Foreword

The International Energy Agency (IEA), founded in November 1974, is an autonomous body within the framework of the Organisation for Economic Co-operation and Development (OECD) which carries out a comprehensive programme of energy co-operation among its 24 member countries. The European Commission also participates in the work of the Agency.

The IEA Photovoltaic Power Systems (PVPS) Programme is one of the collaborative R&D agreements established within the IEA and, since 1993, its Participants have been conducting a variety of joint projects in the applications of photovoltaic conversion of solar energy into electricity.

The overall programme is headed by an Executive Committee composed of one representative from each participating country, while the management of individual research projects (Tasks) is the responsibility of Operating Agents. Currently seven tasks have been established. The twenty-one members of the PVPS Programme are:

Australia (AUS), Austria (AUT), Canada (CAN), Denmark (DNK), European Commission, Finland (FIN), France (FRA), Germany (DEU), Israel (ISR), Italy (ITA), Japan (JPN), Korea (KOR), Mexico (MEX), Netherlands (NLD), Norway (NOR), Portugal (PRT), Spain (ESP), Sweden (SWE), Switzerland (CHE), United Kingdom (GBR), United States (USA).

This International Technical Report has been prepared under the supervision of PVPS Task III by:

Jonathan Bates and Alison Wilshaw
IT Power Ltd, United Kingdom (GBR)

in co-operation with experts of the following countries: Australia, Canada, Finland, France, Germany, Italy, Japan, Korea, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland.

The report expresses, as nearly as possible, a consensus of opinion of the Task III experts on the subjects dealt with.

SHORT ABSTRACT AND KEYWORDS

The International Energy Agency (IEA) is an autonomous body within the Organisation for Economic Co-operation and Development (OECD) formed to encourage co-operative ventures among the 24 member nations. The Agency's efforts include efforts into the research, development and demonstration of new energy technologies.

The Implementing Agreement on Photovoltaic Power Systems was initiated to assist in the development of the world photovoltaic market. The agreement is divided into seven tasks, of which Task III deals with Photovoltaic Power Systems in Stand-alone and Island Applications. Within this Task, applications in developing countries are considered of special interest.

In an effort to accelerate the implementation of stand-alone and island photovoltaic power systems in developing countries, it was realised that a number of steps needed to be taken. Firstly, an understanding of the state of the PV industry in developing countries needed to be formulated. Secondly, the barriers to the increased use of PV power systems needed to be identified. Thirdly, methods of addressing the identified barriers needed to be determined.

To develop an industry baseline, the Task III Experts each completed a survey on a selected developing country. The information provided was collated with data drawn from other sources and a report produced, comparing social and geographic, economic and political, and industrial parameters.

By comparing the successes that different policies and project approaches have engendered, as well as drawing information from other sources, the market barriers preventing the wide-spread implementation of photovoltaic power systems were identified.

Keywords: developing countries, stand-alone PV, survey, renewable energy programmes, rural electrification.

ACKNOWLEDGEMENT

The authors of the report would like to thank the experts from Australia, Canada, Finland, France, Germany, Japan, the Netherlands, Sweden and Switzerland. The authors would also like to thank GTZ for providing additional information on the country reports for Morocco, Namibia, the Philippines, Senegal and Uganda.

This document is an output from contracts awarded by the UK Department for International Development (DFID) for the benefit of developing countries and represents part of UK contribution to the IEA PVPS Programme. The views expressed are not necessarily those of DfID.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Executive Summary

This report is a summary of photovoltaic programmes and applications in selected developing countries as of the end of 1996. The information in the report is based partly on questionnaires completed by the various national experts appointed to Task III and partly on research by the report authors.

The report aims to provide a basic understanding of the state of the photovoltaic market in developing regions of the world at the end of 1996, and to highlight the perceived market barriers to the accelerated implementation of photovoltaic power systems. The countries surveyed are: Brazil, The Cook Islands, The Dominican Republic, Ethiopia, French Polynesia, Ghana, India, Indonesia, Kenya, Malaysia, Mongolia, Morocco, Namibia, The Philippines, Senegal, South Africa, Tanzania, Thailand, Tuvalu, Uganda and Vietnam.

Economic and political aspects

The report details the key demographic and geographic data for reach of the countries in the survey. These data varied very widely between the countries surveyed indicating the wide disparity of conditions in the various countries: land areas ranged from that of Brazil, encompassing 8 460 000 km^2 to Tuvalu, occupying 26 km^2. Population densities ranged from less than 2 people per square kilometre in Mongolia to 380 people per square kilometre in Tuvalu. Literacy rates ranged from an estimated 100 % in French Polynesia to 24 % in Ethiopia. Urban populations ranged from an estimated 79 % in Brazil to 12 % in the Cook Islands.

