "One reason for … [the large number of PV systems in Zimbabwe] has been the low-cost silicon-type solar modules imported from Botswana and South Africa…[while] some companies in

[143] As at 2002, the 12-peak-watt a-Si module was sold as low as $US50, because competition for customers has increased among retailers (Duke *et al*, 2002).
[144], In the early days of PV development in Kenya, installers and companies sold the entire package to consumers. However, by the 1990s consumers had gained enough experience using automatic batteries for TV power that majority of rural people started with the 'do-it-yourself' installation, which involves purchasing systems one piece at a time and installing by themselves. In most cases, however, charge regulators which help protect the batteries are left out (Hankins, 2000).

Zimbabwe have also been known to sell do-it-yourself solar kits, thus making the dissemination of the solar technology user friendly" (p.30).

A key aspect of technical capacity that could have accounted for the disparities in PV dissemination levels in the three countries is the estimated total number of companies and technicians involved in the solar PV industry. It could be argued that the augmentation of awareness/ knowledge on solar PV as well as the broadening of access to the technology depends in part on a large number of available businesses focusing on the technology and vice versa. As indicated in section 7.3.3.2, while there is high awareness about solar PV in Kenya and Zimbabwe, it is low in Ghana. The solar PV businesses scenarios in the three countries are as follows. In the first place, the Kenyan market has more than ten major PV systems importers, 100 to 200 solar PV systems retailers and agents, and approximately 500-1000 solar PV systems installers (Hankins, 2000; BCEOM, EAA, FONDEM Consortia, 2001; ESD, 2003). For Zimbabwe, by 1993, there were approximately ten companies in the PV business, but by September 1998 this had increased to about 73 PV companies and retailers (Bacon, 1998; UNDP/World Bank ESMAP Report 228/00, 2000). The proliferation of PV businesses in the 1990s could be due to the GEF/UNDP project, which created the revolving fund financing mechanism. The 2005 data on Zimbabwean Solar energy organisations reveals 15 PV companies with extensive distribution and installation networks in the country (Solarbuzz™, 2005b). For Ghana, the picture is different. As indicated in section 7.3.3.1 above, there are only 7 small solar PV companies in Ghana, which are exclusively focused on the urban areas (see Appendix 5 for PV companies in Ghana).

Available data also show that there are more subsidiary institutions to support the solar PV industry in Kenya and Zimbabwe than in Ghana. In Kenya, there are approximately 15-20 small scale manufacturers of PV lamps and battery control units or charge regulators (BCEOM, EAA, FONDEM Consortia, 2001; IEA-PVPS T9-07, 2003) and three principal battery manufacturers (ESD, 2003). As of 1998, there were four local companies producing PV lamps and four battery[145] companies that serviced the solar market in Zimbabwe (UNDP/World Bank ESMAP Report 228/00, 2000). By contrast, the PV market in Ghana has lacked these subsidiary local organisations, with almost all PV components being imported.

7.3.5 Disparate Economic and Political Historical Landscapes

The disparate dissemination levels of solar PV in Kenya, Zimbabwe and Ghana could also be partly explained by the direct and indirect factors of disparate economic and political histories of these countries in the 1970s and 1980s, respectively. The political and economic histories of these countries in the 1970s and 1980s are of particular interest, because that was when solar PV dissemination took off in Kenya and Zimbabwe, but not in Ghana. This section therefore pieces together the interrelationship between the political and economic histories of the three countries vis-à-vis the different levels of PV dissemination.

7.3.5.1 Political Historical landscapes

Analysis of the political histories of Kenya, Zimbabwe and Ghana in the 1970s and 1980s, demonstrates that the political status of these countries in this period might

[145] Data on product manufacturer in 2005, however, indicate that one battery manufacturing company currently exists ((Solarbuzz™, 2005).

have influenced the early and subsequent development disparities of their PV industries.

Since independence in 1963, Kenya has consistently maintained a remarkable political stability. This is especially relevant, as a stable political environment is well known as the key to attracting foreign direct investments (FDI) and donor agencies into any economy in the world. Suffice to mention that Kenya is one of the few African countries that have never experienced a coup d'état since independence. It can therefore be argued that Kenya's political stability indirectly played a role in the growth of its solar PV industry, especially in the 1970s and 1980s, when the technology was gradually being transferred to Africa. For instance, Nairobi was the East African regional "hub" of solar PV in the 1980s, a location favoured because of the political stability of Kenya. Jacobson (2004) for instance, observed that, "Kenya's position as the regional "hub" for solar equipment in the 1980s is due largely to its ties to "the west"… [because]…in the decades following independence in 1963, Kenya had developed a reputation as a stable, pro-capitalist country that was a reliable Cold War ally to the U.S and the UK in particular, and NATO countries more generally" (p.132). This unique political[146] stability and the pro-capitalist approach helped Kenya to attract relatively high levels of foreign investment and donor assistance, and many multinational companies and aid agencies selected to base their regional headquarters in Nairobi (Jacobson, 2004).

The 1970s and 1980s in the political history of Zimbabwe represent the colonial and the post-independence epochs, respectively. Prior to independence in 1980,

[146] While Kenya had such political stability at the time, several of its neighbours were either still embroiled in independence struggles (e.g. Uganda, Sudan, Mozambique) or were practising socialism (e.g. Tanzania, Somalia, Ethiopia) — both being distastes of foreign investors.

developments in all sectors of the economy, including energy provision, were skewed in favour of the white settler regime (Davidson and Mwakasonda, 2003). It could be argued that the PV industry in Zimbabwe started growing in the 1970s and 1980s, because native Zimbabweans and rural white farmers that were deprived of electricity but had disposable income started patronising solar PV. In particular, Zimbabwe's proximity to South African and Botswana, (both with a relatively well developed solar PV sector), enabled people to import the low-cost silicon-type solar modules, as noted earlier on in section 7.3.4. Also immediately after independence, Zimbabwe experienced relative political stability, which might have boosted foreign direct investment. The continual political stability of Botswana after independence in 1966 is another case in point that led to high foreign direct investment and transformed it into a middle-income country (United Nations Conference on Trade and Development (UNCTAD), 2002).

On the other hand, although Ghana was the first Sub-Saharan African country to have attained independence in 1957, it became fraught with prolonged political instability in the 1980s. From 1966 to 1992, Ghana had been successively ruled by different military governments through coup d'états[147] which is unparalleled in any other country in Africa. As Aryeetey and Fosu (2003) indicated "…one characteristic of the political economy of Ghana has been the high incidence of coup d'états [as] existing evidence suggests that among African countries, Ghana has had the largest indicator of this form of "elite" political instability…" (p.28). Over two decades of political instability in Ghana could be the driving force behind the paucity of foreign direct investment in its solar PV industry, which in turn played a role in shaping the

[147] In all five military coup d'états took place in Ghana from 1966 to 1992 — 1966, 1972, 1978, 1979 and 1981 (Asare and Wong, 2004).

current low level of PV dissemination as compared to Kenya and Zimbabwe. Unlike Kenya and to some extent Zimbabwe that allowed foreign entrepreneurs to stay after independence, the first military government that came to power in Ghana in 1966 in the post-independence era, literally drove away all foreign nationals (e.g. Asians, Lebanese, Syrians, and Europeans) in the retail trading sector. Firstly, it required all retail trading concerns, whose capital outlay did not exceed half a million cedis at the time to be reserved for Ghanaians; and secondly, this government introduced the "Alien Compliance Order" that evicted all foreigners without proper documentation from the country within two weeks (Asare and Wong, 2004). When asked as to why Ghana is lagging behind Kenya and Zimbabwe in the dissemination of solar PV in an interview with senior civil servant "**A**" at the EC-GH, he remarked that;

> *"Compare the political and economic histories of these countries and you will understand why Ghana is lagging behind".*

Other countries that possibly indicate the influence of political instability on less FDI in solar PV industry, resulting in low level of PV dissemination include Burundi, Eritrea, Uganda, and Djibouti.

7.3.5.2 Historical Economic Landscapes

The relative historical economic development trends of Kenya, Zimbabwe and Ghana in the 1980s could also possibly offer some explanatory power in explaining uneven dissemination levels of solar PV technology. For instance, as depicted in Figure 7.1 above, the Kenyan economy recorded strong growth in the 1970s and 1980s — the periods in which solar PV began to attract attention in rural areas. This growth was largely due to expanding exports of Kenya's principal export commodities (coffee, tea and horticulture) (Acker and Kammen, 1996). Thus, in the 1980s and early 1990s coffee and tea growers in the rural economy had high earnings. Together with rural civil servants, school teachers, business entrepreneurs, they constituted an affluent "rural middle class" with purchasing power but with little hope of getting connected to the national grid, and were therefore targeted by the early PV businesses. Jacobson (2004) believes that "Income from tea farming has, in fact, contributed significantly to the growth of the [Kenya] solar market" (p.129).

Similarly, economic growth in Zimbabwe was fairly steady from the latter part of 1970s through to the latter part of the 1980s (see Figure 7.2). This could be due largely to export earnings from the then commercial farms and ranches, agro-processing industries (e.g. tea, sugar, coffee, tobacco), which were located in the rural areas and employed many people.[148] Like Kenya, there was a rural middle class in the 1980s in Zimbabwe (comprising civil servants, employees in the commercial agricultural sector, private entrepreneurs) with purchasing power for solar PV systems. Indeed, the work of authors such as Mulugetta *et al* (2000) shows that the emergence and development of the Zimbabwean PV market was driven by rural middle class purchasing power.

In contrast, Ghana has had a turbulent economic growth in the 1970s and first half of the 1980s, with predominantly negative growth rates (see Figure 7.4). This decline could have been due to the political instability in those years, because the years in which negative growth was experienced generally coincided with coup d'états. It can therefore be concluded that the prevailing economic situation at the time could not have helped create a rural middle class to start purchasing solar PV. There could have

[148] As of 1997 for example, Zimbabwe was the second largest exporter of tobacco in the world and employed about half a million people in the rural areas (UNDP/World Bank ESMAP Report 228/00, 2000).

been pockets of rural affluent groups, but the political instability might have derailed all investment plans. Although inconclusive, it could be argued that the prolonged political instabilities of countries such as, Burundi, Eritrea, and Uganda in the past might have resulted in poor economic growth and the non-creation of rural middle classes.

7.4 CONCLUSION

With recourse to empirical and historical data, this chapter has made inroads into understanding the driving forces that underpinned the gap in solar PV dissemination levels between Ghana (with low dissemination level) and Kenya and Zimbabwe, both with relatively high dissemination levels. Through critical analysis of these data, the chapter has been able to unpack a range of drivers with direct, indirect, international, or national orientations, which arguably have helped shape the growth disparities of solar PV, especially in the rural areas of the three countries.

With respect to the mature solar PV markets in Kenya and Zimbabwe, it has been argued that they emerged and developed against the backdrop of the interplay among the following historical processes and factors. These included the relatively sound economies and political stability in the 1980s, which served as direct and indirect catalytic drivers, respectively. Other forces included the robust international funding on solar PV, inadequate implementation of governments' policies on the extension of the national grid to rural areas, private PV businesses' market approaches and the relative ubiquity of technical capacity building on solar PV in the two countries, all serving as direct drivers. However, compared to Kenya and Zimbabwe, the immature state of the solar PV market in Ghana and the low dissemination level are arguably shaped by the negative effects of the unique political and economic climates of the country in the late 1970s and 1980s. Alternatively, the relatively fast pace of the grid-based REP in Ghana as compared to Kenya and Zimbabwe, is argued to be a major influence of the state of its PV market development. Overall, there is a relationship between the levels of PV dissemination or the growth of the PV industry in each of these three countries and their specific historical configurations.

With respect to the development trends of the market-based solar electrification in rural Kenya and Zimbabwe as highlighted in the discussion above, it has been evident that most solar PV systems were first adopted by a few rural 'elites' and was then followed by mass adoption. Despite the high dissemination rates of the technology in Kenya and Zimbabwe, it is still evident that most solar PV systems are owned currently by the rural middle class. This ties in with the tenets of the diffusion of innovations theory by Rogers (1995) (see Chapter Two), the innovators and early adopters being the rural middle class, while the late majority and laggards could comprise those with precarious economic conditions.

In addition, the proliferation of the chains of vendors and technicians in the PV business (many of whom are without PV knowledge) in these two countries coupled with the 'do-it-yourself' approach, have resulted in a variety of technical problems — poor quality components and poor quality installations, culminating in systems failure. For instance, although the 12 Wp amorphous-silicon panels are relatively less expensive, they are also very inefficient (Acker and Kammen, 1996; Duke *et al*, 2002). This indicates that although large numbers of solar PV are disseminated in Kenya and Zimbabwe as compared to Ghana, not all of them are still functioning.

In applying the tenets of the Social Construction of Technology (SCOT) theory, these findings reveal that the levels of solar PV dissemination in different countries are heavily contingent on their unique economic, political, policy, and market processes and structures as well as the relative influence of external forces. This implies that the high or low dissemination of a particular technology in different countries does not depend on its resource availability alone, but the national, local and international processes. Consequently, it has been argued that not all successful cases of a technology’s dissemination in one country can be replicated in others so easily, because of the differences in policy, and political discourses.

The findings in this chapter have policy and planning implications for the growth of solar PV in most African countries. These questions are therefore raised: Can the growing trends of solar PV dissemination in Kenya and Zimbabwe be replicated in Ghana as far as its current political and economic environments are concerned? How can it be done differently in order to benefit not just the rural middle class but also the social and economic needs of the poor? The next chapter will address these questions and others.

CHAPTER EIGHT

SUMMARY AND CONCLUSIONS

8.1. INTRODUCTION

This study set out to explore rural electrification and the socio-technical, cultural, institutional, political and economic processes that impinge on the up-take and application of solar PV energy technology in rural Ghana, drawing on the framework of the Social Construction of Technology (SCOT) theory. Conventional wisdom perceives solar PV technology as the most attractive renewable energy option for the developing world, especially rural Sub-Sahara Africa - because of it ubiquitous solar radiation as well as the dispersed nature of its households. However, in spite of the substantial advocacy for utilisation of solar PV technology in rural Sub-Saharan Africa, the general literature on the dissemination of this technology has been incomplete in fostering understanding of a) the discourses surrounding low dissemination rates in rural Ghana compared to countries such as Kenya and Zimbabwe; b) the sustainability of installed solar PV systems; and c) the usefulness of solar PV in serving the needs of the rural poor.

The study came out with a complex mix of factors that underpin the general characteristics of solar PV dissemination processes in rural Ghana, in contrast with the majority of literature that often emphasise cost as the main determining factor. This chapter seeks to synthesise the main empirical findings of the study and to consider other dimensions of these key findings, positioning them within the wider academic literature. Section 8.2 provides a synthesis and discussion of the empirical findings from the study while paying attention to each research question. Section 8.3, considers the implications of the study while section 8.4 considers the theoretical implication of the SCOT theory. Recommendations and suggestions for further research are presented in section 8.5, while section 8.6 concludes this chapter.

8.2 SUMMARY AND DISCUSSION OF EMPIRICAL FINDINGS

Drawing on the Social Construction of Technology (SCOT) theoretical framework, especially in Chapters Five, Six and Seven, this study uncovered several key empirical findings. This section synthesises and discusses these findings.

8.2.1 The Energy Situation in Ghana Today

Baseline data on the main patterns and trends in Ghana's energy landscape (i.e. sources of energy, energy demand and supply in both rural and urban areas, energy utility companies) have been examined in this study. As discussed in Chapter Four, despite limited coal, oil and gas resources, Ghana possesses abundant alternative energy resources, all of which are renewable. With two ecological zones (savanna and closed forest), woodfuel is the dominant biomass energy in Ghana. Furthermore, by virtue of its location in the tropics (see Figures: 4.1 and 4.2), Ghana has abundant solar energy, with a daily solar irradiation ranging between 4 and 6 kWh/m^2 and a corresponding annual sunshine duration of 1800-3000 hours. However, there are geographic variations in both direct and diffuse radiation levels — very low diffuse radiation in the northern regions and the coastal belt along Greater Accra and Central regions, and higher diffuse radiation in most parts of the south.

Ghana also has more than 2,000 MW of wind energy potential (Hamlin and Ofori-Nyarko, 2005). The Ghana-Togo border has the strongest wind power resource in the country - with an annual mean of (>9.0 m/s), while high wind speed regimes are also observable along the coast and parts of Upper East and Upper West regions.

Currently, Ghana has an installed capacity of 1,198 MW of hydropower electricity (Akosombo and Kpong hydroelectric power plants) (RCEER, 2005). However, the new hydro electricity resource potential of the country is approximately 2,000 MW. Thermal energy, mainly from the Takoradi Thermal Power Plant, supplies in total 550 MW, while the Tema Diesel Power Plant also generates 30 MW of electric power. Whilst these findings reveal the abundant diverse energy resources of Ghana, they indicate only their physical potential (which is only one factor out of many in the viability scenario of technology) and not their real viabilities. This supports the view of Jackson and Oliver (2000) that "…the viability of a particular energy technology cannot, with any reliability be judged purely on the basis of the physical resource base" (p.2). For instance, while the country has further 2,000 MW hydroelectricity generating potential, current installed capacity stands at 1,198 MW.

The annual energy consumption of Ghana is estimated at 6.6 million tonnes of oil equivalent (toe), with per capita consumption estimated at 360 kilograms of oil equivalent (kgoe). Fuelwood accounts for about 59 percent of the energy consumption, while petroleum products and electricity constitute 32 and 9 percent respectively. This pattern of energy consumption, especially the percentage share of biomass, fits the normal African pattern, whereby biomass dominates the energy balance. Eighty four percent of rural households in Ghana use fuelwood in its untransformed state for cooking. The overall energy consumption pattern of Ghana also follows this trend: 72 percent for residential use, 14 percent for transport, 13 percent for industry and 1 percent for agriculture/fisheries and commercial/services, demonstrating the lopsidedness in energy consumption and provision in the country.

At the present time, 43 percent of Ghana’s population have access to electricity (77 percent for urban households, but only 17 percent for rural ones). In consequence, approximately 82 percent of rural households still use kerosene, candles, dry cells batteries and oil lamps for lighting. Moreover, population growth, urbanisation and economic expansion are leading to a steady growth in the demand for all forms of energy in the country. The demand for fuelwood is increasing approximately at 3 percent per annum, electricity at 7 percent (AEO, 2004), in the midst of an inadequate energy supply. The inadequate energy supply coupled with high energy consumption and demand patterns in all the sectors of the economy highlight the energy security situation of Ghana and its adverse effects on sustainable economic and social development. This lends credence to Ackom’s (2005) argument that “Ghana is…far from attaining a state of energy security” (p.10).

8.2.2 Characteristics of the Rural Economy of Ghana

The unique characteristics of the rural economy of Ghana are some of the key findings in this work. Agricultural activities (fishing, farming and livestock rearing) are the fundamental economic and subsistence activities in rural Ghana. Crop farming in particular is rain dependent — poor rainfall leads to poor yields and in years of extreme drought, none at all.

Poverty is widespread in rural Ghana, accounting for approximately 84 percent of Ghana’s poor. However, the levels of rural poverty vary across the country with the highest in the north (Upper West, Upper East and Northern regions), followed by the Central and Eastern regions (Ministry of Finance - Ghana, 2000; Amissah-Arthur and Amonoo, 2004). These regional differences in the level of rural poverty largely reflect the economic activities of individual regions. For example, the Ministry of Finance

(2000) points out that "At the national level almost 61 percent of those identified as poor are from households for which food crop cultivation is the main activity" (p.4). In addition, Amissah-Arthur and Amonoo (2004) also note that "those with the highest incidence of poverty are food crop farmers…" (p.6).

Economic activities at the case study sites in the Wa West and Bunkpurugu/Yunyoo districts in the Upper West and Northern regions respectively, are mainly subsistence food cropping and livestock rearing. In particular the subsistence food farming is tied to the short unimodal rainfall regime. In consequence, during the long dry season, no agricultural activities take place, to perpetuating the poverty problem. On the other hand, economic activities in the Kunsu village case study site in the Brong Ahafo region (in the south of Ghana) include commercial farming activities. This remote village lacks potable water sources. The diversity of the economic and other circumstances of these three case study sites is reflected in their diverse energy needs which then have effects on the adoption and non-adoption of solar PV. While the main energy needs focus of the Wa West and Bunkpurugu/Yunyoo districts case study sites require energy sources that will pump water for irrigation farming during the dry season, those of the Kunsu case study site require energy sources that can help provide potable water. However, the analysis of this study has shown that the rural electrification programme of Ghana places much emphasis on lighting to the neglect of the most important rural economic activities (irrigation farming, cottage industries), which the majority of the rural people in Upper West and Northern regions of Ghana engage in. Moreover, energy sources that can help supply potable water, e.g. solar water pumping systems are non-existent in the Kunsu commercial farming community.

8.2.3 The Dynamics of solar PV Adoption and Non-adoption

The combined processes and factors that help explain the adoption and non-adoption of solar PV by rural households in Ghana, constitute some of the key findings in this study. The analyses in Chapters Five and Six showed these processes and factors to include, economic, socio-cultural and behavioural, technical issues, the social needs vis-à-vis the relative importance of energy, political, and institutional issues. The multiplicity of the identified factors underpinning adoption and non-adoption of solar PV resonate with Mozaharul *et al*'s (2003) argument that the diffusion potential of any renewable energy is complex and difficult, because of the influence of a number of issues. These findings therefore go beyond many conventional framings of the adoption and non-adoption of solar PV, which often emphasise the role of cost as the main determinant factor. Thus, while the cost factor is important, it is far from the sole determinant of PV adoption and non-adoption.

8.2.3.1 The Economic Factor

Chapter Five shows that the economic circumstances of the communities studied in this work help partially explain the adoption and non-adoption patterns of solar PV, particularly the distribution of wealth. In a comparison of the composite socio-economic characteristics between solar PV users and non-users in the study communities, it was revealed that the middle class professionals and business men and women, who earn a regular salary, are most likely to opt for solar PV systems, while the less educated, who are engaged in subsistence farming with irregular income are less likely. In the studied rural communities, it was mainly those with some sort of disposable income who could afford the 'luxury' of solar PV.

Using a wealth index of the twenty households with and without solar PV in Wa West and Bunpkurugu/Yunyoo districts, this study revealed the interrelationship between economic factors and the adoption patterns of solar PV. The majority of solar PV users have higher mean annual incomes than non-users of solar PV, and they also have almost three times the material assets of non-users of solar PV. These therefore highlight the economic factor of affordability. Indeed, some 60 percent of households without solar PV in Wa west and Bunkpurugu/Yunyoo districts cited the high cost of solar PV as a reason for non-adoption.

The dominance of the rural middle class in the ownership of solar PV in this study, parallels findings in works undertaken in Kenya and Zimbabwe by a number of researchers, including, Karekezi and Kithyoma (2002), Bacon, (1998), Mulugetta *et al* (2000), and Jacobson, (2004). These studies show that the majority of solar PV systems disseminated in Kenya and Zimbabwe are owned by the rural middle classes, because the majority of the rural poor cannot afford to buy them. Thus, although some authors (Harmon 2000; Payne et al, 2001; Perlin, 2002; Erickson and Chapman, 1995; Kammen, 1996; Balint, 2004) note the decline in solar PV's cost over the years, findings in this work reveal that the cost of the technology is still an important factor, which helps determine which rural households can and cannot adopt solar PV. In particular, this finding of the unevenness of solar PV adoption between the rural middle class and the poor contrasts with Balint (2004) and UNEP (2004) who observe that the prices of solar PV technology have gone down to the extent that they are affordable for a large proportion of poor households in the developing world.

8.2.3.2 The Socio-cultural and Behavioural Factors

Socio-cultural and behavioural factors also emerged from this work, as helpful in explaining the adoption and non-adoption patterns of solar PV. The analysis reveals the complex interrelationships between socio-cultural factors such as household size, cultural value attached to assets (e.g. cattle), the preference and non-preference for a particular energy source, community disharmony, and the adoption and non-adoption of solar PV.

The study shows different household sizes as very important socio-cultural factors that influence the non-adoption of solar PV by some rural households. The disparate sizes of households were found to be interrelated with adoption and non-adoption perspectives of solar PV, because the number of occupants in the household is a key variable in determining the per capita resources availability for the quality of life of the family. In this light, the study found that the majority of households (80 percent) that adopted solar PV systems are ‘small’ (1-6 members), while 70 percent of households without solar PV are much larger (7-12 members). This may be so because the larger the household size, the more its expenditure pattern reflects basic needs (e.g. food, agricultural activities) and vice versa. This interpretation is supported by similar findings from South Africa: “Households that have no electricity [in rural South Africa] are more likely to be those with the largest number of members” (Energy Research Centre, 2004: 11).

This study also reveals that the cultural significance which some societies attach to some economic assets (e.g. cattle) helps to explain solar PV adoption and non-adoption. While the sale of some of these economic assets can provide the cash for buying a solar system, the cultural significance attached to them has restricted their sale. A case in point is the sale of cattle. Although the sale of one or two cattle could be enough to buy/rent solar PV household systems (SHSs), it is perhaps the case that socio-cultural factors (e.g. security, prestige, wealth) attached to cattle might have played some role in the rejection of selling of cattle for the purposes of adopting the technology. Indeed, it has been noted that, in much of Africa, livestock are a symbol of wealth and social status (International Livestock Research Institute (ILRI), 2007).

In addition, one of the socio-cultural elements, which has been found in this work as having an influence on the non-adoption of solar PV in the rural areas is the persistent sentiment that the 'Akosombo' (i.e. the National Grid) will be extended to them in the near future. In fact, in much of rural Ghana, the 'Akosombo' is the only point of reference at the mention of electricity, because that is what some have seen and heard of, and to some extent it is what general policy suggests. As the analysis reveals in Chapter Five, some rural people declined to adopt solar PV during the RESPRO project, because of the fear of not getting the national grid once SHS was installed in their houses. The strong desire for the national grid among these rural communities emerged from the analysis, as 16 of 20 respondents without PV in Wa West and Bunkpuru/Yunyoo districts indicated that they want the national grid and not PV and all 10 respondents in Kunsu commercial farming community suggested the same. This mirrors the South Africa experience, where in the 1990s there was significant criticism and resistance to plans to electrify some rural areas with solar PV rather than the grid, as grid power is viewed by many as an entitlement as well as a real possibility (Annecke, 2002). This issue (the persistent sentiment of waiting for the National Grid) is linked to the political and institutional regime that is still geared to grid extension rather than solar PV dissemination.

Furthermore, this study found that tension between different communities is an important socio-cultural and behavioural factor shaping the non-adoption of solar PV in rural areas of Ghana. As Chapter Five reveals, a community at loggerheads with another feels demeaned if solar PV is supplied to it, whilst the national grid is supplied to the other, because of the significance and prestige which most rural communities attach to the national grid. The influence of this behavioural factor in non-adoption is exemplified by the Kpasa and Nkwanta communities in the Volta River catchments. This particular behavioural factor shows (as the SCOT theory posits) how socio-cultural relations shape meaning or perception given to a certain technology.

8.2.3.3 The Technical Dimension

Another key finding in this study that helps explain the non-adoption patterns of solar PV in rural Ghana is the technical dimension — technical knowledge (of solar PV systems), technical efficiency and the availability of qualified technicians. The study showed that technical factors are significant in the adoption and non-adoption of solar PV in rural Ghana, which support the views of many (e.g. Rogers, 1995) that the perceived difficulty of learning to use and understand a particular technology, partly determines its acceptance and non-acceptance. This study revealed that 65 percent and 55 percent of respondents in Wa west and Bunkpurugu/Yunyoo districts, respectively attributed their non-use of solar PV systems to a lack of technical know-how and the perceived complexity of the technology. In Kenya for instance, scant public technical and/or performance knowledge of solar PV systems led to the sale of inappropriate systems (i.e. systems that were destined to fail either because the load is too great for the panel size, the lights are of inferior quality, or the installation is poor) to some customers in the 1990s (Margolis *et al,* 1996).

The low efficiency of solar PV coupled with the lack of qualified technicians, is another technical issue that influences the non-adoption of solar PV systems in rural Ghana. The short lifespan of some expensive solar PV components, the inability of SHSs to power demanding appliances such as fridges, fans, the absence of qualified solar PV technicians, combine to create a lack of confidence and great uncertainty about the technology's efficiency among existing adopters and non-adopters. As the analysis reveals, 55 percent of non-PV users in Wa west and Bunkpurugu/Yunyoo Districts attribute part of their non-adoption of solar PV to unreliability. In addition, all 20 solar PV users mentioned the lack of qualified solar PV technicians, a lack of parts and non-durable batteries as problems they encounter, while 45 percent indicated that their solar PV systems were malfunctioning. Many others (Duke *et al*, 2002; Paiunly, 2001; Oliver and Jackson, 1999; Gueye *et al*, 2001) have also pointed to aspects of the technical inefficiency of solar PV in influencing solar PV adoption and non-adoption.

8.2.3.4 Social Needs Vis-à-vis the Relative Importance of Energy

It is also helpful to consider the needs of different social groups and the relative importance of energy. As the study reveals, with diverse socio-economic backgrounds, the social needs rankings and the relative importance of energy for different activities differ considerably among solar PV users and non-users. Thus, while solar PV users in Wa West and Bunkpurugu/Yunyoo districts ranked electricity for lighting as the second most important need (after food), non-users ranked food first, building a house second and electricity for lighting only eighth.

In a similar vein, solar PV users in Wa West and Bunkpurugu/Yunyoo districts ranked lighting as the most important activity for which energy is needed, followed by business and cooking. Non-PV users in the same districts ranked energy for irrigation first, followed by cooking and business, while the Kunsu commercial farming community ranked energy for potable water as the most important, followed by energy for cooking, with lighting trailing behind.

This diversity in the social needs and the relative importance of energy (for different activities) among different socio-economic groups in rural Ghana, underscores the fact that not all technologies serve the needs of every socio-economic group. As Moon (2004) argues "for any technology to be truly useful to the poor in Africa, including renewable energy technology, it must address their special social and economic circumstances" (p.8). Thus, access to solar electricity by rural middle class probably influences perceptions of needs, to some extent. With adequate disposable income, it is argued that middle class households have already addressed their 'basic' needs, and can therefore prioritise other factors such as solar electricity.

8.2.3.5 The Political Dimension

The politicisation of solar PV by individuals in authority or those with political ambitions is another key factor which the analysis reveals to be important in influencing solar PV adoption. The influence of this factor in the non-adoption of solar PV is demonstrated by the socio-cultural/behavioural issue related to the persistent sentiment of waiting for the National Grid. As the study reveals, political comments about solar PV being inferior and making great promises of hope for the national grid, have partly influenced the non-adoption rate of solar PV in the rural areas of Ghana.

8.2.3.6 Institutional Arrangements for Solar PV

Additionally, the analysis of the study shows that the existing institutional structures (policy framework, regulatory framework, state facilitation support) for solar PV are some of the key factors that help explain the non-adoption of solar PV in rural Ghana. As the analysis in Chapter Six reveals, the features of any country's institutional arrangements for solar PV have implications for the adoption and non-adoption of solar PV. Effective institutional arrangements could have the effect of boosting the adoption of the technology, and can therefore be classified as 'stimulants' to solar PV adoption. Conversely, ineffective institutional arrangements have the effect of undermining the adoption of solar PV, and distorting the sustainability of installed solar PV systems, and can therefore be classified as 'barriers' to the development and adoption of the technology.

This thesis argues that the overall institutional infrastructures for solar PV in Ghana can be classified as barriers to the adoption of the technology and not stimulants. These institutional structures have not fostered the creation of a level playing field (a component of effective institutional infrastructure) for solar PV and the national grid. Other ineffective features of these institutional arrangements include: the non-existence of innovative policy instruments and PV market models, weak educational measures, functional overlap between the MOE-GH and EC-GH, the discharge of inappropriate functions, poor or even non-existent implementation of solar PV projects, inefficient co-ordination between solar PV implementing bodies, and the absence of consumer protection measures. These elements combine to create a regime that discourages the adoption of solar PV by poor rural communities in Ghana and shows the overriding importance of the need for government involvement. This therefore challenges the argument by others (e.g. Philips and Browne, 1999) that the private sector is the most critical factor for PV market development in the developing world; as well as their advocacy for the removal of subsidies.

8.2.4 Perspectives on Different countries' Processes Vis-à-vis the Level of Solar PV Dissemination

In analysing data within the framework of the Social Construction of Technology (SCOT) theory, this study also yielded results which provide insight into understanding the historical forces and drivers that help explain the disparities in solar PV dissemination levels and the different solar PV development trajectories across Africa. Especially, the examination of empirical evidence and extensive historical literature from Kenya and Ghana, coupled with only historical literature from Zimbabwe, provides examples of the different perspectives of countries, helping to explain the relative differences in solar PV dissemination levels. As Jacobson (2004) notes "…historically rooted similarities and differences among countries play a central role in determining the possibilities for a solar market development in each context" (p. 131).

First and foremost, Chapter Seven link the mature state of solar PV markets and high dissemination in Kenya and Zimbabwe to the interplay among the following historical processes and factors: the relatively healthy economies and political stability in the 1980s; the robust international funding for solar PV, inadequate implementation of governments' policies on the extension of the national grid to rural areas, private PV businesses' market approaches and sound technical capacity building, all serving as direct drivers. In contrast, the immature state of the solar PV market and the low dissemination level in Ghana are shaped by the negative effects of its unique political and economic circumstances in the late 1970s and 1980s; the relatively fast pace of the grid-based REP compared to Kenya and Zimbabwe, inadequate technical capacity building, and relatively low international funding for solar PV. These findings reveal that the levels of solar PV dissemination in different countries are heavily contingent on their individual economic, political, policy, and market histories, as well as the relative influence of external forces.

8.2.5 The Utility of Solar PV

This section discusses those findings that relate to solar PV electrification and broader processes of rural development in Ghana. The results of this study show that while rural middle class incomes provide the purchasing power for the adoption of solar PV as well as its use by politicians to gain votes, the gains in income, work, and general production (education, water provision, cooking) that stem from it are, to date, relatively modest. It seems that solar PV is used for lighting and powering TV, rather than for productive activities. At present, it is a consumption rather than production, item.

Moreover, while lighting service from solar PV is one of its dominant uses in households, it does not benefit all sections of the house. Females, who are the main cooks in the households, become marginalised as solar PV systems do not get installed in the kitchens. In addition, even as solar PV lighting has brought about an increase (i.e.15 percent of the 20 households interviewed) in the number of households studying (reading) in the evening, compared to the number of households (i.e.70 percent of the 20 households interviewed) using solar PV for watching TV, the use of the technology for education is still marginal. These findings suggest that solar PV does not impact positively on all developmental activities, although several studies (e.g. Wamukonya and Davis, 2001; Ahiataku, 2005) indicate a potentially important connection between solar electrification and education. It is interesting to note that the predominance of the use of solar PV for watching TV in rural Ghana is far from unique. For instance, studies from Kenya, Sri Lanka, Zimbabwe, and elsewhere confirm that powering television sets with solar PV is common in many countries (Hankins, 1993; Nieuwenhout *et al,* 2000; Jacobson, 2004).

Outside of the household, the use of solar PV electrification for income generation and productive work is limited, though not unknown. However, it begs the question of whether solar PV is meeting the energy needs of the majority of rural households. The limited income generating activities that use solar PV in rural Ghana include small scale commercial businesses such as bars, retail shops, and open coffee/tea sellers. As Chapter Five reveals, the use of this technology in these businesses has, to a limited extent, boosted their returns in comparison with businesses not using it.

However, as the chapter further reveals, indigenous cottage industries, and agricultural production, which form the core economic activity in rural Ghana, especially for the poor, are not enhanced by solar PV. Although solar PV can be used to supply potable water to the majority of the rural dwellers in Ghana without access to pipe-borne water[149], the study shows that the use of solar PV to supply water to rural Ghana is very limited. While all these findings do not indicate that solar PV rural electrification in Ghana is necessarily unimportant from a productivity point of view, it does show that in many cases solar PV systems are purchased more as a consumer good than as a productive investment.

[149] About 81.2 percent of rural dwellers in Ghana do not access to pipe-borne water (Ahiataku, 2005).

8.3 IMPLICATIONS OF FINDINGS

The results of this study show that Ghana possesses abundant alternative energy resources, all of which are renewable. However, the successful supply of electricity from these forms of energy resources (especially solar energy), to the rural areas is precarious. The findings in this study therefore have wide-ranging implications for the general provision of modern forms of energy (electricity) to the rural areas and for the key elements of solar PV dissemination to rural Ghana.

Firstly, there is the issue of equity and access to solar PV for low income groups in rural Ghana. The current trend in mainstream policy of government towards market-based (unsubsidised) solar electrification under full cost recovery measures has problematic implications for distributional equity as well as access for low income groups in these rural areas. In other words, the effect of lack of government subsidies for solar PV, while emphasising full cost recovery, is that access (i.e. inclusion) to rural solar electricity is defined increasingly in terms of purchasing power alone. This therefore raises the key issue of whether electricity services to the rural areas are to be treated in principle as an entitlement, or whether they are commodities, like any other, to be purchased by only those who can afford it. By and large, contrary to the views of many, redistributive subsidies remain prime components if the poor are to gain access to high quality solar electrification services in the rural areas. There is no denying that there are substantial challenges associated with implementing subsidies successfully to deliver services to low income groups. Indeed, some (including Barnes and Halpern, 2000; IEA PVPS Task 9. Report IEA-PVPS T9-06, 2003) have dealt with the challenges associated with making subsidies work effectively. Nonetheless, I share the view of Jacobson (2004) that “these challenges should not be used as a reason to opt for no subsidies at all, as leaving access to market forces alone always puts low income families at a steep disadvantage" (p.286).

Secondly, the findings in this study have implications for the policy approaches to rural electrification in Ghana. As the tenets of the SCOT theory indicate, the background needs of every social group determine what is present and what is absent. Thus, based on the different socio-economic circumstances of rural households in Ghana, the main energy needs of such disparate households will also be different – either for households' consumption or productive activities. However, the current focus of Ghana's rural electrification is tilted heavily towards household consumption (i.e. lighting and other household uses) as against productive activities. As we saw above, although lighting is very important to a segment of the rural society (i.e. the rural middle class), energy for productive activities and development (e.g. irrigation, potable water, cottage industries) is more important to low income groups in the rural areas. The diverse energy needs in rural areas underscore the call for multi-dimensional foci or integrated approaches to the delivery of rural electrification in Ghana. The viability of these integrated approaches will be contingent on a 'bottom-up' rather than a 'top-down' approach in rural energy decision-making. In other words, energy planning for rural development should have a decentralised component and should involve rural people—the beneficiaries—in planning and decision-making (Amulya *et al,* 2000).

Thirdly, there is the relative success or failure of the four solar PV financing models (cash sale, credit, concession and fee-for-service) in rural Ghana. In order to broaden the adoption of the solar households systems (SHSs) beyond the middle class to the poor income groups, a policy directed at concession and fee-for-service models will be critical. These models make solar PV systems more affordable to the rural poor, by spreading the up-front cost, or reducing the high initial investment barrier (through subsidies and instalment payments). Good maintenance and after sales service are also important financing incentives in concession and fee-for-service approaches. Such incentives are absent in the cash and credit models. As shown in Chapter Two, while only 3-5 percent of the rural population can afford SHSs under the cash sales model, 15-20 and 18-25 percent (i.e. the middle class) can afford the technology under the credit and fee-for-service models respectively. Successful examples of the use of the concession and fee-for-service models in the dissemination of solar PV to low income groups in rural areas exist in Argentina and South Africa. As the study points out, although there is wide adoption of solar PV in rural Kenya and Zimbabwe through the cash model, the majority of adopters belong to the middle class and not the low income groups.

Fourthly, there is the imperfect nature of the current institutional, policy and regulatory frameworks surrounding solar PV in Ghana and the need for efficiency. Effective institutional, policy and regulatory frameworks for solar PV, through the public sector, are vital to off-set the private sector's preoccupation with serving the rural middle class while excluding low income groups. Such measures as favourable financing, equitable tariffs and tax regimes for solar PV (as compared to the national grid) and clear, open and realistic rural electrification policies for different groups in the rural areas should be priorities of the government, if solar PV adoption is to increase.

Additionally, the findings of this study have got implications for those advocating replication of the 'successful' solar PV dissemination cases such as Kenya and

Zimbabwe in other African countries contexts. Such advocacy is often carried out against the backdrop of the ubiquity of solar resource in the region without paying due attention to the social, economic, political, and policy contingency, key elements of the success of solar PV dissemination in Kenya and Zimbabwe. As this study shows, conditions that led to the levels of solar PV development in these two countries are far from universal. In trying to replicate the Kenyan and Zimbabwe cases in other countries national and international policy makers will need to search for the same conditions and processes that underpinned their success.

Furthermore, the findings also show that solar PV technology has not attained closure and stabilisation status in rural Ghana. This is predicated on the diverse interpretations and perceptions ascribed to the technology from the different social groups in the rural areas.

8.4 THEORETICAL IMPLICATION

The Social Construction of Technology's (SCOT) theoretical approach has been fundamental in informing this thesis. However, besides reaffirming the shortcomings of the SCOT theory discussed in Chapter Two, the findings in this study also indicate ways to adapt this theoretical framework in order to make it more applicable in contexts such as this study in the developing world. Whilst the theory has been applied to the analysis of the development and diffusion processes of a variety of artefacts in the developed world — bicycles (Bijker, 1995) fluorescent lighting (Bijker, 1995), space shuttle (Garber, 2001) — it has rarely been used to study the processes of technological development and diffusion in the developing world.

The role played by intermediary bodies mediating between an innovation and its potential adopters or social groups is largely neglected by SCOT theory, yet this study reveals its importance to understanding some of the drivers of the different interpretative flexibilities and the dissemination patterns of an innovation. Intermediary bodies include institutions, individuals, organisations and different groups of people. As this study shows, the intervening actions of intermediary bodies such as politicians, solar PV technicians, private solar PV businesses and the staff of the Ghana Ministry of Energy, between solar PV technology and the rural people, all influenced the different perceptions of solar PV encountered. Reflecting on considerable part the different actions of these intermediary bodies, some rural people described solar PV technology as being useful and worth adopting, while others felt it was inferior and preferred to wait for the national grid. It is therefore recommended here that the SCOT theory should incorporate the concept of *intermediation* in its conceptual framework to examine the roles of intermediary bodies that intervene between an innovation and its potential adopters, and their influence in shaping the interpretation of the innovation and adoption.