Key economic data were also presented in the report as these need to be considered when assessing the state of a given market. Poverty levels, as given by the population on an income of less than 1 USD per day, ranged from a high of 69.3 % in Uganda to less than 2 % in Morocco and Thailand. Consumer price indices ranged from over 640 % in Brazil (this figure has reduced significantly since 1996) to 1.5 % in French Polynesia. GDP per capita in the surveyed countries ranged from 103 USD in Ethiopia to 7 554 USD in French Polynesia.

Electrification status

Data on the status of current electricity generating capacity and production was collected and these are summarised in Table 1. From the Table the wide range in electricity generating capacity and generation can be seen., with per capita electricity generation ranging from 4 916 kWh in South Africa (which was a net exporter of electricity) to 22 kWh in Ethiopia.

Table 1: Estimated electrical capacity and generation[1] and population without access to electricity.

Country	Electricity Generation Capacity 1995 (GW)	Electricity Generation 1995 (GWh)	Electricity Generation per capita (kWh/capita)	Unelectrified population (%)[2]
Brazil	63.77	275 000	1 711	12
Cook Islands[3]	0.014	21	420	NA
Dominican Republic	2.28	6 500	813	NA
Ethiopia	0.33	1 300	22	90
French Polynesia	0.075	275	1 250	12
Ghana	1.8	6 200	344	60
India	81.2	415 000	439	68
Indonesia	11.6	61 200	311	70
Kenya	0.73	3 700	137	90
Malaysia	8	45 500	2 167	19
Mongolia	1.25	NA	NA	60
Morocco	2.4	12 000	444	75
Namibia	0.406	994	925	90
Philippines		29 700	413	45
Senegal	0.215	900	100	75
South Africa	46	187 000	4 916	33
Tanzania	0.405	1 800	60	96
Thailand	10	80 100	1 335	27
Tuvalu	0.0026	3	306	NA
Uganda	0.2	610	31	95
Vietnam		14 400	192	80

Of the surveyed countries, Brazil, India and South Africa had operational nuclear reactors, although they were not reliant to any great degree upon nuclear power. Brazil and Uganda both relies upon hydropower for more than 90 % of electricity generation, while Mongolia, Senegal, South Africa, Ghana and Morocco relied on traditional thermal generation for over 90 %. Of the remaining countries, Indonesia, Malaysia, and the Dominican Republic were heavily reliant upon thermal generation while Ethiopia and Kenya were reliant upon hydropower.

1 World Development Indicators 1998, The World Bank.
2 UK Department of International Development unless stated
3 World Factbook 1997 (http://www.odci.goc/cia/publications/factbook/country.html)

Estimations of the population in each country without access to electricity services were obtained and these ranged from as high as 96 % in Namibia to 12 % in each of Brazil and French Polynesia.

PV programme experiences and policy issues

All of the countries included in the survey had had some experience with stand-alone photovoltaic power systems. For many of the countries, this was largely been for social / health / educational applications, often funded by international agencies and installed as demonstration or pilot programmes. However, a number of countries had developed a commercial PV industry independently of large scale aid projects. Particularly important from this perspective were the industries in Kenya, the Dominican Republic and Namibia.

The installed PV power as of the end of 1996 is shown for each of the surveyed countries in Table 2. It is estimated that the total PV power installed in the surveyed countries was in the region of 53 MWp with over half of this installed in India.

Table 2: Estimated installed PV power at the end of 1996 in the surveyed countries.

Country	PV power installed at the end of 1996 (kW_p)	Country	PV power installed at the end of 1996 (kW_p)
Brazil	2 000	Morocco	1 000
Cook Islands	NA	Namibia	800
Dominican Republic	225	Philippines	133
Ethiopia	NA	Senegal	800
French Polynesia	NA	South Africa	5 500
Ghana	350	Tanzania	NA
India	35 000	Thailand	2 500
Indonesia	1 800	Tuvalu	50
Kenya	2 000	Uganda	150
Malaysia	640	Vietnam	100
Mongolia	80	**TOTAL**	53 078

The countries with the highest total peak power installed at the end of 1996 were Brazil, Kenya, India, South Africa and Thailand, which accounted for 47 MWp. The cumulative installed V power per capita ranged from a high of 5.05 Wp in Tuvalu and 0.4 Wp in Namibia to 1.85 mWp in the Philippines and 1.33 mWp in Vietnam. It is interesting to note that the governments of those countries with the highest PV installed per capita were actively supportive of PV and, with the exception of Senegal, had an active private sector PV industry. In Morocco,

Senegal and Tuvalu, large PV programmes funded by bilateral agencies had been implemented and these had been generally successful in ensuring continued government support. In Namibia and Thailand the PV industry had developed mainly through the active support of the national governments and in the absence of large aid programmes.