The SCOT theory can also be enhanced through the incorporation of a more explicit discussion of the capacity and power of different social groups concerned with a particular innovation. In other words, SCOT needs to examine the resource (economic, political, cultural, wealth) capacity of different social groups as well as the existing social structures, analysing how these influences shape the interpretative flexibilities and adoption patterns of an innovation. The introduction of this modified approach will complement the agency-focused analytical approach that has been favoured to date in the SCOT theory. This complementarity should help provide an enhanced understanding of the dynamics of the development of a technology and its diffusion. For instance, this study revealed that the different interpretations and adoption patterns of solar PV in rural Ghana, and the disparity in the rates of PV dissemination in Kenya, Zimbabwe and Ghana were not only influenced by the interaction of the different social groups (agents), but were also shaped by the differences in resource capacities and structural factors: economics, culture, politics, public policy, international influence, private PV businesses, market forces, institutional and regulatory arrangements.

In addition, the potential pitfalls of applying the snowball sampling approach (i.e. the possibility of excluding relevant social groups) in the SCOT theory's methodology can be reformed to incorporate such possible exclusions. Although cost could be a barrier, it is, however, recommended here that any study underpinned by the SCOT theoretical framework should have two fieldwork elements, with an initial exploratory study, followed by the major fieldwork investigation. The exploratory study is very important because through the analysis of the data that are gathered, the researcher will be able to tease out some of the relevant social groups that might otherwise be excluded for example, in a one-off field survey. Consequently, the results of the exploratory fieldwork will increase the chances of capturing all the categories of relevant social groups in the major fieldwork. For instance, the results of the exploratory study in Kenya helped to determine all the different relevant social groups that were to be interviewed in the major fieldwork in Ghana.

Also, fundamental to enhancing the scope of the SCOT theoretical framework for the conceptualisation of technological development and diffusion dynamics in the developing world is the need to consider the influences of gender and culture. More often than not, males and females have asymmetrical perceptions as well as the utilitarian functions about a particular technological innovation. As has been revealed in this study for example, solar PV technology is generally constructed in the males' domain as an entertainment product (i.e. powering TV and tape recorders); whereas females construct it as a product that should facilitate domestic chores, especially, lighting in the kitchen in the evening during cooking. However, because males are predominantly the heads of families in most developing countries, the adoption and utilisation perspectives of solar PV technology have often favoured their construction (entertainment) than the females' as has been demonstrated in this study's findings. Solar PV technology is therefore seen in some circles in Ghana as a 'male dominant technology'. Also important in understanding the disparate constructions of PV technology in the developing world is culture. The multiplicity of tribes and languages in various countries in the developing world invariably bring about multiple cultures, which in turn lead to varied practices across communities. This was reflected in the various constructions of PV technology in different communities in Ghana. Whereas some tribal communities perceived PV technology as being good, others described it as being inferior, while others described it as a non-functioning technology and will wait for as long as it takes to be connected to the grid.

The potential uses of a SCOT approach in the analysis of the development and diffusion processes of various technological innovations in the developing world contexts will therefore be greatly enhanced if the recommended concepts and other means of reforming the theory as outlined above are incorporated into its framework. Many technologies have been introduced to the developing world; while some have failed and are out of circulation, others have been adopted and continued to be disseminated. Examples of technological innovations that have been widely disseminated in rural and urban areas of the developing world, and are still on the ascent, include bicycles, zinc/aluminium roofing sheets, kerosene lanterns and more recently mobile phones. On the other hand, technological innovations such as, animal-drawn ploughs and kerosene stoves (to mention a few) are less disseminated, especially in Ghana and more particularly the rural areas. Thus, in the developing world contexts, the reformed SCOT approach has the potential to elucidate our understanding on the content of technological innovations such as the aforementioned, the dynamics of their development and processes involved in their successful diffusion, failure or slow pace of dissemination.

8.5 RECOMMENDATIONS FOR FUTURE RESEARCH

Ghana's energy landscape and the place of solar PV within it, is complex and multi-stranded. Understanding this complexity requires further study, at both local and wider levels. Against this backdrop, the following are recommended for future research:

- Extensive energy needs assessment studies across all of rural Ghana are needed. The results of such studies should provide insights regarding the different forms of energy demand dynamics (energy for lighting, energy for productive activities, energy for cooking). Such studies could also help provide details about where the 'niche' market of solar PV is, and what potential users of PV in the rural areas require (technical aspects of the technology) in order to avoid mismatch of supply and demand.

- More studies are needed on how to integrate rural development policies and programmes in energy, health, education, agriculture. Although these sectors are intertwined, rural development initiatives are often singular in their forms.

Studies are therefore needed to provide insight on cross-sectoral implementation of rural development projects in Ghana.

- As the results of this work show, subsidies are very important if the adoption and utilisation of solar PV is to grow in the rural areas of Ghana. In the same vein, the challenges of implementation, especially 'subsidy capture'[150], are well noted. Hence, studies are needed to understand the dimensions of 'subsidy capture' and other subsidy related problems, and how to redress them.

- A major review of international donor projects on solar PV is needed, for more understanding of the relationship between their objectives and the needs of rural beneficiaries, the responsibilities of beneficiaries and their level of involvement in decisions-making. Such studies should also consider the rationale behind the varied levels of international donor investment in solar PV in the developing world.

- More studies involving country comparisons of the levels of solar PV dissemination in Africa in more than three countries would be appropriate. Such studies could further greater understanding of the linkages between the disparate levels of solar PV dissemination and countries' specific conditions and processes.

8.6 CONCLUSION

The physical resource base for solar PV in Ghana and Africa as a whole is effectively unlimited, so the substantial advocacy for its utilisation in the rural areas is not unfounded. However, as this study reveals, possessing a good resource base is not the panacea for successful solar PV dissemination to rural areas. Rather, the adoption/non-adoption perspectives of solar PV in rural Ghana are contingent on

[150] The situation whereby non-targeted groups of consumers, sometimes the wealthiest individuals or companies in a country, tend to benefit substantially from subsidies meant for the poor (WEC, 2003).

multiple circumstances. These include the socio-cultural and behavioural circumstances, economic circumstances, technical factors, the social needs circumstances vis-à-vis the relative importance of energy, the political circumstances, and the circumstances surrounding the institutional arrangements for solar PV.

BIBLIOGRAPHY

Abavana, C. G. 2004. "Ghana: Energy and Poverty Reduction Strategy". Paper presented on behalf of Ghana Government at the EU energy initiative's facilitation workshop and policy dialogue in Ouagadougou, Burkina Faso. 26-29 October 2004. [Online]. Available: www.e4d.net/euei/Ouagadougou/Abavana%20Ghana.doc [Accessed : 28/11/05].

Acheampong, E. 2003. *Sustainable livelihoods of forest fringe communities: Forests, trees and household livelihood strategies in Southern Ghana.* Ph.D. diss., University of Hull.

Acker, R. H. Kammen, D. H. 1996. The quiet (energy) revolution: analysing the dissemination of photovoltaic power systems in Kenya. *Energy Policy*, Vol. 24, Issue 1, pp. 81-111.

Ackom, E. K. 2005. *Technical and economic viability analysis of renewable energy technologies in Ghana*. Ph.D. diss., The Brandenburg University of Technology.

Acutt, N. Boyd, A. A. E. Kim, A. H. J. A. Martell, I. L. M. Pyhala, A. Winkels, A. 2000. An interdisciplinary framework for research on global environmental issues. Centre for Social and Economic Research on the Global Environment (CSERGE) Working Paper GEC 2000-23. [Online]. Available: http://www.uea.ac.uk/env/cserge/pub/wp/gec/gec_2000_23.pdf [12/4/05].

Abdalla, K. L. 1994. Energy policies for sustainable development in developing countries. *Energy Policy*, Vol. 22, Issue 1, pp. 29-36.

Adjaye, J. K. Misawa, B. 2006. Chieftaincy at the confluence of tradition and modernity: Transforming African rulership in Ghana and Nigeria. *International Third World Studies Journal and Review*, Vol. 17, pp. 1-10. [Online]. Available: http://www.unomaha.edu/itwsjr/ThirdXVII/AdjayeMisawa.pdf [Accessed: 11/11/06].

Adurodija, F.O. Asia, I. O. Chendo, M. A. C. 1998. The market potential of photovoltaic systems in Nigeria. *Solar Energy*, Vol. 64, Issues 4-6, pp.133-139.

Afgan, N. H. Al Gobaisi, D. Carvalho, M. G. Cumo, M. 1998. Sustainable energy development. *Renewable and Sustainable Energy Reviews*, Vol.2, Issue 3, pp. 235-286.

Afrane-Okese, Y. Mapako, M. C. 2003. "Solar PV rural electrification lessons from South Africa and Zimbabwe". Paper presented at the Riso International Energy Conference, Roskilde, Demark. 19-21 May 2003. [Online]. Available: http://www.risoe.dk/konferencer/energyconf/presentations/afrane_okese.pdf [Accessed: 11/02/07].

AFREPREN/FWD. 2001. Master Energy Database. AFREPREN/FWD Secretariat, Nairobi.
AFREPREN/FWD. 2002. AFREPREN/FWD Occasional Paper No. 13: African Energy Data and Terminology Handbook. Nairobi: AFREPREN/FWD.

African Economic Outlook (AEO). 2003. Ghana. [Online].Available: http://www.oecd.org/dataoecd/24/28/32429910.pdf [Accessed: 9/05/06].

Agarwal, R. Ahuja, M. Carter, P.E. Gans, M. 1998. Early and Late Adopters of IT Innovations: Extensions to Innovation Diffusion Theory. [Online]. Available: http://disc-nt.cba.uh.edu/chin/digit98/panel2.pdf [Accessed: 23/05/05].

Agumba, M. 2002. Taking Two to Tangle: Africa's Rural Electrification Dilemma! *Solar Energy Network Magazine*, Vol. 4, No. 2, page 2. [Online]. Available: http://www.solarnet-ea.org/downloads/Vol4No2.pdf [Accessed: 23/02/06].

Agumba, M. Osawa, B. 2000. "Kenya's PV Market". Solarnet-Kenya, EAA-Kenya. WIRE-ISES paper, 2000. [Online]. Available: http://wire0.ises.org/wire/doclibs/AUtilSEREA.nsf/0276ee169edca48cc12565a000428ee8/a770d5ec37c41a49c125692000337b95!OpenDocument [Accessed: 12/08/06].

Ahiataku-Togobo, W. 2001. MOE/Spanish funded solar PV electrification in Ghana. *EnergyAfrika Newsletter* Vol. 1, Issue 1, pp. 1-5. [Online]. Available: http://www.worldbank.org/afr/knsea/newsletter/newsletter_1.pdf [Accessed: 10/07/06].

Ahiataku-Togobo, W. 2005. Challenges of solar PV for Remote Electrification in Ghana. [Online]. Available: http://www.zef.de/fileadmin/webfiles/renewables/praesentations/Ahiataku-Togobo_solar%20PV%20Ghana.pdf [Accessed, 31/10/06].

Akuffo, F.O. 1998. 'Options for Meeting Ghana's Future Power Needs'. Renewable Energy Sources.

Akuffo, F.O. 1992. "Strengthening National Energy Policy and Operations Management Capabilities". UNDP Project GHA/89/003.

Alam, M. S. Roychowdhury, A. Waliuzzaman, K.M. and Huq, A.M.Z. 1999. Energy Flow in the Family farming system of a traditional village in Bangladesh. *Energy*, vol. 24, Issue 6, pp. 537-545.

Alsema, E. A. and Nieuwlaar, E. 2000. Energy viability of photovoltaic systems. *Energy Policy*, Vol.28, Issue 14, pp. 999-1010.

Amissah-Arthur, J. Amonoo, J. A. 2004. Study of the Social and Poverty Impacts of Energy Interventions on Rural Communities in Ghana. Final Report. Study Performed under the auspices of the Climate Technology Initiative (CTI) and sponsored by Natural Resources Canada (NRCan). April, 2004.

Amulya, K. N. R. Kirk, R. S. Robert, H. W. 2000. 'Rural energy in developing countries' in Goldeberg, J. (ed.). *World Energy Assessment: energy and the challenge of sustainability.* Washington: UNDP/UN-DESA/WEC. [Online]. Available: http://www.energyandenvironment.undp.org/undp/indexAction.cfm?module=Library&action=GetFile&DocumentAttachmentID=1020 [Accessed: 21/02/07].

Andersson, B. Hedman, J. 2007. Diffusion of Advanced Mobile Services: A Survey of Large Swedish Firms. Presented at the 6th Annual Global Mobility Roundtable 2007 - Los Angeles. 31st May to 1st June 2007. [Online]. Available: http://www.marshall.usc.edu/ctm/Research/GMR/White%20Papers/1.e.%20Andersson%20Hedman%20Diffusion%20of%20Advanced%20Mobile%20Services%20A%20Survey%20of%20Large%20Sw_.pdf [Accessed: 13/06/07].

Annecke, W. 2002. The rich get richer and the poor get renewables: the WSSD, energy and women, a malevolent perspective. *Agenda: Empowering Women for Gender Equity,* no. 52, pp. 8-16.

Arber, S. 1991. The Research Process. In: Gilbert, N., ed. *Researching Social Life.* London: SAGE Publications.

Aryeetey, E. Fosu, A. K. 2003. Economic growth in Ghana: 1960-2000. [Online]. Available: http://www.isser.org/Economic%20Growth%20in%20Ghana%202.pdf [Accessed: 25/01/07].

Asare, B. Wong, A. 2004. An Economic Development of Two Countries: Ghana and Malaysia. *West Africa Review.* Issue 5. [Online]. Available: http://www.africaresource.com/war/issue5/asare-wong.htm [Accessed: 09/03/07].

Bacon, I. 1998. Photovoltaics in Africa and the GEF: The Right Path to Sustainable Development? *Energy and Environment,* Vol. 9, No. 3, pp. 257-277.

Balint J. Peter. 2004. Bringing Solar home systems to rural El Salvador: lessons doe small NGOs. *Energy Policy,* Vol. 34, Issue 6, pp. 721-729.

Banks, D. 2004. Photovoltaic System Delivery Methods for Rural Areas in Africa. In: Krause, M. and Nordstrom, S., eds. *Solar Photovoltaics in Africa*: *Experiences with Financing and Delivery Models.* New York, United Nations Development Programme (UNDP), Global Environment Facility (GEF). [Online]. Available: http://www.undp.org/gef/undpgef_publications/publications/solarphotovoltaics_africa.pdf [Accessed: 11/10/06].

Barnes, D. F. Halpern, J. 2000. The role of energy subsidies. [Online]. Available: http://www.worldbank.org/html/fpd/esmap/energy_report2000/ch7.pdf [Accessed: 12/05/06].

Barnes, D. Jechoutek, K. Young, A. 1998. Financing Decentralised Renewable Energy: New Approaches. *Energy Issues, The World Bank,* No. 15, pp. 1-8.

Baskerville, R. Pries-Heje, J. 2001. A multiple-theory analysis of a diffusion of information technology case. *Information Systems Journal*. Vol. 11, pp. 181-212.

Bawakyillenuo, S. 2002. *Sand winning in Ghana: Issues of environmental impacts and regulation. The case of Greater Accra Region.* MSc. diss., University of Hull.

BCEOM, EAA and FONDEM Consortia. 2001. Study for Solar Quality and Specifications and Market Penetration for Kenya. Final Report.

Bell, J. 1999. *Doing your research project: a guide for first-time researchers in education and social science,* 3rd edn. Buckingham: Open University Press.

Bijker, W.E. 1995a. *Of bicycles, bakelites and bulbs: towards a theory of sociotechnical change*. London: The MIT Press.

Bijker, W.E. 1995b. 'Sociohistorical technology studies'. In: S. Jasanoff *et al.*, eds. *Handbook of science and technology studies*. London: Sage Publications.

Bowden, L.W. 1965. Diffusion of the Decision to Irrigate. Research Paper 97, Department of Geography, Chicago. Illinois: University of Chicago.

Brew-Hammond, A. 1999. "Renewable energy in Ghana: Challenges for the 21st Century". [Online].Available: http://www.worldbank.org/afr/knsea/kb/re_energy_ghana_abeeku.pdf [Accessed : 28/05/06].

Brown, L. A. 1967. *Diffusion processes and location: a conceptual framework and bibliography*. Phildelphia: Regional science research institute.

Brown, L.A. 1981. *Innovation diffusion: a new perspective*. New York: Methuen & co.

Brown, L. A. Moore, E. G. 1968. Diffusion research in geography: A perspective. Department of Geography, Discussion Paper Series No.9, Iowa City, Iowa: The University of Iowa.

Bureau of Africa Affairs. 2007a. “Background Notes: Kenya”. March, 2007. [Online]. Available: http://www.state.gov/r/pa/ei/bgn/2962.htm [Accessed: 23/04/07].
Bureau of Africa Affairs. 2007b. “Background Notes: Zimbabwe”. March, 2007. [Online]. Available: http://www.state.gov/r/pa/ei/bgn/5479.htm [Accessed: 27/04/o7].

Burgelman, R. A. Sayles, L. R. 1986. *Inside Corporate Innovation: Strategy, Structure, and Managerial Skills*. The Free Press, New York.

Byrne, J. Shen, B. Wallace, W.1998. The economics of sustainable energy for rural development: a case study of renewable energy in rural China. *Energy Policy*, Vol. 26, No. 1, pages. 45-54.

Cabraal, A. Cosgrove-Davies, M. Schaeffer, L. 1996. Best Practices for Photovoltaic household electrification programs. Lessons from experiences in selected countries. World Bank Technical Paper 324. [Online]. Available: http://www.worldbank.org/astae/pvpdf/pvbest.pdf [Accessed: 07/01/07].

Callon, M. 1986. Some elements of a sociology of translation: domestication of the scallops and the fishermen of St Brieuc Bay. In Law, J. (ed) *Power, Action and Belief: A New Sociology of Knowledge?* Vol. 32: Sociological Review Monographs, pp. 196–233. London: Routledge & Keagan Paul.

Callon, M. 1987. Society in the making: the study of technology as a tool for sociological analysis. In Bikjer, W.E. Thomas, P. H. Pinch, J.T. eds. *The Social Constructions of Technological Systems: New Directions in the Sociology and History of Technology*, Cambridge: The MIT Press.

Carmody, E. R. Sakar, A. U. 1997. Solar box cookers: towards a decentralized sustainable energy strategy for sub-Saharan Africa. *Renewable and Sustainable Energy Reviews*, Vol. 1, Issue 4, pp. 291-301.

Cassell, J. 1988. ‘The Relationship of Observer to Observed when studying up’. In: Burgess, R.G., ed. *Studies in Qualitative Methodology*. JAI Press, Greenwich, CT and London.

Chakrabarti, S. Chakrabarti S. 2002. Rural electrification programme with solar energy in remote region-a case study in an island. *Energy Policy*, Vol.30, Issue 1, pp. 33-42.

Chambouleyron, I. 1996. Photovoltaics in the developing world. *Energy*, Vol. 21, Issue 5, pp. 343-434.

Chuks, J. 2004. Population Ageing and Poverty in Rural Ghana. *Regional Institute for Population Studies, University of Ghana*. [Online]. Available: http://www.uaps.org/confageing/chuksmba.pdf [Accessed, 07/07/06].

CIA World Factbook-Ghana. 2007. [Online]. Available: http://www.cia.gov/cia/publications/factbook/geos/gh.html [Accessed: 16/02/07].

CIA World Factbook-Kenya. 2007. [Online]. Available: https://www.cia.gov/cia/publications/factbook/geos/ke.html [Accessed: 25/02/07].

CIA World Factbook-Zimbabwe. 2007. [Online]. Available: https://www.cia.gov/cia/publications/factbook/geos/zi.html [Accessed: 17/02/07].

Ciscar, J. C. 1997. Photovoltaic Technology and Rural Electrification in Developing countries: The Socio-economic Dimension. [Online]. Available: http://www.jrc.es/iptsreport/vol19/english/NEE1E196.htm [12/10/03].

Clark, G. 1984. *Innovation diffusion: contemporary geographical approaches*. Norwich: Geo Books.

Coleman, J. S. Katz, E. Menzel, H. 1957. The diffusion of an innovation among physicians. *Sociometry*, Vol. 20, No. 4, pp. 250-70.

Colin, Robson. 1993. *Real World Research: A resource for social scientists and practitioner-researchers*. Oxford: Blackwell Publishers.

Colorado University. 2007. Writing guides: Content analysis (1993-2007). [Online]. Available: http://writing.colostate.edu/guides/research/content/com2b2.cfm [Accessed: 30/7/06].

Cook, I. 1997. Participant Observation. In: Flowerden, R. Martin, D., eds. *Methods in Human Geography*. (2nd edition). London: Pearson Education.

Creswell, J. C. 1994. *Research Design; Quantitative and Qualitative Approaches*. London: Sage Publications Ltd.

Davidson, O. R. Mwakasonda, S. A. 2003. Southern Africa Sub-regional study: South Africa and Zimbabwe. Paper prepared for the Global Network on Energy for Sustainable Development. Energy and Development Research Centre, University of Cape Town. [Online]. Available: http://www.erc.uct.ac.za/publications/Southern%20Africa%20regional%20study%20-%20Electricity%20access%20theme%201.pdf [Accessed: 14/03/07].

Davis, M. 1998. Rural household energy consumption: The effects of access to electricity-evidence from South Africa. *Energy Policy*, Vol.26, Issue 3, pp. 207-217.

de Vaus, D. 1996. *Surveys in Social Research*. London: UCL Press.

Dube, I. 2001. PV for rural areas - the power utility (ZESA) Zimbabwe's experience. *Renewable energy*, Vol. 24. Issue 3-4, pp. 517-520.

Duke, R. D. Jacobson, A. Kammen, D.M. 2002. Photovoltaic module quality in the Kenyan solar home systems market. *Energy Policy*, Vol. 30, Issue 6, pp. 477-499.

Dunne, R. Asaly, R. 2005. Country Report: Kenya. [Online]. Available: http://www-personal.umich.edu/~kathrynd/kenya.2005.pdf [Assessed: 12/01/07].

EarthTrends. 2003. 'Energy and Resources--Ghana'. [Online]. Available: http://earthtrends.wri.org [Accessed : 23/05/06].

Edjekumhene, I. 2003. Status of Renewable Energy and Energy Efficiency Systems in West Africa. Background Paper (1st Draft) Prepared for the West African Regional REEEP Consultation Meeting in Accra. Kumasi Institute of Technology and Environment (KITE). [Online]. Available: http://www.reeep.org/media/downloadable_documents/WE%20background%20paper.pdf [Accessed: 18/07/06].

Edjekumhene, I. Atakora, S. B. Atta-Konadu, R. Brew-Hammond, A. 2001. Implementation of Renewable Energy Technologies - Opportunities and Barriers. Ghana country case study. Denmark: UNDP Collaborating Centre on Energy and Environment, Risø National Laboratory. [Online]. Available: http://www.uneprisoe.org/RETs/GhanaCountryStudy.pdf [Accessed: 03/11/04].

Encyclopaedia of the nations. 2006. Burkina Faso: Energy and power. [Online]. Available:http://www.nationsencyclopedia.com/Africa/Burkina-Faso-ENERGY-AND-POWER.html [Accessed:12/05/06].

Energy Commission – Ghana (EC-GH). 1997. Energy Commission Act, 1997 (Act 541).

Energy Commission - Ghana (EC-GH). 2003. Reconnaissance/Feasibility Studies for Solar PV Rural Electrification in Off-grid Communities in Ghana. (Unpublished).

Energy Commission - Ghana (EC-GH). 2005. Strategic National Energy Plan 2006-2020. Vol. One. Demand Sector of the Economy. Government of Ghana. October, 2005.

Energy Alternatives Africa Ltd (EAA). 1999. Making solar energy a reality in Africa : activity report 1995-99. EAA Company Brochure, Nairobi, Kenya.

Energy Alternatives Africa Ltd (EAA). 2003. Modern Energy for Rural Areas. EAA Policy Briefing no.4 on Sustainable Energy in Kenya Series. March, 2003. [Online]. Available : http://policydialoguekenya.energyprojects.net/ [Accessed : 13/03/07].

Energy Research Centre, University of Cape Town. 2004. Supporting innovation in the delivery of energy services to the rural poor : Off-grid electrification via concessions in rural South Africa. [Online]. Available :
http://www.erc.uct.ac.za/publications/Eastern%20Cape%20%20-%20baseline%20Report%20-%202004.pdf [Accessed : 23/08/06].

Entsua-Mensah, C. 1994. Towards Effective Institutional Networking for Renewal Energy Research and Development (R&D) Activities in Ghana; Some Issues for Consideration. *Journal of Energy Research and Technology*, Vol.6. Special Issue (Proceedings of the National Energy Symposium), pp. 226-231.

Erickson, D. J. Chapman, D. 1995. Photovoltaic Technology: Markets, Economics, and Rural Development. *World Development*, Vol. 23, No. 7, pp. 1129-1141.

Energy for Sustainable Development (ESD). 2003. Study on PV Market Chains in East Africa. Report for the World Bank, October 2003, by Energy for Sustainable Development (ESD), Nairobi, Kenya.

ESI-Africa. Hydropower Potential in Africa. *ESI-Africa*, Issue 3, 2004. [Online] Available: http://www.esi-africa.com/archive/esi_3_2004/35_1.php [12/04/06].

Essandoh-Yeddu, J. 1994. Solar PV technologies price build-up and strategies for marketing in Ghana. *Journal of Energy Research and Technology*, Vol.6. Special Issue (Proceedings of the National Energy Symposium), pp. 226-231.

Fisher, D. Wright, L. M. 2001. "On Utopias and Dystopias: Towards an understanding of the discourse surrounding the Internet". *Journal of Computer Mediated Communications*, Vol. 6, Issue. 2. [Online]. Available:
(http://www.ascusc.org/jcmc/vol6/issue2) [19/10/04].

Fliegel, F. C. Kivlin, J. E. 1962. Farm practice attributes and adoption rates. *Social Forces*, No. 40, pp. 368-370. May, 1962.

Flowerdew, R. Martin, D., eds. 1997. *Methods in Human Geography*. London: Pearson Education.

Foley, G. 1990. *Electricity for rural people*. London: Panos Publications Ltd.

Forest Products Inspection Bureau (FPIB). 1993. "Log Production Statistics", Forest Products Inspection Bureau.

Fucks, D. A. Maarten, J. A. 2002.Green electricity in the market place: the policy challenge**.** *Energy Policy*, Vol.30. Issue 6, pp. 525-538.

Garber, J. S. 2001. Why Does the Space Shuttle Have Wings? A Look at the Social Construction of Technology in Air and Space. [Online]. Available: http://history.nasa.gov/sts1/pages/scot.html [Accessed: 03/06/06].

Garland, K. P. 1991. Diffusion and adoption of instructional technology. In: Anglin, G.J., ed. *Instructional technology: Past, present, and future.* (Second edition). Englewood, CO: Libraries Unlimited.

Geohive. 2006. Population Census Dates and Results. [Online]. Available: http://www.geohive.com/global/geo.php?xml=census&xsl=census [Accessed, 05/06/6].

Ghana Demographic and Health Survey, 1993.

Ghana Homepage. 2007a. Maps of Ghana. [Online]. Available: http://ghanaweb.com/GhanaHomePage/geography/maps.php [Accessed: 30/1/07].

Ghana Homepage. 2007b. History of Akosombo Dam. Available: http://www.ghanaweb.com/GhanaHomePage/history/akosombo_dam.php [Accessed: 22/02/07].

Ghana Living Standards Survey IV (GLSS) Report. 2000.

Ghana Population and Housing Census. 2000. [Online]. Available: http://www.ghanaweb.com/GhanaHomePage/geography/population.php [Accessed: 22/03/05].

Ghana Statistical Service. 2003. Key Social/Economic/Demographic Indicators. [Online]. Available: http://www.gss.gov.gh/key.htm [Accessed: 29/4/06].

Global Energy Network Institute (GENI), 2006. "Proof it can exist: A non-subsidized market for photovoltaics in rural Kenya". [Online]. Available: http://www.geni.org/globalenergy/research/ruralelectrification/casestudies/kenya/index.shtml (Accessed: 13/12/060).

Global Environment Facility (GEF) Homepage. 2006. Projects: climate change. Available: http://www.gefweb.org/projects/Focal_Areas/climate/climate.html [Accessed: 21/07/06].

Granovetter, M. S. 1973. "The strength of weak ties". *American Journal of Sociology*, vol. 78, pp: 1360-80.

Granovetter, M. S. 1978. "Threshold models of collective behaviour". *American Journal of Sociology*, vol. 83, No. 6: pp.1420-1443. [Online]. Available: http://www.jstor.org/view/00029602/dm992642/99p0297a/0 [Accessed: 22/05/05].

Granovetter, M. S. 1983. “The strength of weak ties: a network theory revisited”. *Sociological Theory*, vol. 1, pages 201-233.

Green, D. 2004.Thailand’s solar white elephants: an analysis of 15yr of solar battery charging programmes in northern Thailand. *Energy Policy*, vol.32, Issue 6, pp. 747-760.

Green, M.A. 2000. Photovoltaics: technology overview. *Energy Policy*, Vol.28, Issue 14, pp. 983-998.

Gueye, A. McNary, J. Okai, J. 2004. Solar Energy and Rural Development: Constraints and Insights from the Developing World. [Online]. Available: http://www.gwu.edu/~oid/Solar_Energy.pdf [Accessed: 06/11/06].

Gustavsson, M. Ellegård, A. 2004. The impact of solar home systems on rural livelihoods. Experiences from the Nyimba Energy Service Company in Zambia. *Renewable energy*, Vol. 29. Issue 7, pp. 1059-1057.

Gyan-Baffour, G. 2003. The Ghana Poverty Reduction Strategy: Poverty Diagnostics and Components of the Strategy. [Online]. Available: http://casmsite.org/Documents/Elmina%202003%20-%20Workshop%20-%20Poverty%20Reduction%20-%203.pdf [Accessed: 10/05/07].

Habtetsion, S. Tsighe, Z. 2002. The Energy Sector in Eritrea-institutional and policy options for improving rural energy services**.** *Energy Policy*, vol. 30, Issue 11-12, pp.1107-1118.

Hagan, E. B.1997. Pre-feasibility Study on Proposed Letus Power Plant, Ghana.

Hagerstrand, T. 1967. *Innovation diffusion as a spatial process*. Chicago: The University of Chicago Press.

Hahn, K. L. Schoch, N.A.1997. Applying diffusion theory to electronic publishing: a conceptual framework for examining issues and outcomes. [Online], Available: http://www.asis.org/annual-97/hahnk.htm [21/12/04].

Hamakawa, Y. 2002. Solar PV energy conversion and the 21st Century’s civilization. *Solar Energy Material and Solar cells*, Vol. 74, Issues 1-4, pp. 13-23.

Hamlin, E. Ofori-Nyarko, E. 2005. Wind and Solar Resource Assessment in Africa. *ESI Africa*. Issue 3. [Online]. Available: http://www.esi-africa.com/archive/esi_3_2005/18and20.pdf. [Accessed: 20/10/05].

Hankins, M. 1993. Solar Rural Electrification in the Developing World. Four Case Studies: Dominican Republic, Kenya, Sri Lank, Zimbabwe. Solar Electric Fund (SELF), Washington, DC.

Hankins, M. 2000. A case study on private provision of photovoltaic systems in Kenya. In: Penelope, J. Smith, S., eds. *Energy Services for the World's Poor*. World Bank Energy Sector Management Assistance Programme (ESMAP), Washington, DC. [Online]. Available:
http://www.worldbank.org/html/fpd/esmap/energy_report2000/ch11.pdf
[Accessed: 14/1106].

Hankins, M. 2001a. Commercial breaks - building the market for PV in Africa. In: Renewable Energy World, July-August, 2001. London: James and James Science Publishers Ltd. [Online]. Available:
http://www.jxj.com/magsandj/rew/2001_04/commercial_breaks.html
[Accessed: 23/01/04].

Hankins, M. 2001b. 'The Kenya PV Experience'. Energy and Development Research Centre, University of Cape Town. (Draft). November 2001. [Online]. Available: http://roo.undp.org/gef/solarpv/docs/bgmaterial/Misc%20PV%20Papers/The%20Kenya%20PV%20Experience%20-%20M.%20Hankins.doc [Accessed: 24/12/05].

Hankins, M. 2004. Choosing Financing Mechanisms for Developing PV Markets: Experiences from Several African Countries. In: Krause, M. Nordstrom, S., eds. *Solar Photovoltaics in Africa*: *Experiences with Financing and Delivery Models.* New York, United Nations Development Programme (UNDP), Global Environment Facility (GEF). [Online]. Available:
http://www.undp.org/gef/undpgef_publications/publications/solarphotovoltaics_africa.pdf [Accessed: 11/10/06].

Hanley, N. Nevin, C. 1999. Appraising Renewable Energy Developments in Remote Communities: The case of the north Assynt Estate, Scotland. *Energy Policy,* Vol. 27, Issue 9, pp. 527-547.

Harmon, C. 2000. Experience curves of Photovoltaic Technology. International Institute for Applied Systems Analysis (IIASA). Interim Report IR-00-014. [Online]. Available: http://www.iiasa.ac.at/Publications/Documents/IR-00-014.pdf [12/02/04].

Hedon Household Energy Network. 2004. Global Environment Facility (GEF). [Online]. Available: http://www.hedon.info/goto.php/GEF [Accessed: 21/03/06].

Hooko, D. K. 1999. *The private urban residential development process in Tamale, Ghana: An application of structure and agency institutionalism.* Ph.D. diss., University of Aberdeen.

Howard, J. A. 1969. *The Theory of Buyer Behaviour*. New York: John Wiley.

Howard, S. 1997. Methodological issues in overseas fieldwork: experiences from Nicaragua's northern Atlantic coast. In: Robson, R. Willis, K., eds. *Postgraduate Fieldwork in Developing Area: A Rough Guide. IBG Developing Area Research Group Monograph* 9. London: IBG, 19-35.

Ingvar, B. F. 2000. Energy: 2000 - global energy issues. UN Chronicle [Online]. Available: http://www.findarticles.com/ [Accessed: 13/09/04].

Institute for Security Studies (ISS). 2006. African country files: Ghana. [Online]. Available:http://www.issafrica.org/index.php?link_id=14&slink_id=3920&link_type=12&slink_type=12&tmpl_id=3&link_country_id=57 [Accessed: 21/10/06].

International Energy Agency (IEA). 1995. World Energy Outlook, 1995 edition. [Online]. Available: http://www.iea.org/textbase/nppdf/free/1990/weo1995.pdf [Accessed: 23/7/04].

International Energy Agency (IEA). 2002. World Energy Outlook 2002, second edition. November 2002. [Online]. Available: http://www.iea.org/textbase/nppdf/free/2000/weo2002.pdf [Accessed; 02/12/04].

International Atomic Energy Agency (IAEA). 2006a. Energy and Environment Data Reference Bank (EEDRB): Republic of Kenya. [Online]. Available: http://www.iaea.org/inisnkm/nkm/aws/eedrb/data/KE-elp.html [Accessed: 12/12/06].

International Atomic Energy Agency (IAEA). 2006b. Energy and Environment Data Reference Bank (EEDRB): Republic of Zimbabwe. [Online]. Available: http://www.iaea.org/inisnkm/nkm/aws/eedrb/data/ZW-elp.html [Accessed: 20/12/06].

International Atomic Energy Agency (IAEA). 2006c. Energy and Environment Data Reference Bank (EEDRB): Republic of Ghana. [Online]. Available: http://www.iaea.org/inisnkm/nkm/aws/eedrb/data/GH-elp.html [Accessed: 10/11/06].

International Energy Agency Photovoltaic Power Systems Programme Task 9-02 (IEA PVPS T9-02). 2003. Summary of Models for the Implementation of Photovoltaic Solar Home Systems in Developing Countries. Part 1: Summary. March 2003. [Online]. Available: http://www.ieapvps.org/products/download/rep9_02_2.pdf [Accessed: 21/04/06].

International Energy Agency Photovoltaic Power Systems Programme Task 9-06 (IEA-PVPS T9-06). 2003. Institutional Framework and Financial Instruments for PV Development in Developing Countries. September 2003. [Online]. Available: http://www.iea-pvps.org/products/download/rep9_06.pdf [Accessed: 20/04/05].

International Energy Agency Photovoltaic Power Systems Programme Task 9-07 (IEA-PVPS T9-07). 2003. 16 Case Studies on the Deployment of Photovoltaic Technologies in Developing Countries. September 2003. [Online]. Available : http://www.iea-pvps.org/products/download/rep9_07.pdf [Accessed: 17/05/04].

International Finance Corporation (IFC). 1998. India, Kenya, Morocco: Photovoltaic Market Transformation Initiative (PVMTI). [Online]. Available: http://roo.undp.org/gef/SolarPV/docs/workshop/projdocs/Kenya.pdf [Accessed: 01/03/07].

International Livestock Research Institute (ILRI), 2007. Animal agriculture to reduce poverty, hunger and environmental degradation in developing countries. [Online]. Available: http://www.ilri.org/ [Accessed: 14/05/07].

Jackson, T. Oliver, M. 2000. The viability of solar photovoltaics. *Energy Policy*, Vol. 28, Issue 14, pp. 983-988.

Jacobson, A. E. 2004. *Connective Power: Solar Electrification and Social Change in Kenya*. Ph.D. diss., University of California, Berkeley. [Online]. Available: http://erg.berkeley.edu/erg/people/AJacobson_PhD_Diss_final04.pdf [Accessed: 12/02/07].

Jacobson, A. Duke, R. Kammen, D. M. Hankins, M. 2000. Field Performance measurements of amorphous silicon photovoltaic modules in Kenya. Conference Proceedings, American Solar Energy Society (ASES), Madison, Wisconsin, USA, June 16-21.

Jacobsson, S. Johnson, A. 2000. The diffusion of renewable energy technology: an analytical framework and key issues for research. *Energy Policy*, Vol.28, Issue 9, pp. 625-640.

Jain, P. K. Lungu, E. M. Mogotsi, B. 2002. Renewable energy education in Botswana: needs, status and proposed training programmes. *Renewable energy*, Vol. 25, Issue 1, pp.1-170.

Johansson, T.B. Reddy, H.K.N. Williams, R.H. Burnham, L. 1993.Critical comments on renewable energy. *Energy*, Vol.21, Issue 6, pp. 511-517.

Kammen, M. D. 1996. Household Power in a new light: Policy lessons, and questions, for photovoltaic technology in Africa. *Tiempo: Global Warming and the third world*, Issue No. 20, pp. 1-8. [Online]. Available: http://rael.berkeley.edu/oldsite/tiempo.html [Accessd : 13/12/03].

Karekezi, S. 2002a. Poverty and energy in Africa - A brief review**.** *Energy Policy*, Vol.30, Issues 11-12, pp. 915-919.

Karekezi, S. 2002b. Renewables in Africa-meeting the Energy needs of the poor. *Energy Policy*, Vol. 30, issues 11-12, pp. 1059-1069.

Karekezi, S. Kimani, J. 2002. Status of power sector reform in Africa: impact on the poor. *Energy Policy*, Vol.30, Issues 11-12, pp. 923-945.

Karekezi, S. Kimani, J. Majoro, L. Kithyoma, W. 2004. African Energy Data and Terminology Handbook. Year 2003-2004. African Energy Policy Research Network (AFREPREN) Occasional Paper No. 23.

Karekezi, S. Kithyoma, W. 2002. Renewable energy strategies for rural Africa: is a PV-led renewable energy strategy the right approach for providing modern energy to the rural poor of sub-Sahara Africa? *Energy Policy*, Vol. 30, Issue 11-12, pp. 1071-1086.

Karekezi, S. Kithyoma, W. 2004. Overview of Renewables and Energy for Rural Development in Sub-Sahara Africa. In: Mapako, M. Mbewe, A., eds. *Renewables and Energy for Rural Development in Sub-Sahara Africa.* London: Zed Books Ltd.

Karekezi, S. Kithyoma, W., eds. 2005. *Sustainable Energy in Africa: Cogeneration and Geothermal in the East and Horn of Africa - Status and Prospects.* Nairobi: AFREPREN/FWD and Heinrich Boll Foundation (HBF).

Karekezi, S. Ranja, T. 1997. *Renewable Energy Technologies in Africa*. London & New Jersey: Zed Books Ltd.

Kassiap, D. 2002. Promoting equity in large-scale renewable energy development: the case of Mauritius. *Energy Policy*, Vol.30, Issue 11-12, pp.1129-1142.

Katz, E. 1999. Theorizing Diffusion: Tarde and Sookin revisited. In: Heston, A. W. Weiner, A. N. Lopes, D. P. Durfee, M., eds. *The Social Diffusion of Ideas and Things*. The Annals of the American Academy of Political and Social Science, Vol. 566, No. 1, pp. 144 -155. November, 1999. [Online]. Available: http://ann.sagepub.com/cgi/content/abstract/566/1/144 [Accessed: 20/10/06]. Sage Publications.

Kaufmann, S. Duke, R. Hansen, R. Rogers, J. Schwartz, R. Trexler, M. 2000. Rural electrification with solar energy as a climate protection strategy. *Renewable Energy Project*, No. 9. January, 2000. [Online]. Available: http://www.crest.org/repp_pubs/pdf/rurElec.pdf [Accessed: 18/01/05].

Keatiny, M. 1993. *Agenda for Change*. Centre for Our Common Future. Geneva, Switzerland.

Keiffenheim, M. 2004. Sunrise at the Equator. *Solar Energy Network Magazine*, Vol. 5, No. 2, pp. 20-23.

Kesby, M. Kindon, S. Pain, R. 1997. Participatory Approaches and Diagramming Techniques. In: Flowerden, R. Martin, D., eds. *Methods in Human Geography.* (Second edition). London: Pearson Education.

Khan, M. E. Manderson, L. 1992. Evaluation methodology: Focus groups in rapid assessment procedures. *Food and Nutrition Bulletin,* Vol. 14, No. 2, June 1992. [Online]. Available: http://www.unu.edu/unupress/food/8F142e/8F142E07.htm#Focus%20groups%20in%20rapid%20assessment%20procedures [Accessed: 25/09/06].