PV had been used for a variety of applications in the surveyed countries. In India, PV had been used in many applications including water pumping, street lighting systems, solar home systems and solar lanterns as well as large scale (>100 kWp) PV power plants and telecommunications. PV in South Africa had been largely used in solar home systems, water pumping, electrification of schools and clinics as well as in professional applications such as telecommunications. In Thailand, PV had been installed for village battery charging stations, schools and clinics and water pumping applications. In Brazil, the first PV applications were for telecommunication relay stations but since 1992, PV had been used in solar home systems, schools and water pumping. In Kenya, PV had been largely used for solar home systems and solar lanterns, almost entirely in the private sector.

Many countries had plans with regard to the electrification of rural areas. A number of countries had policies and targets for rural electrification that explicitly included reference to the use of PV and/or other renewable energy sources. A summary of existing programmes on rural electrification and PV and the status of import duties and tariffs in the surveyed countries is given in the main report.

Many of the surveyed countries had developed and implemented coherent plans focused on encouraging the growth of the photovoltaic industry. The various programmes were not comparable, as the size of the populations being served were very different and the goals of the programmes quite different. Indonesia was attempting to develop a rural infrastructure for both supplying electrification and supplying credit on a massive scale, while Tuvalu and French Polynesia, with small populations, were attempting to achieve electrification with PV almost entirely as a demonstration project. The Malaysian government, in contrast, was leaving the development of the industry almost entirely to the private sector in the belief that PV should only be implemented on an economically justifiable basis.

In countries with limited governmental interest in promoting PV systems on a wide scale, private sector interest and internationally funded Aid projects can support industrial activity to some degree. Kenya had a thriving private sector photovoltaic industry, although it was supported by Aid projects throughout the region and its success was largely due entirely to the private sector. The Dominican Republic had also developed a successful private sector industry despite confusing government policies and tariffs, although the industry suffered

from some difficulties in the development of customer finance mechanisms. The PV industry in Namibia had also developed independently of large scale aid programmes, although there had been government support for the technology.

Domestic PV industries

Many of the survey countries lacked the industrial base and trained technicians required to produce all of the components of a photovoltaic power system. However, the production of PV modules from cells bought on the international market or manufactured by parent companies overseas took place in a number of countries including South Africa, Thailand and Vietnam. There were three companies in India involved in the manufacture of PV cells, as well as module manufacture. Facilities for module manufacture did exist in Brazil but these were no longer in production.

Most of the countries had the ability to produce some, if not all, of the components for a stand-alone PV system. These typically included charge controllers, batteries, DC lamps, wiring etc. Most of the batteries that were manufactured were automotive batteries rather than the more expensive solar batteries.

Demonstration programmes had encouraged the creation of photovoltaic firms for assembling and installing components in all of the countries surveyed; however, many of these firms were dormant between projects, as the local market volume was too low to sustain employment.

Financing Options

One of the common features among the survey countries was the lack of finance available for the purchase of PV systems, either through cash sales or through affordable credit. This was especially problematic in rural areas, where the population was often reliant upon subsistence agriculture and informal employment. As this demographic group represented the largest market for stand-alone photovoltaic power systems, the problem of finance needs to be addressed in order to develop the potential market.

In general, many of early demonstration projects were not implemented with any intention of recovering costs, and many public sector projects follow this tradition. Electrification of medical clinics and schools was usually performed on a grant basis, and only recently had solar pumping projects begun to attempt cost recovery. Cost recovery was seen as both inducing a sense of ownership on the part of the people paying for the system and providing funds to sustain the project beyond initial installation.

Three main methods of developing the necessary infrastructure were being used in the survey nations: strengthening local lending bodies, expanding state owned enterprises, and encouraging private sector development. The majority of the projects covered by the surveys relied upon funding from Non-Governmental Organisations (NGOs) and bilateral grants.

Attempts to either strengthen traditional lending mechanisms or introduce culturally sympathetic mechanisms among the local population had achieved a level of success. With the assistance of NGOs, revolving credit schemes and local credit co-operatives were both used frequently as a means of distributing available funds to the consumers. The advantages of these schemes included the strengthening of social ties within the community and the minimal administration costs.

The success of PV in both Namibia and Kenya was largely a result of private sector demand in the absence of any large scale donor funded electrification programmes. There were no specific financing schemes in either country for solar home systems, although hire purchase schemes finance as many as 2 000 solar home systems per year in Kenya. It was estimated that as many as 50 000 solar home systems had been sold on a commercial basis in Kenya and 2 000 in Namibia, with a further 2 000 systems sold for installation in schools, clinics, community farms and shops. The hire purchase schemes were generally over 12 or 24 month period and interest levels could be as high as 40 %.

More recently the concept of the Energy Service Company or ESCO, has been pioneered in South Africa. These companies can be a PV manufacturer, a local electricity utilities, who own and maintain the PV system and charge either a flat monthly rate or according to the energy consumed.

1. Introduction

The International Energy Agency (IEA) formed an agreement in 1993 with the intention of accelerating the implementation of photovoltaic systems through improvements in cost effectiveness and the opening of new markets. This agreement, the Photovoltaic Power Systems Programme, was originally divided into 6 Task areas, each dealing with a different aspect of photovoltaic power systems (PVPS):

- Task I: Exchange and dissemination of information on photovoltaic power systems.
- Task II: Operational performance and design of photovoltaic power systems and subsystems.
- Task III: Use of photovoltaic power systems in stand-alone and island applications.
- Task V: Design and grid interconnection of building integrated and other dispersed photovoltaic systems.
- Task VI: Design and operation of modular photovoltaic plants for large scale power generation.
- Task VII: Photovoltaics in the built environment.
- Task VIII: Very large-scale photovoltaic power generation systems in remote areas.
- Task XI: Deployment of photovoltaic technologies: co-operation with developing countries.

1.1 Task III Objectives

Task III is subdivided into three groups, each focusing upon one issue intended to demonstrate the "added value" which international co-operation can bring to the photovoltaic market, specifically with regard to stand-alone and island systems. Group A, under which this report falls, is focused upon the implementation of stand-alone PV programmes. As such, it includes the application of PV in developing countries, and has involved collaborating with institutes in developing countries and international organisations to encourage the widespread use of stand-alone PV systems.

1.2 Survey Objectives

This report is, in part, based on questionnaires completed by Task III IEA PVPS experts from participating countries concerning the state of the photovoltaic industry in a particular country. The surveys were intended to provide a basic understanding of the current state of the photovoltaic market in developing regions of the world, and to highlight the perceived market barriers to the accelerated implementation of photovoltaic power systems. Where the data

provided by the questionnaires was insufficient, further research was undertaken by the authors.

The survey focused upon past renewable energy programmes: how many there have been; how they were perceived by officials and consumers; what the local and national government policy issues have been; and how the programmes have affected the technical, financial and institutional infrastructure of the country. By investigating these issues, it was anticipated that an overview of the ability of each country to implement and support sustainable PV programmes would be derived. This report is the result of this activity.

1.3 Participation and Data

The following countries have been examined: fourteen by Task III participants in the survey and a further seven countries surveyed by IT Power Ltd. The countries are detailed in Table 3.

Table 3: Countries surveyed by Task III experts and IT Power

Countries surveyed by Task III experts.	**ISO Country Code**	**Countries surveyed by IT Power.**	**ISO Country Code**
Brazil	BRA	Dominican Republic	DOM
Cook Islands	COK	Ghana	GHA
Ethiopia	ETH	Kenya	KEN
French Polynesia	PYF	Philippines	PHL
India	IND	South Africa	ZAF
Indonesia	IDN	Uganda	UGA
Malaysia	MYS	Vietnam	VNM
Mongolia	MNG		
Morocco	MAR		
Namibia	NAM		
Senegal	SEN		
Tanzania	TZA		
Thailand	THA		
Tuvalu	TUV		

The selection of countries surveyed was made by the individual Task III experts, with each National expert providing data on a selected country. In order to try and provide a more balanced selection, seven additional countries were surveyed by IT Power. Additional data from the surveyed countries were also provided by the authors. Countries were selected on the basis of the state of the PV market. The report has a bias towards Asia and Africa and, apart from Brazil, has not really addressed Central and South America.

The economic data for this report and the Country Reports have been sourced from the World Bank, World Development Indicators 1998. The data in this publication is mostly for 1996.

The percentage of the population without access to electricity, or unelectrified was difficult to ascertain as it was dependent upon the exact definition of access. In this report the population without access to electricity has been taken to be the percentage of the population without an electricity connection. It is important to distinguish this from the definitions that relate to the percentage of population or country covered by the electricity distribution system.

It was very difficult to obtain data for the population that did not have electricity supply as national statistics do not tend to include this information. As far as possible data supplied by the UK Department for International Development has been used although data was not available for the Cook Islands, Dominican Republic, French Polynesia, Ghana, Mongolia, Morocco, Senegal or Tuvalu from this source.

1.4 Survey Limitations

The survey was based initially on questionnaires distributed to the Task III National Experts. The questionnaire was designed to provide information on the status of the PV market in each country. The information was often based on the individual experts' knowledge of a particular country.

The PV market globally is in a state of unprecedented expansion, with global shipments of PV modules from IEA member countries in the region of 100 MWp in 1998[4]. The situation in many of the countries surveyed is in a continual state of change and this report provides an overview of the status of PV in these countries as of the end of 1996.

[4] IEA PVPS Report 1-06: 1998: *Trends in PV Power Applications in selected IEA countries between 1992 and 1996.*

2. Economic and Political Aspects

The key demographic and geographic data varied very widely between the countries surveyed. Table 4 shows approximate land area, population figures, population densities and population growth rates from the surveyed countries as well as percentage urban population and literacy rates.