Kilitsi, E.A.K., 2003. "Problems and Prospects for Hydropower Development in Africa". Paper Presented for the Workshop for African Energy Experts on Operationalizing the NGPAG Energy Initiative. 2-4 June, 2003. Novotel, Dakar, Senegal. [Online]. Available: http://www.un.org/esa/sustdev/sdissues/energy/op/nepadkalitsi.pdf [Accessed: 19/9/6].

Kintampo District Statistics - Ghana, 2002.

Klein, H. K. and Kleiman, D.L. 2002. The Social Construction of Technology: Structural Considerations. *Science, Technology and Human Values*, Vol. 27, No.1, pp. 28-52.

Kumasi Institute of Technology and Environment (KITE). 2005. "Increasing Access to Energy Services for Populations in Rural and Sub-urban Areas in order to achieve the Millennium Development Goals". Ghana Country Report UNDP-REPP & ECOWAS. October, 2005.

Kui-nang, M. Jayarao, G. Walter, S. 2001.Energy and sustainable development: issues and options, strategies and actions. 18th Congress, Buenos Aires, October 2001.

Kurokawa, K., ed. 2003. *Energy from the Desert. Feasibility of Very Large Scale Photovoltaic Power Generation (VLS-PV) System.* London: James and James Science Publishers Ltd.

Kurokawa, K. 1997. Areal Evolution of PV systems. *Solar Materials and Solar Cells*, Vol. 47, Issues 1-4, pp. 27-36.

Latour, Bruno. 1987. *Science in Action: How to follow scientists and engineers through society.* Harvard: Harvard University Press.

Latour, B. 1991. Technology is society made durable. In: Law, L., ed. *A Sociology of Monsters: Essays on Power, Technology and Domination*. London: Routledge. pp. 103-131.

Lenardic, D. 2004. Photovoltaic economics (2001-2004). Available: http://www.pvresources.com/en/economics.php [Accessed: 21/11/04].

Lew, D. J. 2000. Alternatives to coal and candles, wind power in China. *Energy Policy,* vol. 28, Issue 4, pp. 271-286.

Lucas, H.C. 1994. Marketing and Technology Strategy in a medium-tech startup. *Information and Management*, Vol. 27, Issue 4, pp.247-257.

Mackenzie, D. Wajcaman, J. 1985. Introductory essay and general issues. In: Mackenzie, D. Wajcman, J., eds. *The social shaping of technology*. Philadelphia: Open University Press.

Magambo, K. 2004. Renewable Energy Resources Exploitation in Kenya. [Online]. Available: http://ttclear.unfccc.int/ttclear/presentations/Kenya/KM.ppt [Accessed: 15/03/07].

Mamprusi East District statistics - Ghana, 2000.

Mapako, M. C. 2002. Renewables and rural energy for development in Zimbabwe. Working Paper No. 301, AFREPREN/FWD, Nairobi. 53pp.

Mapako, M. C. 2004. "Rural electrification and Poverty Alleviation: Lesson from Zimbabwe". Presented at the EUEI facilitation workshop and Policy Dialogue. Ouagadougou, Burkina Faso. 26-29 October, 2004. [Online]. Available: http://www.e4d.net/euei/Maputo/presentations/Mapako_Zim%20presentation%20Maputo.ppt#1 [Accessed: 13/03/07].

Mapako, M. C. Afrane-Okese, Y. 2002. "Experiences and lessons in the implementation of solar home systems from Zimbabwe". Presented at the domestic use of energy conference, Cape Technicon, Cape Town, South Africa. 1-3 April 2002. [Online]. Available: http://www.afrepren.org/Pubs/articles/mapak.htm [Accessed: 9/10/06].

MARA/ARMA. 2001. Ghana: Total population distribution 1995. [Online]. Available: http://www.mara.org.za/pdfmaps/GhaTotPopulation95.PDF [Accessed : 10/11/ 05].

Marchetti, C. 1979. *Energy* **4**, pp. 17-1107.

Marchetti, C. 1995. *Energy* **16,** pp. 75-563.

Marchetti, C. 1995. From Principles to World Government. International Institute for Applied System Analysis.

Margolis, R. M., Faber, J.S., Kammen, D.M. 1996. Solar Decisions: Changing Photovoltaic Energy Demand in Kenya and South Africa. Draft Paper for *Sustainable Energy News*. October 25, 1996.

Marketbuzz™. 2006: Annual World Solar Photovoltaic Industry Report. March 15, 2006. [Online]. Available: http://www.solarbuzz.com/Marketbuzz2006-intro.htm [Accessed: 25/11/06].

Martinot, E. 2001. Renewable energy investment by the World Bank. *Energy Policy*, Vol.29, Issue 9, pp. 689-699.

Martinot, E. 2005. Renewables 2005 global status report. Paper prepared for Renewable Policy Network for the 21st Century. [Online]. Available: http://www.ren21.net/pdf/RE2005_Global_Status_Report.pdf [Accessed: 25/1/07].

Martinot, E. Cabraal, A. Mathur, S. 2001. World Bank/GEF solar home systems projects: experiences and lessons learned 1993-2000. *Renewable and Sustainable Energy Reviews*, Vol. 5, Issue 1, pp. 39-57.

Martinot, E., Ramankutty, R., Rittner, F. 2000. The GEF Solar PV Portfolio: Emerging Experience and Lessons. Monitoring and Evaluation Working Paper 2. August 2000. [Online]. Available: http://www.cleanairnet.org/lac_en/1415/articles-41080_recurso_1.pdf [Accessed: 10/11/06].

Mason, M. 1990. *Rural electrification: a review of World Bank and USAID financed projects*. Background Paper, Washington, April, 1990.

Matthew, D. Carole, D. S. 2003. *Social Research*: *The Basics*. London: Sage Publications Ltd.

MBendi Information Services Ltd. 2006. Ghana - Oil and Gas: Crude petroleum and natural gas extraction. [Online]. Available: http://www.mbendi.co.za/indy/oilg/ogus/af/gh/p0005.htm [Accessed 25/02/06].

Mbewe, A. 1992. Rural Electrification in Zambia. In: Ranganathan, V. ed. *Rural Electrification in Africa*. London: Zed Books Ltd.

Medows, D. Meadows, H. Randers, D. L. Behrens J. 1972. *The Limits of Growth.* New York: Universe Book.

Miller, D. Hope, C. 2000. Learning to lend for off-grid solar power: policy lessons from World Bank loans to India, Indonesia, and Sri Lanka. *Energy Policy*, Vol.28, pp. 87-105.

Ministry of Mines and Energy - Ghana (MME-GH). 1998. Report GHA/96/G31 - Renewable Energy Services Project (RESPRO).

Ministry of Energy – Ghana (MOE-GH). 2001a. Document of the National Electrification Scheme (NES) and the Self-Help Electrification Programme (SHEP).

Ministry of Energy–Ghana (MOE-GH). 2001b. Document of the Energy Sector Policy Framework.

Ministry of Energy - Ghana (MOE-GH). 2003. Household energy in Ghana. [Online]. Available: http://www.energymin.gov.gh/traditional_energy.htm [Accessed: 11/04/06].

Ministry of Energy-Ghana (MOE-GH) Meet The Press. 2005. Enhancing Energy Security and Access. December 13, 2005.

Ministry of Finance and Economic Planning-Ghana (MOFEP-GH). 2000. Interim Poverty Reduction Strategy Paper, 2000-2002. [Online]. Available: http://www.imf.org/external/NP/prsp/2000/gha/01/063000.pdf [Accessed: 29/06/06].

Ministry of Finance and Economic Planning - Ghana (MOFEP-GH). 2006. *"Remarks by the minister of finance and economic planning, Mr. Kwadwo Baah-Wiredu, on the occasion of the signing of a supplier's credit agreement between the government of Ghana and China international water and Electric Corporation"*. November 22, 2006. [Online]. Available: http://www.mofep.gov.gh/ [Accessed: 05/02/07].

Ministry of Food and Agriculture-Ghana (MOFA-GH). 1997. Agriculture in Ghana: Facts and figures. Policy Planning, Monitoring and evaluation (PPME) Department, Accra, Ghana.

Moon, N. 2004. You Got The Power! Renewables against Poverty (RAP): Makes Sense for Mother Earth and our Wallets. *Solar Energy Network Magazine*, Vol. 5 No. 2, pp. 7-9, 11.

Mozaharul, A. Rahman, A. Eusuf, M. 2003. Diffusion potential of renewable energy technology for sustainable development: Bangladeshi experience. *Energy for Sustainable Development*, Vol.7, No. 2, pp. 88-96.

Mulugetta, Y. Nhete, T. Jackson, T. 2000. Photovoltaics in Zimbabwe: lessons from the GEF Solar project. *Energy Policy*, Vol.28, pp. 1069-1080.

Munasinghe, M. 1988. Rural Electrification: International Experience and Policy in Indonesia. *Bulletin of Indonesian Economics Studies*, Vol. 24, No.2, pp. 87-105.

Murthy, M. R. L. N. 2001. PV Promotion in Developing countries by World Bank and other International organisations**.** *Solar Energy Materials and Solar cells*, vol. 67, Issues 1-4, pp. 629-637.

National Renewable Energy Laboratory (NREL). 2004. International Wind Resource Maps. [Online]. Available:
http://www.nrel.gov/wind/international_wind_resources.html [Accessed: 23/11/05].

Neudoerffer, R. C. Dalhart, P. Ramna, P. V. 2001. Participatory rural energy planning in India - a policy context. *Energy Policy*, Vol.29, Issue 5, pp. 371-381.

Nieuwenhout, F. D. J. U. van Dijk, V. A. P. Hirsch, D. Lasschuit, P. E. van Roekel, G. Arriaza, H. Hankis, M. Sharma, B. D. Wade, H. 2000. Monitoring and evaluations of solar home systems: experiences with applications of solar PV for households in developing countries. [Online]. Available:
http://www.ecn.nl/docs/library/report/2002/rx02001.pdf [Accessed: 20/02/04].

Nketia, K. S. 1992. The Prospects for Commercial Charcoal Production from logging Residues in Ghana.

Nsiah-Gyabaah, K. 1994. Solar Lantern for rural lighting: A way to sustainable rural development in Ghana. *Journal of Energy Research and Technology*, Vol. 6. Special Issue (Proceedings of the National Energy Symposium), pp. 226-231.

Oakes, S.C.C. 2000. *Wild but wired? The co-construction of society and the technology in rural Strathclyde*. Ph.D. diss., University of Middlesex.

Ogburn, W. F. 1964. *On cultural and social change: Selected papers.* Chicago: University of Chicago Press.

Oliver, M. Jackson, T. 1999. The market for solar photovoltaics. *Energy Policy*, Vol. 27, Issue 7, pp. 371-385.

Oppong-Anane, K. 2001. Country Pasture/Forage Resource Profiles - Ghana. [Online]. Available: http://www.fao.org/ag/agp/agpc/doc/Counprof/ghana/Ghana.htm [Accessed: 08/06/06].

Osei-Safo, C. 1998. Biogas utilization and its agricultural implications in Ghana. [Online]. Available: ftp://ftp.fao.org/docrep/nonfao/LEAD/x6195e/x6195e00.pdf [Accessed: 27/08/06].

Otieno, D. 2004. Solar PV in Kenya. Hurdles faced due to the fraudulent labelling of solar panels. *Solar Energy Network Magazine,* Vol. 6, No.2, p.23. January 2004.

Owusu-Ansah, D. 1994. Society and its Economy. In: Berry, L.V. ed. *Country Studies/Area Handbook Programme.* Federal Research Division, Library of Congress, Washington, D.C., U.S.A. November 1994. [Online]. Available: (http://lcweb2.loc.gov/frd/cs/ghtoc.html). [Accessed: 7/02/06].

Painuly, J. P. 2001. Barriers to renewable energy penetration; a framework for analysis. *Renewable energy,* Vol. 24, Issue 1, pp. 73-89.

Painuly, J. P. Fenhann, J. V. 2002. Implementation of Renewable Energy Technologies (RETs) Project - Opportunities and Barriers; Egypt, Ghana, and Zimbabwe studies. Denmark: UNDP Collaborating Centre on Energy and Environment, Risø National Laboratory.

Panayotou, T. 1998. *Instruments of change: Motivating and financing sustainable development*. London: Earthscan Publications Limited.

Pandey, R. 2002. Energy policy modelling: agenda for developing countries. *Energy Policy*, Vol. 30, Issue 2, pp. 97-106.

Payne, A. Duke, R. Williams, R. H. 2001. Accelerating residential PV expansion: supply analysis for competitive electricity markets. *Energy Policy*, Vol. 29, Issue10, pp. 787-800.

Perlin, J. 2002. From space to earth: The story of solar electricity. [Online]. Available: http://www.californiasolarcenter.org/history_pv.html [Accessed: 18/04/04].

Philip, L. J. 1998. Combining qualitative and quantitative approaches to social research in human geography - an impossible mix? *Environment and planning* A, No. 30, pp. 261-76.

Philips, M. Browne, B. H. 1999. Accelerating PV Markets in Developing Countries. [Online]. Available: http://www.crest.org/repp_pubs/pdf/pv7.pdf [Accessed:15/01/07].

Pinch, J. T. Bijker, W.E. 1987. The Social Construction of Facts and Artefacts: Or How the Sociology of Science and the Sociology of Technology Might Benefit Each Other In: Bikjer, W.E. Thomas, P. H. Pinch, J.T. eds. *The Social Constructions of*

Technological Systems: New Directions in the Sociology and History of Technology, Cambridge: The MIT Press.

Prah, E.A. 1994. *Sustainable Management of the Tropical High Forest of Ghana.* Commonwealth Secretariat, London, 73pp.

Project Brief - Botswana. 1999. Renewable Energy-Based Rural Electrification Programme for Botswana. [Online]. Available: http://www.thegef.org/Documents/Work_Programs/wp_Feb04/CC_-_Botswana_-_Project_Document.pdf [Accessed: 27/04/07].

Punch, K. 2005. *Introduction to Social Research: Quantitative and Qualitative* (Third edition). London: Sage Publications.

Raja, P. B. R. Nayar, C. V. 2002. Conceptual model for marketing solar based technology to developing countries. *Renewable energy*, Vol. 24, Issue 4, pp. 511-524.

Resource Centre for Energy Economics and Regulation (RCEER). 2005. *Guide to electric power in Ghana* (First edition). Accra: Institute of Statistical Social and Economic Research, University of Ghana.

Reddy, S. Painuly, J. P. 2004. Diffusion of renewable energy technologies - barriers and stakeholders' perspectives. *Renewable energy*, Vol. 29, Issue 9, pp. 1431-1447.

Renewable Energy Services Project (RESPRO). 2000. Report GHA/96/G31: First Tripartite Review Meeting. 13 &14 June 2000. Tamale, Ghana.
Richard, D. D. Jacobson, A. Kammen, D. M. 2002. Photovoltaic module quality in the Kenyan solar home systems market. *Energy Policy*, Vol. 30, pp. 477-499.

Richardson, J. C. 2006. Learning from Failure: Property Rights, Land Reforms, and the Hidden Architecture of Capitalism. *American Enterprise Institute for Public Policy Research (*AEI*)*, No. 2, April 6, 2006. [Online]. Available: http://www.aei.org/publications/pubID.24196/pub_detail.asp [Accessed: 04/03/07].

Riordan, M. Hoddereson, L. 1997. *Crystal Fire*. New York: Norton.

Roberts, J. 2004. *Environmental Policy.* London: Routledge Taylor and Francis Group.

Robson, E. 1997. From Teacher to Taxi Driver: Reflections on Research Roles in Developing Areas. In: Robson, R. Willis, K., eds. *Postgraduate Fieldwork in Developing Area: A Rough Guide. IBG Developing Area Research Group Monograph* 9London: IBG, 19-35.

Rogers, E. M. 1995. *Diffusion of innovations* (Fourth edition). New York: The Free Press.

Rogers, E. M. Scott, K. L. 1997. The Diffusion of Innovations Model and Outreach from the National Network of Libraries of Medicine to Native American Communities. Draft paper prepared for the National Network of Libraries of Medicine, Pacific Northwest Region, Seattle. http://www.nnlm.nih.gov/pnr/eval/rogers.html [Accessed: 9/04/04].

Rogers, E. M. Shoemaker, F. F. 1971. *Communication of Innovations: A Cross Cultural Approach*: New York, Free Press.

Rose, D. Sullivan, O. 1996. *Introducing Data Analysis for Social Scientists* (Second edition). Buckingham: Open University Press.

Russell, S. 1986. The social construction of artefacts: A response to Pinch and Bijker. *Social Studies of Science,* Vol.16, No.2, pp. 331-46.

Sarkar, M. A. R. Islam, S. M. N. 1998. Rural Energy and its Utilisation in Bangladesh**.** *Energy,* Vol. 23, Issue 9, pp. 785-789.

Sawin, J. L. 2004. National Policy Instruments: Policy Lessons for the Advancement and Diffusion of Renewable Energy Technologies around the World. Thematic Background Paper for the International Conference for Renewable Energies, Bonn, January 2004. [Online]. Available: www.**renewable**s2004.de/pdf/tbp/TBP03-policies.pdf. [Accessed : 05/05/06].

School of Engineering, KNUST. 2003. Strategic National Energy Plan 2000-2020, Republic of Ghana. Technology Catalogue. April, 2003.

Solarbuzz, LL. 2006. Photovoltaic Industry Statistics: Countries. [Online]. Available: http://www.solarbuzz.com/StatsCountries.htm [Accessed: 25/11/06].

Solarbuzz™. 2005a. Ghana Solar Energy Organisations. [Online]. Available: http://www.solarbuzz.com/CompanyListings/Ghana.htm [Accessed: 12/1/07]

Solarbuzz™. 2005b. Zimbabwe Solar Energy Organisations. [Online]. Available: http://www.solarbuzz.com/CompanyListings/Zimbabwe.htm [Accessed: 14/1/07].

Solar Sam’s ® Innovations. [Online]. Available: http://www.solarsam.com/Main/AboutSolarEnergy/history.html [Accessed: 12/12/04].

Sonnenwald, D. H. Maglaughlin, K. L. Whitton, M.C. 2001. Using Innovation Diffusion Theory to Guide Collaboration Technology Evaluation: Work in Progress. [Online]. Available: http://www.adm.hb.se/personal/dis/wetice-2001.pdf [Accessed: 23/04/05].

Sorokin, A. P. 1959. *Social and Cultural Mobility ; containing complete reprints of Social Mobility and Chapter V from Volume IV of Social and Cultural Dynamics.* Illinois : The Free Press of Glencoe.

Southern Centre for Energy and Environment (SCEE). 2001. Implementation of Renewable Energy Technologies - Opportunities and Barriers. Zimbabwe country case study. Denmark: UNDP Collaborating Centre on Energy and Environment, Risø National Laboratory. [Online]. Available: http://www.uneprisoe.org/RETs/ZimbabweCountryStudy.pdf [Accessed: 12/02/07].

Spalding-Fecher, R. Clark, A. Davis, M. Simmonds, G. 2002. The economics of energy efficiency for the poor - A South African case. *Energy*, Vol. 27, Issue 12, pp. 1099-1117.

Strang, D. Soule, S. A. 1998. Diffusion in Organizations and Social Movements: From Hybrid corn to Poison Pills. *Annual Review of Sociology*, Vol. 24, pp.265-290.

Surry, D. W. 1997. Diffusion Theory and Instructional Technology. Paper presented at the Annual Conference of the Association for Educational Communications and Technology *(*AECT*)*, Albuquerque, New Mexico. February 12-15, 1997.

Tarde, Gabriele de. 1903. *The Laws of Imitation.* New York: Henry Holt & co.

The World Bank.1996. Rural Energy and Development. Improving Energy Supply for Two Billion People. "Development in Practice" series. Washington DC.

Tse, M. 1999. Feasibility of the commercial manufacture of photovoltaic system components: A case study of Ghana. AFREPREN study 1999.

Tse, M. 2000. Commercialisation of Renewable Energy Technologies in Ghana: Barriers and Opportunities. Paper presented at the expert/stakeholder workshop on renewable energy in Ghana. 15-17 August, 2000.

United Nations Conference on Trade and Development (UNCTAD). 2002. Investment Policy Review: Botswana. [Online]. Available: http://www.unctad.org/Templates/WebFlyer.asp?intItemID=2811&lang=1 [Accessed: 22/04/07].

United Nations Development Programme (UNDP). 1997. Human Development Report 1997: Human Report to Eradicate Poverty. [Online]. Available: http://hdr.undp.org/reports/global/1997/en/ [Accessed: 15/02/07].

United Nations Development Programme (UNDP). 2006. Human Development Report 2006. Beyond Scarcity: Power, Poverty and the global water crisis. [Online]. Available: http://hdr.undp.org/hdr2006/pdfs/report/HDR06-complete.pdf [Accessed: 09/03/07].

United Nations Development Programme/World Bank Energy Sector Assistance Programme (UNDP/ESMAP) Report 228/00. 2000. Zimbabwe Rural Electrification Study. March 31, 2000. [Online].Available:
http://wwwwds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2000/10/07/000094946_00092205342251/Rendered/PDF/multi_page.pdf
[Accessed: 2/1/04].