The figures indicate the large disparities amongst the surveyed nations: country areas ranged from that of Brazil, encompassing 8 460 000 km^2 to Tuvalu, occupying 26 km^2. Population densities ranged from less than 2 people per square kilometre in Mongolia to 380 people per square kilometre in Tuvalu. Literacy rates ranged from an estimated 100 % in French Polynesia to 24 % in Ethiopia. Urban populations ranged from an estimated 79 % in Brazil to 12 % in the Cook Islands.

Table 4: Population details of surveyed countries[5]

Country	Population ($x10^3$)	Land area (km^2)	Population density (inhabs per km^2)	Population growth rate (1980-96)	Urban population (1996)	Literacy (%)
BRA	161 000	8 460 000	19.0	1.8 %	79 %	83
COK	20[6]	240[6]	83.3	1.08 % (1995)[6]	NA	80[7]
DOM	8 000	48 000	166.7	2.1 %	63 %	83
ETH	58 000	1 100 000	52.7	2.7 %	16 %	24
PYF	233[3]	3 660[6]	64.7	1.89 % (1995)[6]	NA	100[7]
GHA	18 000	228 000	78.9	3.1 %	36 %	60
IND	945 000	3 287 000	287.5	2.0 %	27 %	52
IDN	197 000	1 812 000	108.7	1.8 %	36 %	77
KEN	27 000	569 000	47.5	3.1 %	30 %	69
MYS	21 000	329 000	63.8	2.5 %	54 %	78
MNG	3 000	1 570 000	1.9	2.6 %	61 %	83
MAR	27 000	446 000	60.5	2.1 %	53 %	35
NAM	2 000	823 000	2.4	2.7 %	37 %	38
PHL	72 000	298 000	241.6	2.5 %	55 %	95[6]
SEN	9 000	193 000	46.6	2.7 %	44 %	38
ZAF	38 000	1 220 000	31.1	2.0 %	50 %	76
TZA	30 000	884 000	33.9	3.1 %	25 %	46
THA	60 000	511 000	117.4	1.6 %	20 %	94
TUV	10[6]	26[6]	380.8	1.45 % (1995)[6]	NA	NA
UGA	20 000	200 000	100.0	3.5 %	13 %	48
VNM	75 000	325 000	230.8	2.1 %	19 %	94[6]

Figures regarding population density must however be taken on the understanding that they varied greatly within a country. For instance, the

5 World Development Indicators 1998, The World Bank.
6 World Factbook 1997 (http://www.odci.goc/cia/publications/factbook/country.html)
7 Task III Expert

population of Brazil was clustered mainly along the Atlantic coastal plane, such that the population density in these areas was far higher than the statistics indicate, whereas the interior was very sparsely populated. This has had an influence on the development of these countries in that they have concentrated on providing services to the urban populations rather than meeting the needs of the isolated rural population.

Statistics for French Polynesia, The Cook Islands as well as Tuvalu, were also interesting in that although the population densities were not especially low, the population was scattered on a number of small isolated islands making central electricity generation impractical. The small and dispersed nature of the population makes countries such as these prime candidates when considering renewable energy programmes. Indonesia, the Philippines, and to a lesser extent Malaysia, suffer from the same population dispersion, but have much larger populations.

The traditional Mongolian lifestyle of nomadic animal husbandry, with seasonal migrations determined by the growing seasons, meant that the basic population density figure is unlikely to be statistically significant. This lifestyle also makes it difficult to develop a centralised power distribution system to supply the large rural population.

The higher population growth rates, such as those seen in Ethiopia, Ghana, Kenya, Namibia, Senegal, Tanzania and Uganda, were often linked with poorer countries. With limited economic capacity to provide funding for infrastructure development, these countries - together with Morocco, and South Africa - had large areas of scattered villages engaged in subsistence agriculture.

Thailand and Malaysia, both Pacific Rim nations, have a very definite split between urban and rural populations. Urban areas tend to be westernised and technically advanced, while the rural areas maintain traditional lifestyles. The rapidity with which development has occurred in the urban areas has left much of the rest of the country lagging behind, as resources have been focused upon maintaining growth in industrialised areas.

The economic indicators of Gross Domestic Product (GDP), growth rate and inflation rate are given in Table 5, along with estimates of the population with an income less than 1 USD per day and the consumer price index.

Table 5: Economic indicators of countries surveyed[8]

Country	GDP 1996 (MUSD)	GDP per capita (USD)	GDP growth rate 1990-96	Consumer Price Index 1990-96	Population below 1 USD/day[9]
Brazil	749 000	4 652	2.9 %	643.9 %	23.6 % (95)
Cook Islands	57 (1993)[10,11]	2 850 (1993)[10,11]	8.7 % (1995)[11]	5.8 % (1994)[11]	NA
Dominican Republic	13 200	1 646	4.7 %	10.9 %	19.9 % (89)
Ethiopia	5 990	103	3.9 %	8.9 %	46 % (82)
French Polynesia	1 760 (1993)[10,11]	7 554 (1995)[10,11]	NA	1.5 % (1994)[11]	NA
Ghana	6 340	352	4.4 %	29.8 %	NA
India	356 000	377	5.8 %	9.9 %	52.5 % (92)
Indonesia	226 000	1 146	7.7 %	8.8 %	11.8 % (95)
Kenya	9 220	342	1.9 %	23.5 %	50.2 % (92)
Malaysia	99 213	4 724	8.7 %	4.2 %	5.6 % (89)
Mongolia	972	324	3 %[11]	53 % (1996)[11]	NA
Morocco	36 800	1 364	2.1 %	5.5 %	<2 % (91)
Namibia	3 230	1 615	4.1 %	11.2 %	NA
Philippines	83 800	1 164	2.9 %	9.5 %	28.6 % (91)
Senegal	5 160	573	1.8 %	7.6 %	54.0 % (94)
South Africa	126 000	3 324	1.2 %	10.4 %	23.7 % (93)
Tanzania	5 840	195	3.2 %	26.8 %	10.5 % (93)
Thailand	185 000	3 084	8.3 %	4.8 %	<2 % (92)
Tuvalu	7.8 (1995)[10,11]	788 (1995)[10,11]	NA	2.9 % (1989)[11]	NA
Uganda	6 120	306	7.2 %	16.9 %	69.3 % (90)
Vietnam	23 300	311	8.5 %	6.0 %[7]	NA

As can be seen from the figures in Table 2, the economic development of the surveyed countries, as measured by GDP, varied widely. Due to the wide variations in population, the overall productivity of the countries is less indicative of the relative wealth of the citizens than the value of per capita GDP. However, GDP per capita figures can be misleading, as in many of the countries there is a large disparity between the relative wealth of the poorest sections of society and the richest.

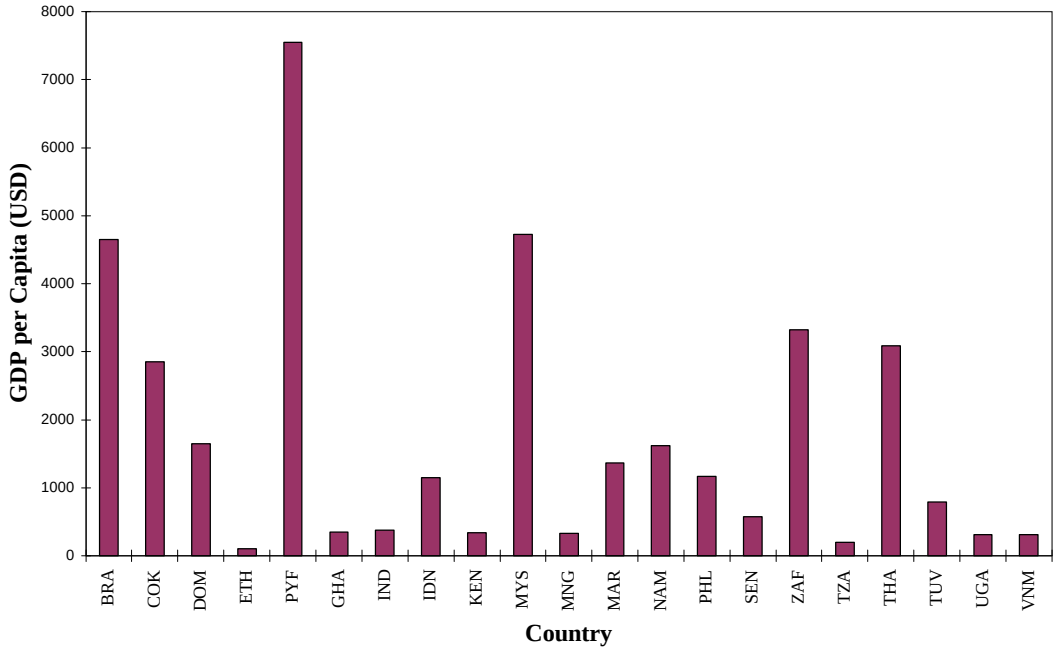
8 World Development Indicators 1998, The World Bank.
9 Year of data in brackets
10 Purchasing power parity
11 World Factbook 1997 (http://www.odci.goc/cia/publications/factbook/country.html)

The population on an income of less than 1 USD per day ranged from a high of 69.3 % in Uganda to less than 2 % in Morocco and Thailand. Consumer price indices ranged from over 640 % in Brazil (this figure has reduced significantly since 1996) to 1.5 % in French Polynesia. The economic indicators for French Polynesia must be interpreted in the light of the fact that in 1996 nearly a third of the nation's GDP was transfer payments from the French government.

It was difficult to obtain data on the economic development of Mongolia, as it was still in transition after a period of centrally planned economic activity under a communist government. As the economy was liberalised and state owned enterprises privatised, statistics were overcome by events.

GDP per capita figures are shown graphically in Figure 1. GDP per capita in the surveyed countries ranged from 103 USD in Ethiopia to 7 554 USD in French Polynesia.