United Nations Environment Programme (UNEP). 2004. Photovoltaic Energy Technology Fact sheet. [Online]. Available: www.uneptie.org/energy [Accessed: 20/2/05].

United Nations Environment Programme (UNEP). 2005. Thousand of Megawatts of New Renewable Energy Potential. [Online]. Available:
http://www.unep.org/Documents.Multilingual/Default.asp?DocumentID=430&ArticleID=4771&l=en. [Accessed: 20/02/06].

United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP). 2006. Intergrating environmental considerations into the economic decision-making process. [Online]. Available:
http://www.unescap.org/drpad/publication/integra/volume1/philippines/1pl03a.htm
[Accessed: 11/10/06].

United Nations Framework Convention on Climate Change (UNFCCC). 1998. Abstracts from the secretariat's technical paper on Barriers and opportunities related to the transfer of Technology (Document FCCC/TP/1998/1). [Online].Available:
http://unfccc.int/files/documentation/workshops_documentation/application/pdf/arusha.pdf [Accessed: 22/02/06].

United Nations (UN) Millennium Project. 2004. Preliminary Country Profile: Kenya. February, 3, 2004. [Online]. Available:
http://www.unmillenniumproject.org/documents/KenyaPreliminaryCountryProfileFeb03-04.pdf [28/02/07].

U.S. State Department Background Notes on Ghana. 2006. [Online]. Available:
http://www.state.gov/r/pa/ei/bgn/2860.htm. [Accessed: 16/02/06]

Valentine, G. 2005. Tell me about …: Using interviews as a research methodology. In: Flowerden, R. Martin, D., eds. *Methods in Human Geography*. (Second edition). London: Pearson Education.

van Campen, B. Guidi, D. Best, G. 2000. Solar Photovoltaics for Sustainable Agriculture and Rural Development. Environment and Natural Resources Working Paper No.2, FAO, Rome. [Online]. Available:
http://www.fao.org/sd/EGdirect/EGdocuments/PVfulltext.pdf [Accessed: 18/03/06].

van der Plas, R. J. Hankins, M. 1998. Solar electricity in Africa: a reality. *Energy Policy*, Vol. 26, Issue 4, pp. 295-305.

van der Vleuten-Balkema, F. Nienke, S. van der Jeroen, L. 2003. Selling rural electrification: Developing solar market infrastructure in Africa and Asia. *Renewable Energy World.* November-December, 2003. Available:
http://www.jxj.com/magsandj/rew/2003_06/solar_market.html [Accessed: 24/04/05].

Village Power. 1997.Conference Proceedings; Washington DC. [Online]. Available: http://rsvp.nrel.gov/vpconference/html/main.htm [Accessed:20/04/06].

Wa Municipal Assembly statistics - Ghana, 2002.

Walsh-Russo, C. 2004. "From Spin-off to Spillover: Theoritical Approaches to Diffusion in Social Movement Literature". Presented to the Historical Dyanamics Workshop. November 4th, 2004. Columbia.

Wamukonya, N. Davis, M. 2001. Socio-economic impacts of rural electrification in Namibia: comparisons between grid, solar and unelectrified households. *Energy for Sustainable Development,*Vol. 5, No.3, pp.5-13.

Westrum, R. 1991. *Technologies and society.* Belmont, California: Wadsworth Publishing.

Williams, R. Edge, D. 1996. The Social Shaping of Technology. *Research Policy*, Vol. 25, pp. 856-899.

Williams-Jones, B. Graham, J.E. 2003. Actor-Network Theory: a tool to support ethical analysis of commercial genetic testing. *New Genetics and Society*, Vol. 22, No. 3, pp. 271-296.

Winner, L. 1993. Upon opening the black box and finding it empty: Social constructivism and the philosophy of technology. *Science, Technology, and Human Values*, Vol.18, pp. 362-78.

World Bank. 1992. *World Development Report 1992: Development and the Environment.* Oxford: Oxford University Press.

World Council for Renewable Energy (WCRE). 2004. World Renewable Energy Agenda. Civilization at the Turning Point: A Breakthrough for Renewable Energy [*Online*]. Available:
http://www.world-council-for-renewable-energy.org/downloads/WREA.pdf
[Accessed : 12/8/04].

World Energy Council (WEC). 2000. Energy for Tomorrow's World - Acting Now! [Online]. Available:
http://www.worldenergy.org/wecgeis/publications/reports/etwan/introduction/introduction.asp [Accessed: 11/07/04].

World Energy Council. 2001. Energy Information: Ghana. Extract from the survey of energy resources 2001. [Online]. Available:
http://www.worldenergy.org/wec-geis/edc/countries/Ghana.asp [accessed: 21/02/07].

World Energy Council. 2001. Energy Information: Kenya. Extract from the survey of energy resources 2001. [Online]. Available:
http://www.worldenergy.org/wec-geis/edc/countries/Kenya.asp [Accessed: 17/01/07].

World Energy Council (WEC). 2003. The Challenge of Rural Energy Poverty in Developing Countries. [Online]. Available:
http://www.worldenergy.org/wecgeis/publications/reports/rural/rural_development_and_energy/rural_development_and_energy.asp [Accessed: 12/11/04].

World Energy Council and Food and Agriculture Organisation (WEC/FAO). 1999. 'The Challenge of Rural Energy Poverty in Developing Countries'. [Online]. Available: http://www.worldenergy.org/wec-geis/global/downloads/rural.pdf
[Accessed: 14/07/06].

World Health Organisation (WHO). 2006. Country Cooperation Strategy at a glance: Ghana. [Online]. Available:
http://www.who.int/countryfocus/resources/ccsbrief_ghana_gha_06_en.pdf
[Accessed: 09/03/07].

Yoshihiro, H. 2002. Solar PV conversion and the 21st century's civilization. *Solar Energy Material and Solar Cells*, Vol. 74, pp.13-23.

Zomers, A. A. 2001. *Rural Electrification*. PhD. Diss., University of Twente. Twente University Press. [Online]. Available: http://doc.utwente.nl/fid/1409 [Accessed: 23/08/04].

WEBSITES

http://stage.itp.tsoa.nyu.edu/~pr442/solar/pv_history.html [Accessed: 13/04/04].

http://www.solarsam.com/ [Accessed: 17/05/04].

http://www.nigc.org/eia/ghana.asp [Assessed: 25/02/06].

http://ghanaweb.com/ [Accessed: 30/01/07].

APPENDIX 1

QUESTIONNAIRE ON THE SOCIO-ECONOMIC, CULTURAL, TECHNICAL, INSTITUTIONAL AND POLITICAL ISSUES OF SOLAR PV ADOPTION AND UTILISATION IN RURAL GHANA

1) QUESTIONNAIRE FOR HOUSEHOLDS WITHOUT SOLAR PV IN WA WEST DISTRICTS AND BUNKPURUGU/YUNYOO

Date of Interview……………………….. Questionnaire Number……………………..
Name of Village………………………… House Number……………………………..
Interviewer's Name…………………………………………………………………..

Section A: Preliminary details of respondent

I would be glad if you could provide some information about yourself, by responding to these questions.

1. Sex of respondent Male [ ] Female [ ]

2. Age of respondent

25-35 years	[ ]1
36-45 years	[ ]2
46-55 years	[ ]3
56-65 years	[ ]4

3. What is your marital status?

Single	[ ]1
Married	[ ]2
Divorced	[ ]3
Widowed	[ ]4

4. What is your educational attainment?

Never been to school	[ ]1
Primary school	[ ]2
Middle school	[ ]3
Secondary school	[ ]4
Training college	[ ]5
Advanced/University	[ ]6
Other (specify)	[ ] 7 …………………………

5. What leadership position do you hold in this community?

None	[ ]1
Development committee chairman	[ ]2
Community watchdog member	[ ]3
Development committee member	[ ]4
Village chief	[ ]5
Other (specify)	[ ]6 ……………………….

6. What is your tribe?

Dagao	[ ]1
Walla	[ ]2

Frafra [ ]3
Kasena [ ]4
Akan [ ]5
Dagomba [ ]6
Mosi [ ]7
Other (specify) [ ]8 ………………

7. What is your religion?
Christian [ ]1
Islam [ ]2
Traditionalist [ ]3
Pagan [ ]4
Other (specify) [ ]5 …………………

Section B: Sources of energy in rural areas

I would now like to ask you some questions about rural energy.

8. What are your main sources of energy, and how long have you used them? (Tick as many as apply for the energy sources). Use the following codes for the number of years the respondent has been using the energy source: **1** [1-10years]; **2** [11-20 years]; **3** [21-30 years]; **4** [31-40 years]; **5** [41-50 years] **6** [51-60 years]

A SOURCE/FORMS OF ENERGY		**B YEARS**
Biomass	[ ]1	[ ]
Dry cell batteries	[ ]2	[ ]
Kerosene	[ ]3	[ ]
Sheabutter	[ ]4	[ ]
Candles	[ ]5	[ ]
Electricity	[ ]6	[ ]
Sunlight	[ ]7	[ ]
Car battery	[ ]8	[ ]
Diesel Generator	[ ]9	[ ]
Other (specify)	[ ]10 ……………………………	[ ]

9. If you chose biomass, what do you use it for? (Tick as many as apply)
Cooking [ ]1
Heating [ ]2
Lighting [ ]3
Local industry [ ]4
Local rituals (specify) [ ]5 ……………………………………
Other uses (specify) [ ]6 ……………………………………

10. If you chose dry cell battery, what do you use it for? (Tick as many as apply)
Lighting [ ]1
Tape recorder [ ]2
Hunting [ ]3
Others (specify) [ ]4 ……………………………………

11. If you chose kerosene, what do you use it for?
Cooking [ ]1
Lighting [ ]2

Local industry [ ]3
Agriculture (specify) [ ]4
Other (specify) [ ]5 ……………………………………

12. If you chose sheabutter, what do you use it for?
Lighting [ ]1
Local ritual [ ]2
Others (specify) [ ]3 ……………………………

13. If you chose sunlight, what do you use it for?
Drying [ ]1
Lighting [ ]2
Entertainment [ ]3 Name them ………………………………...
Heating [ ]4
Agriculture [ ]5
Local industry [ ]6
Other (specify) [ ]7 ……………………………………………..

14. If you chose electricity, what do you use it for?
Cooking [ ]1
Hot water [ ]2
Entertainment [ ]3 Name them ………………………………...
Lighting [ ]4
Agriculture [ ]5
Other (specify) [ ]6 ……………………………………………..

15. If you chose car battery, what do you use it for?
Lighting [ ]1
Television [ ]2
Charge mobile phone [ ]3
Radio [ ]4
Tape recorder [ ]5
Other (specify) [ ]6…………………………………………..

16. If you chose diesel generator, what do you use it for?
Lighting [ ]1
Television [ ]2
Charge mobile phone [ ]3
Radio [ ]4
Tape recorder [ ]5
Other (specify) [ ]6……………………………………………

17. Which of these activities is energy so precious to you? Rank them in the other of their importance to you, using a scale of 1 to 5. Where 1, is less important and 5 very important.

ACTIVITY	**RANKING:1,2,3,4,5**
Energy for irrigation	
Energy for entertainment	
Energy for cooking	
Energy for lighting	
Energy for my business	

Section C: Socio-economic features of rural households

Please, let's move on to questions on the social and economic conditions of rural households.

18. What is your main occupation?

Agriculture	[ ]1
Business (specify)	[ ]2……………………………….
Government employment (specify)	[ ]3 ……………………………….
Other (specify)	[ ]4………………………………..

19. How many persons are there in your household?

Children (<18)	Adults (18-60)	Old (>60)
None [ ]1	1-3 [ ]1	None [ ]1
1-3 [ ]2	4-6 [ ]2	1-3 [ ]2
4-6 [ ]3	7-9 [ ]3	4-6 [ ]3
7-9 [ ]4	10-12 [ ]4	7-9 [ ]4
10-12 [ ]5	>12 [ ]5	10-12 [ ]5
>12 [ ]6		>12 [ ]6

20. What are the various sources of your household income?

Agriculture	[ ]1
Petty trading activity (specify)	[ ]2 …………………………………
Brewing of local drink (specify)	[ ]3 …………………………………
Gov't employment (specify)	[ ]4
Remittances	[ ]5
Hunting	[ ]6
Night/day security activities	[ ]7
Pottery making	[ ]8
Soap making	[ ]9
Other (specify)	[ ]10 …………………………………

21. If you mentioned agriculture as one of your sources of income, what type of agricultural activities do you practise?

Seasonal farming	[ ]1
Irrigation farming	[ ]2
Rearing (specify the animals and number)	[ ]3 ………………………….
All the three	[ ]4

If you carry out irrigation farming, then answer question 22, otherwise move to question 23.

22. Please, give reason (s) for not doing irrigation farming.

No energy (i.e. mechanical device) to pump water	[ ]1
No irrigation dam	[ ]2
Not profitable	[ ]3
There is sufficient foodstuff	[ ]4
Other reasons (specify)	[ ]5 …………………………...

....

23. In which activities do you use energy?

Domestic chores	[ ]1
Agriculture	[ ]2

Industry [ ]3
Hunting [ ]4
Others (specify) [ ]5 ……………………………………………

24. What was your annual household income for each of the past five years? Fill in as applicable.

Sources of income	*Years and Respective amount in cedi (¢)*				
	2000	2001	2002	2003	*2004*
Agriculture					
Salaries (Gov't worker)					
Remittances					
Trading					
Brewery					
Casual labour					
Pottery wares					
Hunting					
Other (specify) 1. 2. 3					
Total					

25. What were your household expenditures on the items in the table for the past six months? Fill in as applicable.

Type of expenditures	*Months and Respective amount in cedi (¢)*					
	Jan	Feb	March	April	May	June
Food						
Clothing						
Schooling						
Health						
Energy						
Funerals						
Festivals/ceremonies						
Housing						
Livestock						
Drinks						
Total						

26. Please, rank these according to your priorities in life - using a scale of 1 to 11 where 1, is the lowest on your preference list and 11 the most preferred). Tick (√) the appropriate box on each row.

Needs	Scale 1 to 11										
	1	2	3	4	5	6	7	8	9	10	11
Food											
House											
Electricity											
Potable water											
Bicycle											
Education											
Energy for Irrigation farming											
Cattle											
Open a shop											
Buy more land											

Section D: Cultural practices of rural households

29. What type of energy do you use during the day?

Biomass for cooking [ ]1
Car batteries for entertainment [ ]2
Dry cell batteries for entertainment [ ]3
Other energy (specify) [ ]4 ………………………………

30. Where does the household do its cooking during the day in the house?

In the Courtyard [ ]1
On the veranda [ ]2
In a kitchen [ ]3
In the backyard [ ]4

31. Where does the household do its cooking in the evening in the house?

In the courtyard [ ]1
On the veranda [ ]2
In the kitchen [ ]3
In the backyard [ ]4

32. What social activities do the adults in your household do in the evening?

33. What activities do the children do in the evening?

34. Do the evening social activities (of both adults and children) involve the use of any form of energy?

Yes [ ]1 go to Question 35
No [ ]2 continue from Question 36

35. If yes, list the activities and the corresponding forms of energy.

SOCIAL ACTIVITIES **FORMS OF ENERGY**

1…………………………………… 1……………………………....

2…………………………………… 2………………………………
3…………………………………… 3………………………………

36. Would you want to maintain these forms of energy?

Yes [ ]1 go to Q37 and continue from Q38
No [ ]2 continue from Q38

37. Why do you want to maintain them? Because…

……………………………………………………………………………………….

38. Why do you want to change these forms of energy? Because...

……………………………………………………………………………………….

39. What forms of energy do you want to change to?

……………………………………………………………………………………….

40. Why do you want these forms of energy? Because…

……………………………………………………………………………………….

40. In your household, who decides the type of energy to use? Tick as many as apply

Husband [ ]1
Wife [ ]2
Children [ ]3
Old [ ]4

41. What time does your household usually go to bed?

Between 7pm to 8pm [ ]1
Between 8pm to 9pm [ ]2
Between 9pm to 10pm [ ]3
Between 10pm to 11pm [ ]4
Between 11pm to 12 midnight [ ]5
Between 12 midnight to 1am [ ]6

42. What are your reasons for going to bed at the time above?

………………………………………………………………………………………

Section E: Technology/technical knowledge and meanings, which rural communities attribute to PV technology

43. What electrical gadgets are used in your household? (Tick as many as apply)

Television [ ]1
Wireless (Radio) [ ]2
Tape recorder [ ]3
Mobile phone [ ]4
No electrical gadget [ ]5
Other (specify) [ ]6…………………………………………….

44. What form of energy do you use to power them?

Dry cell batteries [ ]1
Car batteries [ ]2
Motor batteries [ ]3
Other (specify) [ ]4 ……………………………………………..

45. Have you ever heard of Photovoltaic/solar energy technology?

Yes [ ]1 move to Q46 and continue
No [ ]2 move to Q16 and continue

46. How did you hear about it? (Tick as many as applied).

On the radio [ ]1
Through a friend [ ]2 Probe how the friend heard of it
Through public demonstration [ ]3
In the market [ ]4
Through the village crier [ ]5
Other sources (Specify) [ ]6 ……………………………………

47. What are its functions?

It generates electricity [ ]1
It generates energy for cooking [ ]2
It can be used to pump water [ ]3
I don't know its uses [ ]4
Other uses you know (specify) [ ]5 ………………………………

48. Do you like it?

Yes [ ]1
No [ ]2

49. What is/are your reason(s) for not using PV technology? (Tick as many as apply).

I am content with the present sources of energy [ ]1
It is costly [ ]2
It is complex [ ]3
The capital cost of PV can't enhance my family finances than PV [ ]4
It is not reliable [ ]5
Not accessible [ ]6
I don't understand how it operates [ ]7
I want grid electricity and not PV [ ]8
Because of theft [ ]9
Other (specify) [ ]10…………………………

……………………………………………………………………………………..
.

Section F: Policies, institutions, market models and the legal framework on rural electrification, especially PV.

51. Do you know the government institutions tasked with the provision of PV energy technology to the rural areas?

Yes [ ]1
No [ ]2 → No.53

52. What are they?
……………………………………………………………………………………..

53. Do you know the government policy towards rural electrification in the country?

Yes [ ]1

No [ ]2 → No. 55

54. Kindly tell me a bit about this policy.

……………………………………………………………………………………

55. Please, indicate (√) how you feel about the legal and institutional frameworks on PV technology dissemination in Ghana, on the scales listed below.

Feelings	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
There is adequate public education on technology					
I am happy with the available market models					
Gov't has greatly promoted PV to the rural areas					
There is a strong legislation, which protects PV consumers against fraud					
The gov't has implemented its rural electrification programmes					

2) QUESTIONNAIRE FOR HOUSEHOLDS WITH SOLAR PV IN WA WEST AND BUNKPURUGU/YUNYOO DISTRICTS

Date of Interview………………………..Questionnaire Number……………………...
Name of Village…………………………House Number……………………………...
Interviewer's Name…………………………………………………………………..

Section A: Preliminary details of respondent

I would be glad if you could provide some information about yourself, by responding to these questions.

1. Sex of respondent Male [ ] Female [ ]

2. Age of respondent
   - 25-35 years [ ]1
   - 36-45 years [ ]2
   - 46-55 years [ ]3
   - 56-65 years [ ]4

3. What is your marital status?
   - Single [ ]1
   - Married [ ]2
   - Divorced [ ]3
   - Widowed [ ]4

4. What is your educational attainment?
   - Never been to school [ ]1
   - Primary school [ ]2
   - Middle school [ ]3
   - Secondary school [ ]4

Training college [ ]5
Advanced/University [ ]6
Other (specify) [ ] 7 ……………………………………………

5. What leadership position do you hold in this community?

None [ ]1
Development committee chairman [ ]2
Community watchdog member [ ]3
Development committee member [ ]4
Village chief [ ]5
Other (specify) [ ]6 ……………………….

6. What is your tribe?

Dagao [ ]1
Walla [ ]2
Frafra [ ]3
Kasena [ ]4
Akan [ ]5
Dagomba [ ]6
Mosi [ ]7
Other (specify) [ ]8 ……………………………………

7. What is your religion?

Christian [ ]1
Islam [ ]2
Traditionalist [ ]3
Pagan [ ]4
Other (specify) [ ]5 ……………………………………

Section B: Sources of energy in rural areas

I would now like to ask you some questions about rural energy.