Figure 1: GDP per capita in the surveyed countries.



3. Electrification Status

Table 6 provides the estimated electricity generation capacity, annual electricity generation, per capita generation figures and transmission losses for the survey nations. Again, the per capita estimations must be taken in the light of the fact that there were a wide disparity of living conditions, as highlighted in Section 2 of this report.

Table 6: Estimated electrical capacity, production and transmission losses[12]

Country	Electricity Generation Capacity 1995 (GW)	Electricity Generation 1995 (GWh)	Electricity Generation per capita (kWh/capita)	Transmission & distribution losses 1995 (%)
Brazil	63.77	275 000	1 711	17
Cook Islands[13]	0.014	21	420	NA
Dominican Republic	2.28	6 500	813	25
Ethiopia	0.33	1 300	22	3
French Polynesia[13]	0.075	275	1 250	NA
Ghana	1.8	6 200	344	4
India	81.2	415 000	439	18
Indonesia	11.6	61 200	311	12
Kenya	0.73	3 700	137	16
Malaysia	8	45 500	2 167	10
Mongolia	1.25	NA	NA	NA
Morocco	2.4	12 000	444	4
Namibia	0.406	994	925	NA
Philippines		29 700	413	16
Senegal	0.215	900	100	13
South Africa	46	187 000	4 916	6
Tanzania	0.405	1 800	60	13
Thailand	10	80 100	1 335	8
Tuvalu[13]	0.0026	3	306	NA
Uganda	0.2	610	31	NA
Vietnam		14 400	192	22

South Africa had an excess of generating capacity and exported electricity to its neighbours. The country had instituted an ambitious plan to connect more users

12 World Development Indicators 1998, The World Bank.
13 World Factbook 1997 (http://www.odci.goc/cia/publications/factbook/country.html)

to the national distribution grid. This plan is unlikely to extend out into the rural areas, due to the high costs involved in large scale grid extension and the large population in urban areas without access to electricity, and so should not be seen as competing with stand-alone photovoltaic applications.

Brazil, India and South Africa had operational nuclear reactors, although they were not reliant to any great degree upon nuclear power. The ability to operate and maintain nuclear power stations indicated the ability to produce highly trained technicians and engineers.

Brazil and Uganda both relies upon hydropower for more than 90 % of electricity generation, while Mongolia, Senegal, South Africa, Ghana and Morocco relied on traditional thermal generation for over 90 %. Of the remaining countries, Indonesia, Malaysia, and the Dominican Republic were heavily reliant upon thermal generation while Ethiopia and Kenya were reliant upon hydropower. Details of the breakdown of electricity generation are given in Figure 2[14].

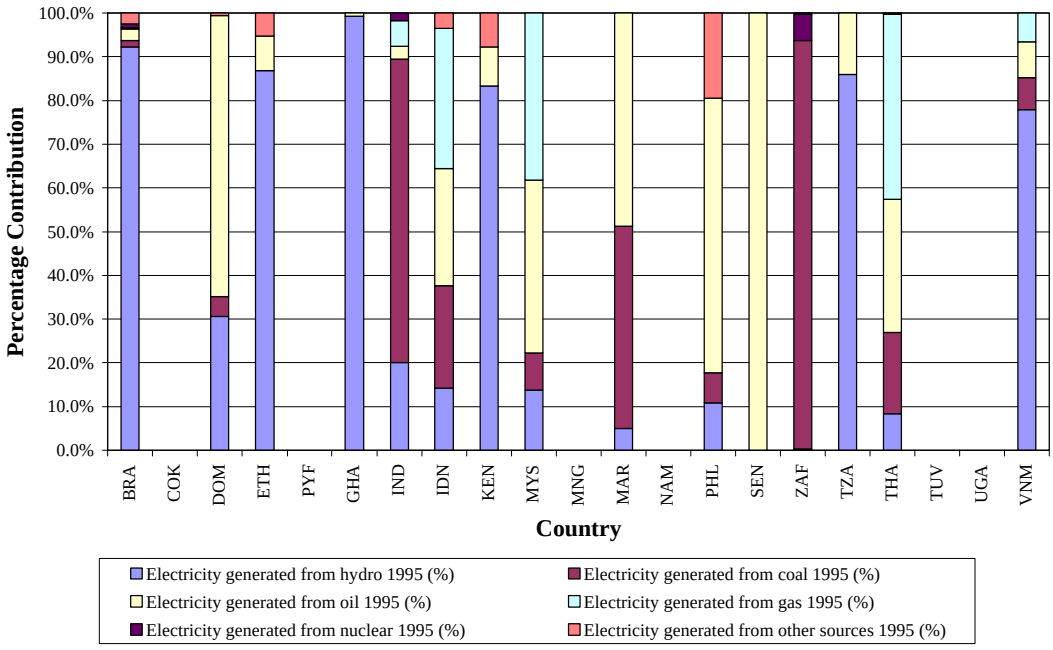


Figure 2: Electricity generation breakdown by source.