8. What are your main sources of energy, and how long have you used them? (Tick as many as apply for the energy sources). Use the following codes for the number of years the respondent has been using the energy source: **1** [1-10years]; **2** [11-20 years]; **3** [21-30 years]; **4** [31-40 years]; **5** [41-50 years] **6** [51-60 years]

A SOURCE/FORMS OF ENERGY		**B YEARS**
Biomass	[ ]1	[ ]
Dry cell batteries	[ ]2	[ ]
Kerosene	[ ]3	[ ]
Solar PV	[ ]4	[ ]
Candles	[ ]5	[ ]
Electricity	[ ]6	[ ]
Sunlight	[ ]7	[ ]
Car battery	[ ]8	[ ]
Diesel Generator	[ ]9	[ ]
Other (specify)	[ ]10 ……………………………	[ ]

9. If you chose biomass, what do you use it for? (Tick as many as apply)

Cooking [ ]1
Heating [ ]2

Lighting [ ]3
Local industry [ ]4
Local rituals (specify) [ ]5 ……………………………………
Other uses (specify) [ ]6 ……………………………………

10. If you chose dry cell battery, what do you use it for? (Tick as many as apply)
Lighting [ ]1
Tape recorder [ ]2
Hunting [ ]3
Others (specify) [ ]4 ……………………………………

11. If you chose kerosene, what do you use it for?
Cooking [ ]1
Lighting [ ]2
Local industry [ ]3
Agriculture (specify) [ ]4
Other (specify) [ ]5 ……………………………………

12. If you chose photovoltaic energy technology, what do you use it for?
Drying [ ]1
Lighting [ ]2
Entertainment [ ]3 Name them ………………………………...
……………………………………………………………………………………
Heating [ ]4
Agriculture [ ]5
Local industry [ ]6
Other (specify) [ ]7 ……………………………………………..

13. If you chose electricity, what do you use it for?
Cooking [ ]1
Hot water [ ]2
Entertainment [ ]3 Name them ………………………………...
Lighting [ ]4
Agriculture [ ]5
Other (specify) [ ]6 ……………………………………………..

14. If you chose car battery, what do you use it for?
Lighting [ ]1
Television [ ]2
Charge mobile phone [ ]3
Radio [ ]4
Tape recorder [ ]5
Other (specify) [ ]6……………………………………………..

15. If you chose diesel generator, what do you use it for?
Lighting [ ]
Television [ ]2
Charge mobile phone [ ]3
Radio [ ]4
Tape recorder [ ]5
Other (specify) [ ]6……………………………………………..

16. Which of these activities is energy so precious to you? Rank them in the other of their importance to you, using a scale of 1 to 5. Where 1, is less important and 5 very important.

ACTIVITY	RANKING:1,2,3,4,5
Energy for irrigation	
Energy for entertainment	
Energy for cooking	
Energy for lighting	
Energy for my business	

Section C: Socio-economic features of rural households

Please, let's move on to questions on the social and economic conditions of rural households.

17. What is your main occupation?

Agriculture [ ]1
Business (specify) [ ]2……………………………….
Government employment (specify) [ ]3 ……………………………….
Other (specify) [ ]4………………………………..

18. How many persons are there in your household?

Children (<18)	Adults (18-60)	Old (>60)
None [ ]1	1-3 [ ]1	None [ ]1
1-3 [ ]2	4-6 [ ]2	1-3 [ ]2
4-6 [ ]3	7-9 [ ]3	4-6 [ ]3
7-9 [ ]4	10-12 [ ]4	7-9 [ ]4
10-12 [ ]5	>12 [ ]5	10-12 [ ]5
>12 [ ]6		>12 [ ]6

19. What are the various sources of your household income?

Agriculture [ ]1
Petty trading activity (specify) [ ]2 …………………………………
Brewing of local drink (specify)[ ]3 …………………………………
Gov't employment (specify) [ ]4
Remittances [ ]5
Hunting [ ]6
Night/day security activities [ ]7
Pottery making [ ]8
Soap making [ ]9
Other (specify) [ ]10 …………………………………

20. If you mentioned agriculture as one of your sources of income, what type of agricultural activities do you practise?

Seasonal farming [ ]1
Irrigation farming [ ]2
Rearing (specify the animals and number) [ ]3 ………………………….
All the three [ ]4

If you do not carry out irrigation farming, then answer question 21, otherwise move to question 22.

21. Please, give reason (s) for not doing irrigation farming.
    No energy (i.e. mechanical device) to pump water [ ]1
    No irrigation dam [ ]2
    Not profitable [ ]3
    There is sufficient foodstuff [ ]4
    Other reasons (specify) [ ]5 …………………………...
....

22. In which activities do you use energy?
    Household activities [ ]1
    Agriculture [ ]2
    Industry [ ]3
    Hunting [ ]4
    Others (specify) [ ]5 ……………………………………………

23. What was your annual household income for each of the past five years? Fill in as applicable.

Sources of income	*Years and Respective amount in cedi (¢)*				
	2000	2001	2002	2003	*2004*
Agriculture					
Salaries (Gov't worker)					
Remittances					
Trading					
Brewery					
Casual labour					
Pottery wares					
Hunting					
Others (specify)					
Total					

24. What were your household expenditures on the items in the table for the past six months? Fill in as applicable.

Type of expenditures	*Months and Respective amount in cedi (¢)*					
	Jan	Feb	March	April	May	June
Food						
Clothing						
Schooling						
Health						
Energy						
Funerals						
Festivals/ceremonies						
Housing						
Livestock						
Drinks						
Total						

25. Please, rank these according to your priorities in life - using a scale of 1 to 11 where 1, is the lowest on your preference list and 11 the most preferred). Tick (√) the appropriate box on each row.

Needs	Scale 1 to 11										
	1	2	3	4	5	6	7	8	9	10	11
Food											
House											
Electricity											
Potable water											
Bicycle											
Education											
Energy for Irrigation farming											
Cattle											
Open a shop											
Buy more land											

Section D: Cultural practices of rural households

26. What type of energy do you use during the day?

Biomass for cooking [ ]1
Car batteries for entertainment [ ]2
Dry cell batteries for entertainment [ ]3
PV for entertainment [ ]4
Other energy (specify) [ ]5 ………………………………

27. Where does the household do its cooking during the day in the house?

In the Courtyard [ ]1
On the veranda [ ]2
In a kitchen [ ]3
In the backyard [ ]4

28. Where does the household do its cooking in the evening in the house?

In the courtyard [ ]1
On the veranda [ ]2
In the kitchen [ ]3
In the backyard [ ]4

29. What social activities did the adults in your household do in the evening before you adopted photovoltaic energy technology?
…………………………………………

30. What activities did the children do in the evening before you adopted PV?
…………………………………………

31. Did the evening social activities (of both adults and children) involve the use of any form of energy?

Yes [ ]1 go to Question 32
No [ ]2 continue from Question 33

32. If yes, list the activities and the corresponding forms of energy.

SOCIAL ACTIVITIES	**FORMS OF ENERGY**
1……………………………………	1……………………………....
2……………………………………	2………………………………
3……………………………………	3………………………………
4……………………………………	4………………………………

33. In your household, who decides the type of energy to use? Tick as many as apply

Husband [ ]1
Wife [ ]2
Children [ ]3
Old [ ]4

34. What time did your household usually go to bed prior to the adoption of PV?

Between 7pm to 8pm [ ]1
Between 8pm to 9pm [ ]2
Between 9pm to 10pm [ ]3
Between 10pm to 11pm [ ]4
Between 11pm to 12 midnight [ ]5
Between 12 midnight to 1am [ ]6

35. What were your reasons for going to bed at the time above?

…………………………………………………………………………………

…………………………………………………………………………………

Section E: Technology/technical knowledge and meanings, which rural communities attribute to PV technology

36. When did you start using photovoltaic energy technology in your household?

YEAR:

37. What is the capacity of your photovoltaic system?

50 watts [ ]1
100 watts [ ]2
150 watts [ ]3

38. Who in the family decided that you go in for photovoltaic energy technology and who paid/pays?

DECISION MAKER		**PAYER**
Husband	[ ]1	[ ]1
Wife	[ ]2	[ ]2
Children	[ ]3	[ ]3
The whole family	[ ]4	[ ]4
Others (specify)	[ ]5 ……………………………………………………………	

………………………………………………………………………………………….

39. Which parts of the house does the PV system supply light to? (Tick as many as applicable)

The husband and wife's bedroom [ ]1
The children bedroom [ ]2
The kitchen [ ]3
The living room [ ]4
Others (specify) [ ]5 ……………………………………….

40. How did you get it?
Through the government [ ]1
Through a private PV company [ ]2
Through donation by a charity organisation [ ]3
Through donation by a family member [ ]4
Other means (specify) [ ]5 ………………………………….
……………………………………………………………………………………………

41. a) If you got it through the government, how much did you spend prior to its installation?
AMOUNT:

b) What criteria did the government agents use to give out these systems to the current users in your community?
……………………………………………………………………………………………
……………………………………………………………………………………………

c) What was/is the mode of payment for this system (PV)?

Outright purchase [ ]1
Fees for service basis [ ]2
Instalment basis [ ]3
Others (specify) [ ]4 ……………………………………………………

d) If the mode of procurement was/is by a fees-for-service basis, how often do you pay your tariff?
Monthly [ ]1
Every six months [ ]2
Others (specify) [ ]3 …………………………………………………...

e) How much tariff do you pay under the mode of tariff payment mentioned in (e) above?
Amount: ¢

f) Are you happy with this tariff payment system?
Yes [ ] → go to h
No [ ] → got to g

g) Why are you not happy with this tariff payment system?
……………………………………………………………………………………………
……………………………………………………………………………………………

h) Whose property is the system that is installed in your house in the case of fees for service basis?
It is my property [ ]1
It is the gov't's [ ]2 → go to i
It is for both of us [ ]3

i) What is your reaction to this pattern of ownership?
……………………………………………………………………………………………
……………………………………………………………………………………………

42. a) If you got it through the private business, how much did you spend prior to its installation?
AMOUNT: ¢

b) What was/is the mode of payment for this system (PV)?
Outright purchase [ ]1
Fees for service basis [ ]2 Amount per month: ¢
Instalment basis [ ]3 Amount per month: ¢

Others (specify) [ ]4 …………………………………………………
………………………………………………………………………………………….

43. What forms of energy were you using prior to adopting photovoltaic energy technology? (Tick as many as apply)

Kerosene lanterns [ ]1
Candles [ ]2
Sheabutter 'Fintele' [ ]3
Car battery [ ]4
Diesel generator [ ]5
Dry cells batteries [ ]6
Others (specify) [ ]7 …………………………………………………
………………………………………………………………………………………….

44. Why did you decide to use photovoltaic energy technology instead of any other energy source (e.g. diesel generator, car battery,)?
…………………………………………………………………………………………
…………………………………………………………………………………………

45. Compared to before you had PV, is there any change in the length of the day?

Shorter [ ]1 → 47
The same [ ]2 → 47
Longer [ ]3

46. What will you say this additional time has brought to you and your household? (Rank 1 to 3)

More time for housework [cooking, cleaning, ironing, sewing] [ ]1
More time for entertainment [ ]2
More time for youth education [ ]3
More time for small businesses [ ]4
More time for outside activities [ ]5
More time agriculture product processing [ ]6
More time for animal breeding activities [ ]7
Other (specify)………………………………………………………… [ ]8

47. Now that you are using photovoltaic energy technology, should in case the national grid gets to this community, will you continue to use the photovoltaic technology or you will switch to the national grid?

I will continue to use the PV [ ]1 → No.49
I will switch to the national grid [ ]2 → No.50

48. Why will you want to continue with photovoltaic energy technology?
…………………………………………………………………………………………
…………………………………………………………………………………………

49. Why will you want to switch to the national grid?
…………………………………………………………………………………………
…………………………………………………………………………………………

50. Do you encounter any difficulties in maintaining or repairing your system?

Yes [ ]1
No [ ]2 → No. 53

51. If yes, what kind of difficulties? (Tick as many as applicable)

High maintenance cost [ ]1
Difficult to find spare parts [ ]2

Lack of knowledge about PV [ ]3
Complicated maintenance [ ]4

Unprofessional official [ ]5
Lack of technicians [ ]6
Others (specify) [ ]7 ………………………………………………..
…………………………………………………………………………………………..

52. What other social problems do you encounter in the use of photovoltaic energy technology?
…………………………………………………………………………………………
…………………………………………………………………………………………

Section F: Policies, institutions, market models and the legal framework on rural electrification, especially PV.

53. Do you know the government institutions tasked with the provision of PV energy technology to the rural areas?

Yes [ ]1 → No.55
No [ ]2 → No. 56

54. What are they?
……………………………………………………………………………………..
……………………………………………………………………………………..

55. Do you know the government policy towards rural electrification in the country?

Yes [ ]1
No [ ]2 → 55

56. Kindly tell me a bit about this policy

…………………………………………………………………………………………

57. Please, indicate (√) how you feel about the legal and institutional frameworks on PV technology dissemination in Ghana, on the scales listed below.

Feelings	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
There is adequate public education on technology					
I am happy with the available market models					
Gov't has greatly promoted PV to the rural areas					
There is a strong legislation, which protects PV consumers against fraud					
The gov't has implemented its rural electrification programmes					

3) QUESTIONNAIRE FOR KUNSU COMMERCIAL FARMING COMMUNITY - NON-USERS OF PV

Date of Interview……………………… Questionnaire Number……………………..
Name of Village……………………… House Number………………………………
Interviewer's Name………………………………………………………………

Section A: Preliminary details of respondent

I would be glad if you could provide some information about yourself, by responding to these questions.

1. Sex of respondent Male [ ] Female [ ]
2. Age of respondent
   - 25-35 years [ ]1
   - 36-45 years [ ]2
   - 46-55 years [ ]3
   - 56-65 years [ ]4

3. What is your marital status?
   - Single [ ]1
   - Married [ ]2
   - Divorced [ ]3
   - Widowed [ ]4

4. What is your educational attainment?
   - Never been to school [ ]1
   - Primary school [ ]2
   - Middle school [ ]3
   - Secondary school [ ]4
   - Training college [ ]5
   - Advanced/University [ ]6
   - Other (specify) [ ] 7 ……………………………………………

5. What is your tribe?
   - Dagao [ ]1
   - Walla [ ]2
   - Frafra [ ]3
   - Kasena [ ]4
   - Akan [ ]5

6. What is your religion?
   - Christian [ ]1
   - Islam [ ]2
   - Traditionalist [ ]3
   - Pagan [ ]4
   - Other (specify) [ ]5 ……………………………………

Section B: Sources of energy in rural areas

I would now like to ask you some questions about rural energy.

7. What are your main sources of energy, and how long have you used them? (Tick as many as apply for the energy sources). Use the following codes for the number of

years the respondent has been using the energy source: **1** [1-10years]; **2** [11-20 years]; **3** [21-30 years]; **4** [31-40 years]; **5** [41-50 years] **6** [51-60 years]

A SOURCE/FORMS OF ENERGY		**B YEARS**
Biomass	[ ]1	[ ]
Dry cell batteries	[ ]2	[ ]
Kerosene	[ ]3	[ ]
Sheabutter	[ ]4	[ ]
Candles	[ ]5	[ ]
Sunlight	[ ]6	[ ]

8. If you chose biomass, what do you use it for? (Tick as many as apply)
   - Cooking [ ]1
   - Heating [ ]2
   - Lighting [ ]3
   - Local industry [ ]4
   - Local rituals (specify) [ ]5 ……………………………………
   - Other uses (specify) [ ]6 ……………………………………

9. If you chose dry cell battery, what do you use it for? (Tick as many as apply)
   - Lighting [ ]1
   - Tape recorder [ ]2
   - Hunting [ ]3
   - Others (specify) [ ]4 ……………………………………

10. If you chose kerosene, what do you use it for?
   - Cooking [ ]1
   - Lighting [ ]2
   - Local industry [ ]3
   - Agriculture (specify) [ ]4
   - Other (specify) [ ]5 ……………………………………

11. If you chose sheabutter, what do you use it for?
   - Lighting [ ]1
   - Local ritual [ ]2
   - Others (specify) [ ]3 ……………………………

12. If you chose sunlight, what do you use it for?
   - Drying [ ]1
   - Lighting [ ]2
   - Entertainment [ ]3 Name them ………………………………...
   - Heating [ ]4
   - Agriculture [ ]5
   - Local industry [ ]6
   - Other (specify) [ ]7 ……………………………………………..

13. Which of these activities is energy so precious to you? Rank them in the other of their importance to you, using a scale of 1 to 5. Where 1, is less important and 5 very important.

ACTIVITY	RANKING:1,2,3,4,5
Energy for irrigation purposes	
Energy to enhance entertainment	
Energy to enhance cooking	
Energy for lighting	
Energy for my business	

Section C: Socio-economic features of rural households

Please, let's move on to questions on the social and economic conditions of rural households.

14. What is your main occupation?

Agriculture (farming and rearing) [ ]1
Business (specify) [ ]2……………………………….
Government employment (specify) [ ]3 ……………………………….
Other (specify) [ ]4………………………………..

15. How many persons are there in your household?

Children (<18)	Adults (18-60)	Old (>60)
None [ ]1	1-3 [ ]1	None [ ]1
1-3 [ ]2	4-6 [ ]2	1-3 [ ]2
4-6 [ ]3	7-9 [ ]3	4-6 [ ]3
7-9 [ ]4	10-12 [ ]4	7-9 [ ]4
10-12 [ ]5	>12 [ ]5	10-12 [ ]5
>12 [ ]6		>12 [ ]6

16. What are the various sources of your household income?

Agriculture [ ]1
Petty trading activity (specify) [ ]2 …………………………………
Brewing of local drink (specify)[ ]3 …………………………………
Gov't employment (specify) [ ]4
Remittances [ ]5
Hunting [ ]6
Night/day security activities [ ]7
Pottery making [ ]8
Soap making [ ]9
Other (specify) [ ]10 …………………………………

17. In which activities do you use energy?

Domestic chores [ ]1
Agriculture [ ]2
Industry [ ]3
Hunting [ ]4
Others (specify) [ ]5 ……………………………………………

18. What was your annual household income for each of the past five years? Fill in as applicable.

Sources of income	*Years and Respective amount in cedi (¢)*				
	2000	2001	2002	2003	*2004*
Agriculture					
Trading					
Casual labour					
Hunting					
Total					

19. Please, rank these according to your priorities whenever you earn something from your agricultural activities. Use the scale of 1 to 11, where 1, is the lowest on your preference list and 11 the most preferred. Tick (√) the appropriate box on each row.

Priorities/Needs	Scale 1 to 11										
	1	2	3	4	5	6	7	8	9	10	11
Buy a tractor											
Build a House											
Acquire energy											
Saving											
Bicycle											
Send children to school											
Buy grinding mill											
Cattle											
Open a shop											
Expand farmland											

Section D: Cultural practices of rural households

20. What type of energy do you use during the day?

Biomass for cooking [ ]1
Car batteries for entertainment [ ]2
Dry cell batteries for entertainment [ ]3
Other energy (specify) [ ]4 ………………………………

21. Where does the household do its cooking during the day in the house?

In the Courtyard [ ]1
On the veranda [ ]2
In a kitchen [ ]3
In the backyard [ ]4

22. Where does the household do its cooking in the evening in the house?

In the courtyard [ ]1
On the veranda [ ]2
In the kitchen [ ]3
In the backyard [ ]4

23. What social activities do the adults in your household do in the evening?

1…………………………………………
2…………………………………………

24. What activities do the children do in the evening?

1…………………………………………

2………………………………………

25. Do the evening social activities (of both adults and children) involve the use of any form of energy?

Yes [ ]1 go to Question 35

No [ ]2 continue from Question 36

26. If yes, list the activities and the corresponding forms of energy.

SOCIAL ACTIVITIES	**FORMS OF ENERGY**
1……………………………………	1…………………………….....
2……………………………………	2………………………………

27. What time does your household usually go to bed?

Between 7pm to 8pm [ ]1

Between 8pm to 9pm [ ]2

Between 9pm to 10pm [ ]3

Between 10pm to 11pm [ ]4

Between 11pm to 12 midnight [ ]5

Between 12 midnight to 1am [ ]6

28. What are your reasons for going to bed at the time above?

1………………………………………………………………………………

2………………………………………………………………………………

Section E: Technology/technical knowledge and meanings, which rural communities attribute to PV technology

29. What electrical gadgets are used in your household? (Tick as many as apply)

Television [ ]1

Wireless (Radio) [ ]2

Tape recorder [ ]3

Mobile phone [ ]4

No electrical gadget [ ]5

Other (specify) [ ]6………………………………………….

30. What form of energy do you use to power them?

Dry cell batteries [ ]1

Car batteries [ ]2

Motor batteries [ ]3

Other (specify) [ ]4 …………………………………………..

31. Have you ever heard of Photovoltaic/solar energy technology?

Yes [ ]1 move to Q46 and continue

No [ ]2 move to Q16 and continue

32. How did you hear about it? (Tick as many as applied).

On the radio [ ]1

Through a friend [ ]2 Probe how the friend heard of it

Through public demonstration [ ]3

In the market [ ]4

Through the village crier [ ]5

Other sources (Specify) [ ]6 …………………………………….

33. What are its functions?

It generates electricity [ ]1

It generates energy for cooking [ ]2

It can be used to pump water [ ]3

I don’t know its uses [ ]4

34. Do you like it?

Yes [ ]1
No [ ]2

35. What is/are your reason(s) for not using PV technology? (Tick as many as apply).

I am content with the present sources of energy [ ]1
I don’t know it [ ]2
It is complex [ ]3
The capital cost of PV can’t enhance my family finances than PV [ ]4
It is not reliable [ ]5
Not accessible [ ]6
I don’t understand how it operates [ ]7
I want grid electricity and not PV [ ]8

Section F: Policies, institutions, market models and the legal framework on rural electrification, especially PV.

36. Do you know the government institutions tasked with the provision of PV energy technology to the rural areas?

Yes [ ]1
No [ ]2 ⟶ No.53

37. What are they?

……………………………………………………………………………………………..

38. Do you know the government policy towards rural electrification in the country?

Yes [ ]1
No [ ]2 ⟶ No. 55

39. Kindly tell me a bit about this policy.

………………………………………………………………………………………………

40. Please, indicate (√) how you feel about the legal and institutional frameworks on PV technology dissemination in Ghana, on the scales listed below.

Feelings	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
There is adequate public education on technology					
I am happy with the available market models					
Gov’t has greatly promoted PV to the rural areas					
There is a strong legislation, which protects PV consumers against fraud					
The gov’t has implemented its rural electrification programmes					

4) INTERVIEW QUESTIONS FOR KEY ENERGY INSTITUTIONS (EC-GH, MOE-GH, VRA) IN GHANA

1. What are the roles of this institution in the provision of energy to the citizens of Ghana?

2. What are the government energy policy discourses towards the urban and rural areas of Ghana?

3. What forms of energy programmes are promoted within the rural areas of the country?

4. When were these rural electrification programmes initiated/started?

5. What are the outcomes of these rural electrification programmes?

6. What is the rationale behind the strong advocacy for photovoltaic technology for the rural areas?

7. Is the technology (PV) demand-driven or supply-driven?

8. What meanings/perceptions do rural inhabitants associate with photovoltaic energy technology as compared to other technologies?

9. Do these meanings/perceptions they associate with photovoltaic energy technology, influence the way they adopt the technology?

10. What are the available institutional structures in place as far as the development of photovoltaic energy technology is concerned in this country?

11. How adequate are these institutional structures?

12. What regulatory frameworks govern the use and trade of photovoltaic energy technology in Ghana?

13. How adequate are these regulatory frameworks?

14. In which part of the country do we have photovoltaic energy technology installations?

15. What are the market models in existence as far as photovoltaic energy technology can be talked of?

16. How appropriate are these market models for the rural areas?

5) SURVEY QUESTIONS FOR RURAL BUSINESSES IN GHANA

Date of Interview……………………………….. Questionnaire Number…………….
Name of Village………………………………… House Number…………………….
Interviewer's Name……………………………………………………………………….

Section A: Preliminary details of respondent

I would be glad if you could provide some information about yourself, by responding to these questions.

1. Sex of respondent Male [ ] Female [ ]
2. Age of respondent
   - 25-35 years [ ]1
   - 36-45 years [ ]2
   - 46-55 years [ ]3
   - 56-65 years [ ]4
3. What is your marital status?
   - Single [ ]1
   - Married [ ]2
   - Divorced [ ]3
   - Widowed [ ]4
4. What is your educational level?
   - Never been to school [ ]1
   - Primary school [ ]2
   - Middle school [ ]3
   - Secondary school [ ]4
   - Training college [ ]5
   - Advanced/University [ ]6
   - Other (specify) [ ] 7 …………………………………………
5. What leadership position do you hold in this community?
   - None [ ]1
   - Development committee chairman [ ]2
   - Community watchdog member [ ]3
   - Development committee member [ ]4
   - Village chief [ ]5
   - Other (specify) [ ]6 ……………………….
6. What is your tribe?
   - Dagao [ ]1
   - Walla [ ]2
   - Frafra [ ]3
   - Kasena [ ]4
   - Akan [ ]5
   - Dagomba [ ]6
   - Mosi [ ]7
   - Other (specify) [ ]8 ……………………………………
7. What is your religion?
   - Christian [ ]1
   - Islam [ ]2
   - Traditionalist [ ]3
   - Pagan [ ]4

Other (specify) [ ]5 ……………………………………

8. Please, what is the name of this rural business of yours?

…………………………………………………………………………………………

9. When did you start this business?

……………………………………………………………………………………………

10. How do you conduct this business?

……………………………………………………………………………………………

11. Please, can you tell me your annual income from this business?

……………………………………………………………………………………………

12. What type of energy does your business use in its operation process?

……………………………………………………………………………………………

13. Please, can you tell why you are using this type of energy in the operation of your business?

……………………………………………………………………………………………

14. Is there another source of energy, which you wish to use in the operation of this business, but not using it now?

Yes [ ] No [ ]

*If **YES,** answer questions 15 and 16, otherwise move to question 17.*

15. Please, can you tell me the name of this energy source you wish to use?

……………………………………………………………………………………………

16. Please, can you tell me why you wish to use this energy source in the operation of your business?

……………………………………………………………………………………………

(*Only for those rural businesses using PV)*

17. When did you start using solar-photovoltaic in your business?

Year:

18. Are there some changes to your business since you started using solar-photovoltaic?

Yes [ ] → Go to No.19

No [ ]

19. What changes occurred to your business since you started using solar-photovoltaic?

………………………………………………………………………………………

20. Do you encounter problems while using solar-photovoltaic energy?

Yes [ ] → No. 21

No [ ] → No. 22

21. What are the problems you encounter while using solar-photovoltaic energy?

……………………………………………………………………………………

22. Are your energy needs being met in the current rural electrification programme?

Yes [ ]

No [ ] → No. 23

23. Why are your energy needs not being met?

…………………………………………………………………………………………

24. How effective is the dissemination process of solar-photovoltaic energy technology in this part of the country?

…………………………………………………………………………………………

End of interview for rural businesses using solar-PV

(For rural businesses that are not using solar-photovoltaic)

25. Have you heard of photovoltaic energy technology?

YES [ ] NO [ ]

26. Do you know how it functions?

YES [ ] NO [ ]

27. Why don't you use photovoltaic energy technology in the operation of your business instead of the current energy source you are using?

…………………………………………………………………………………………

28. How effective is the dissemination process of photovoltaic energy technology to this part of the country?

…………………………………………………………………………………………

29. Are your energy needs being met in the country rural electrification programme of the country?
Yes [ ]
No [ ] → No 30.
30. Why are your energy needs not being met?

…………………………………………………………………………………………

6) SURVEY QUESTIONS FOR ENVIRONMENTAL ORGANISATIONS IN GHANA

1. Which modern energy issues does your organisation research into or support?

…………………………………………………………………………………………

2. What is the rationale behind the strong advocacy for photovoltaic technology for the rural areas in Ghana?

…………………………………………………………………………………………

3. Will photovoltaic energy technology solve the energy needs of the rural people in Ghana?

…………………………………………………………………………………………

4. What perception do the rural inhabitants harbour as far as photovoltaic energy technology is concerned?

…………………………………………………………………………………………

5. How adequate are the government institutional structures in the provision of this energy type to the rural areas?

…………………………………………………………………………………………

6. What is your assessment of the government rural electrification programme, in terms of its adequacy?

…………………………………………………………………………………………

7. What is your assessment of the regulatory frameworks of the use and trade of the photovoltaic energy technology in Ghana?

…………………………………………………………………………………………

8. What are the market models in Ghana as far as photovoltaic energy technology is concerned?

…………………………………………………………………………………………

9. How adequate are these models in facilitating the dissemination of this technology?

…………………………………………………………………………………………

7) SURVEY QUESTIONS FOR RURAL CLINICS/HOSPITALS, CHURCHES, AND SCHOOLS IN GHANA

SECTION A: RURAL CLINICS/HOSPITALS, CHURCHES AND SCHOOLS WITH PV

1. When was this photovoltaic energy technology facility installed?

…………………………………………………………………………………………

2. Who sponsored the installation of this facility?

…………………………………………………………………………………………

3. What benefits do you get from this photovoltaic energy technology facility?

…………………………………………………………………………………………

4. Why was this energy technology installed and not diesel generator or other forms of energy technology?

…………………………………………………………………………………………

5. Do you have the technical expertise to service the photovoltaic energy technology facility when there is a problem?

YES [ ] NO [ ]

6. If yes, how did you or the person get the training?

…………………………………………………………………………………………

7. If no, then who does the servicing when the photovoltaic energy technology facility breaks down?

…………………………………………………………………………………………

8. What measures has your institution adopted to ensure the sustainability of this photovoltaic energy technology facility?

…………………………………………………………………………………………

9. Have you installed photovoltaic energy systems in your various homes?

YES [ ] NO [ ]

10. If yes, what inspired you to install them?

…………………………………………………………………………………………

11. If no, can you give reasons behind the non-installation?

…………………………………………………………………………………………

SECTION B: RURAL CLINICS/HOSPITALS AND SCHOOLS WITHOUT PV

12. What type of energy source do you use in your institution?

…………………………………………………………………………………………

13. Why do you use this particular energy source in your institution?

…………………………………………………………………………………………

14. Is this particular energy source able to meet all the energy requirement of the institution?

…………………………………………………………………………………………

15. Are you aware of the existence of other sources of energy, especially photovoltaic energy technology and diesel generators?

YES [ ]   NO [ ]

16. In your opinion, which of these energy technologies (photovoltaic energy technology and diesel generators) do you prefer for your institution?

…………………………………………………………………………………………

17. Why do you prefer this energy technology to the other one?

…………………………………………………………………………………………

18. Why is photovoltaic energy technology facility not being installed in your institution?

…………………………………………………………………………………………

19. Does any staff member of this institution use photovoltaic energy technology in his/her home?

YES [ ]   NO [ ]

If YES, move to question 19, and if NO, move to question 20.

20. Kindly tell me why he/she uses photovoltaic energy technology facility in the house and not diesel generator?

…………………………………………………………………………………………

21. Kindly tell me why nobody uses photovoltaic energy technology facility in the house?

…………………………………………………………………………………………

22. Does any staff member of this institution use diesel generator in his/her house?

YES [ ]   NO [ ]

If YES, answer question 22, and if NO, answer question 23.

23. Kindly tell me why he/she uses diesel generator and not photovoltaic energy technology in the house?

…………………………………………………………………………………………

24. Kindly tell me why nobody uses diesel generator in the house?

…………………………………………………………………………………………

8) SURVEY QUESTIONS FOR PHOTOVOLTAIC COMPANIES IN GHANA

1. What is the name of your business/company?

2. When was it established?

3. What are the types of energy systems your company supply?

4. Which places has your company supplied photovoltaic energy technology systems to?
5. To the best of your knowledge, how many companies are engaged in the photovoltaic energy technology business in this region (or in the country)?

6. Why are there few photovoltaic energy technology business dealers in the region/country?

7. Do you think photovoltaic energy technology is demand-driven or supply-driven in the country?

8. Who are the advocates of the technology (i.e. photovoltaic energy technology)?

9. Who are those buying photovoltaic energy technology in the rural areas as far as the different social groups (i.e. rich, poor, youth, elderly, associations) are concerned?

10. Can you explain why there is this demand pattern in the rural areas (as mentioned in question 9)?

11. What sort of the energy needs of the rural people does photovoltaic energy technology serve?

12. What are the various means and modes you use to disseminate information about photovoltaic energy technology to the rural areas of Ghana?

13. What is your assessment on the public education on photovoltaic technology uses in the country? How far has it gone?

14. Please, kindly describe the work structure of photovoltaic energy technology companies in rural areas of Ghana – sale, installation, and after sale service.

15. What market models do you use to commercialise the photovoltaic energy technology in the rural areas?

16. Why these market models and not any other models?

17. Please, can you describe how photovoltaic energy technology operates?

18. Which institutions control the operations of photovoltaic energy companies in the country?

19. How effective are these institutional structures that control photovoltaic energy technology in the country?

20. What are the regulations that bind companies, which are into the photovoltaic energy business?

21. How effective are these regulatory frameworks, which govern the dealership/market of photovoltaic energy technology in Ghana?

22. What are some of the problems you encounter in this photovoltaic energy technology business?

23. In your view, what needs to be done to enhance the commercial market of PV as well as its adoption and utilisation in Ghana?

APPENDIX 2

QUESTIONNAIRE USED IN KENYA FIELDWORK

1) INTERVIEW QUESTIONS FOR SOLAR PHOTOVOLTAIC COMPANIES

1. What sort of alternative energy does your Company supply?

2. Which areas has the company supplied alternative energy to?

3. How many companies are engaged in the PV business in Kenya?

4. Is the technology demand-driven or supply-driven and why?

5. Who are the advocates of the technology?

6. According to the literature, there are about 200,000 institutional and household adoption of this technology even in the midst lack of subsidy and poor income. True or false?

7. What percentage of this figure constitutes the rural inhabitants?

8. Who are those buying the technology?

9. What sort of the energy needs of the rural people does PV serve?

10. Does the use of PV in the rural areas help in the reduction of the use of fuel wood?

11. What is your reaction concerning western world or some African governments pronouncement that PV is the solution to rural energy needs?

12. Where do you think the solution lies?

13. Are prices of the modules and BOS reducing or increasing and what accounts for such a scenario?

14. What lessons should other countries learn from Kenya in the PV industry?

15. What incentives has the government established as far as PV is concerned?

16. In a bigger picture, is it therefore true that PV is the beacon for developing countries energy needs?

17. What are some of the marketing strategies being adopted in Kenya?

18. What are some of the problems in the PV market?

2) INTERVIEW QUESTIONS FOR SCHOOLS

1. When was the PV system installed in this school and by which organisation?

2. What are the benefits of the PV system being installed in the School?

3. Do you use the system in the evening and in what way?

4. How many households in your community are using PV systems apart from the School?

5. Are there any factors/issues which you think obstruct people from adopting the PV system?

6. When you talk of the local houses, how are they like and not being suitable for the installation of PV systems?

7. Are there any more social cultural factors affecting the adoption of PV system?

8. In your opinion, what is the most essential energy need of such a rural area?

9. What is the main concern of these rural people when it comes to energy?

10. What type of energy are you (teachers) using in your houses?

11. What is your opinion about the statement that 'PV has spread very wide in Kenya'?

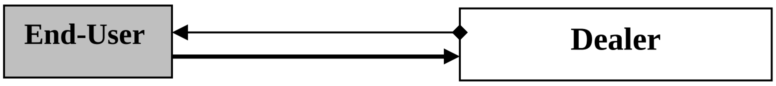
12. Right now, who is benefiting more from PV?

13. Has your area political leader been educating inhabitants about the goodness of PV to the other rural dwellers?

APPENDIX 3

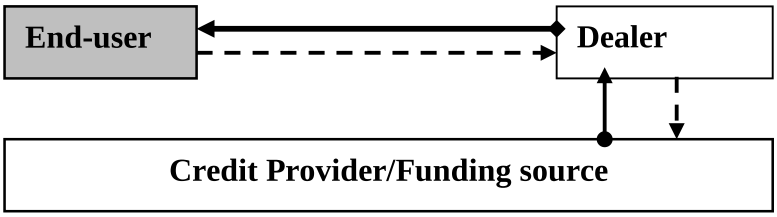
DIAGRAMMATIC REPRESENTATION OF SOLAR PV FINANCING MODELS

1) Transfer of cash and ownership for Cash Sales model



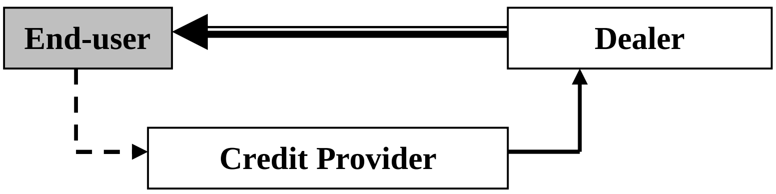
	Transfer of PV system
	Transfer of cash (single tranche)
	Ultimate owner of the PV system

2) Transfer of cash and ownership for Dealer Credit model



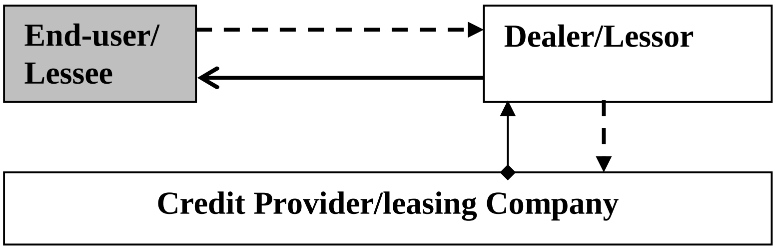
	Transfer of PV system
	Transfer of cash (instalments)
	Transfer of cash (single tranche)
	Ultimate owner of the PV system

3) Transfer of cash and ownership for End-user Credit model



	Transfer of PV system
	Transfer of cash (single tranche)
	Transfer of cash (instalments)
	Ultimate owner of the PV system

4) Transfer of cash and Ownership for Lease/Hire Purchase model



	Transfer and ownership of PV system at the end of the hire-purchase tem
	Transfer of cash (single tranche)
	Transfer of cash (instalments)
	Ultimate owner of the PV system

Sources: IEA PVPS Task 9, Report IEA PVPS T9-02:2003

APPENDIX 4

EXAMPLES OF SOLAR PV HOME SYSTEMS' PRICE PACKAGES IN GHANA

Solar Home Lighting Systems

Solar Home Systems are a cost effective and reliable way to provide power for lighting and small home appliances. They ensure that you get power nearly 100% of the time, better than any current alternative. These systems are also modular and can be expanded with your operations or extended to nearby premises at anytime.

Small Home Lighting System

Appliances	Rating	Quantity	Hrs/Day	Days/Wk
Outside Lights	20watt	1	12hrs	7 days
Small TV Set	40watt	1	3hrs	7 days
Interior Lights	15watt	4	5hrs	7 days

Small Home System Features

- ? 2 Solar Panels
- ? 2 Deep Cycle Batteries
- ? 1 LVD Charge Controller
- ? 1 Inverter
- ? Mountings, switches, cabling and installation

PRICE: $ 2,500

Standard Home Backup System (3 Bedroom House)

Appliances	Rating	Quantity	Hrs/Day	Days/Wk
Outside Lights	20watt	2	12hrs	1 day
Interior Lights	15	8	5hrs	1 day
Stereo	50	1	6hrs	1 day
TV Set	80	1	6hrs	1 day

Standard Home System Features

- ? 2 Solar Panels
- ? 4 Deep Cycle Batteries
- ? 1 LVD Charge Controller
- ? 1 Inverter
- ? Mountings, switches, cabling and installation

PRICE: $4,200

Deluxe Backup System (4/5 Bedroom House)

Appliances	Rating	Quantity	Hrs/Day	Days/Wk
Outside Lights	20watt	4	12hrs	1 day
Utility Lights	15	4	6hrs	1 day
Interior Lights	15	15	5hrs	1 day
Stereo	50	1	6hrs	1 day
TV Set	80	2	6hrs	1 day
Fridge	200	1	6hrs	1 day
Freezer	200	1	6hrs	1 day

Deluxe Backup System Features

- ? 2 Solar Panels
- ? 8 Deep Cycle Batteries
- ? 1 LVD Charge Controller
- ? 1 Inverter
- ? Mountings, switches, cabling and installation

PRICE: $5,800

Superior Hybrid System (4/5 Bedroom House)

Appliances	Rating	Quantity	Hrs/Day	Days/Wk
Outside Lights	20watt	2	12hrs	7 days
Interior Lights	15	10	5hrs	7 days
Stereo	50	1	6hrs	1 day
TV Set	80	1	6hrs	1 day
Fridge	200	1	6hrs	1 day

Superior Hybrid System Feathures

- ? 2 Solar Pan els
- ? 12 Deep Cycle Batteries
- ? 1 Inverter with LVD Charge Controller
- ? Mountings, switches, cabling and installation

PRICE: $8,100

Notes:

- ? All prices are indicative only, and are for complete and installed systems.
- ? Additional panels may be needed if the system is used for more days than those indicated.
- ? Additional batteries are needed if more appliances are to be used. A larger inverter may also be required.

SOLAR LIGHT Co.

Solar Light Company Ltd.
60 Faanofa Rd., Kokomlemle, Accra
P. O. Box 11241 Accra-North, Ghana
Phone (233-21) 234349, Fax 245675
E-mail: solar@africaonline.com.gh
Website: www.solar-light.com

APPENDIX 5

SOLAR PV COMPANIES AND THEIR LOCATIONS IN GHANA

NAME OF COMPANY	***LOCATION***
B.E.S.T SOLAR Co.	Tamale
Danafco Engineering (DENG)	Accra
Gold River Solar Electric	Accra
Solar Light Co.	Accra
Solar Power Co.	Kumasi
Solarco Ltd.	Accra
S.U.N Solar Ltd.	Accra

Sources: Tse, 1999; Fieldwork, 2005

APPENDIX SIX

LIST OF ANONYMISED KEY INFORMANTS AND INTERVIEWEES

ORGANISATIONS	**ANONYMS OF INTERVIEWEES**
Renewable Energy Services Company (RESPRO), Ghana	Solar PV technicians **'B'** and **'C'**
Energy Commission, Ghana (EC-GH)	Senior civil servants **'A', 'C'** and **'D'**
Wechiau Solar Project, Ghana	Solar PV technician **'A'**
Ministry of Energy, Ghana (MOE-GH)	Senior civil servant **'B'**
African Energy Policy Research Network and Foundation for Woodstove Dissemination (AFREPREN/FWD), Kenya	Energy think-tank **'A'**
Baba Energy Systems Technology (B.E.S.T) Solar Company, Ghana	Spokesperson **'A'**
Solar Utilisation Network (S.U.N) Ltd, Ghana	Spokesperson **'B'** and technician **'D'**
Solar Light Company, Ghana	Spokesperson **'C'**
Solarnet Ltd, Kenya	Solar PV technician **'E'**