Recent difficulties in Malaysia's financial markets have cast doubts on the large scale hydropower scheme, the Bukan dam project, which had been expected to power Malaysia's continued drive toward economic development. It is likely that even with the increased generating capacity provided by the project, the outlying

14 World Development Indicators, World Bank 1998.

islands of Malaysia would still not be electrified, due to the expense involved in extending grid power across large water masses.

A reasonable correlation between per capita electricity production and GDP per capita can be seen from Figure 3. The data point for the high electricity production per capita is for South Africa, which exports electricity to neighbouring countries. The data point for the high GDP per capita is for French Polynesia which receives significant amounts of French bilateral aid.

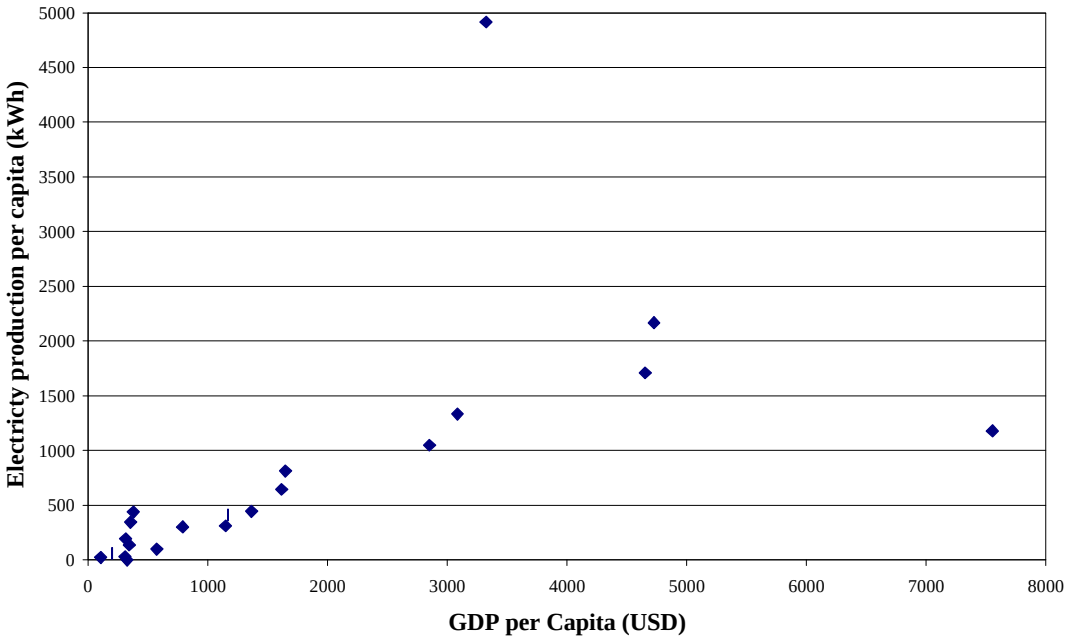


Figure 3: Electricity production per capita versus GDP per capita (1995)

In an effort to develop a better understanding of the circumstances in the rural areas, estimates of the percentage of the population without access to electricity were collated. The figures provided were compared with the estimated labour force and estimated percentage of the labour force engaged in agriculture. Figures are shown in Table 7.

Table 7: Extent of rural electrification compared with rural employment

Country	Labour Force[15] (1996)'000s	Agriculture[15] (%)	Unelectrified (%)[16]
Brazil	72 000	23	12
Cook Islands	6	NA	NA
Dominican Republic	3 000	25	NA
Ethiopia	26 000	86	90
French Polynesia	76	15	12[17]
Ghana	8 000	59	60[17]
India	418 000	64	68
Indonesia	91 000	55	70
Kenya	13 000	80	90
Malaysia	8 000	27	19
Mongolia	1 000	32	60[17]
Morocco	11 000	45	75[17]
Namibia	1 000	49	90
Philippines	30 000	45	45
Senegal	4 000	77	75[17]
South Africa	15 000	14	33
Tanzania	16 000	84	96
Thailand	30 000	40	27
Tuvalu	NA	NA	NA
Uganda	10 000	84	95
Vietnam	38 000	71	80

From Table 7, it can be seen that a large proportion of the workforce in many of the countries was involved in agriculture.

Specific statistics were rarely quoted for the Pacific Islands, however it is known that the primary occupation in Tuvalu and the Cook Islands was fishing, and the economy of French Polynesia was undergoing restructuring since the removal of the French government as a major employer.

The correlation between the population engaged in agriculture and lacking access to electricity appeared to be clear, as can be seen from Figure 4. It can be assumed that the rural population made up the majority of both statistics.

15 World Development Indicators, World Bank, 1998
16 UK Department of International Development unless stated
17 Task III Expert

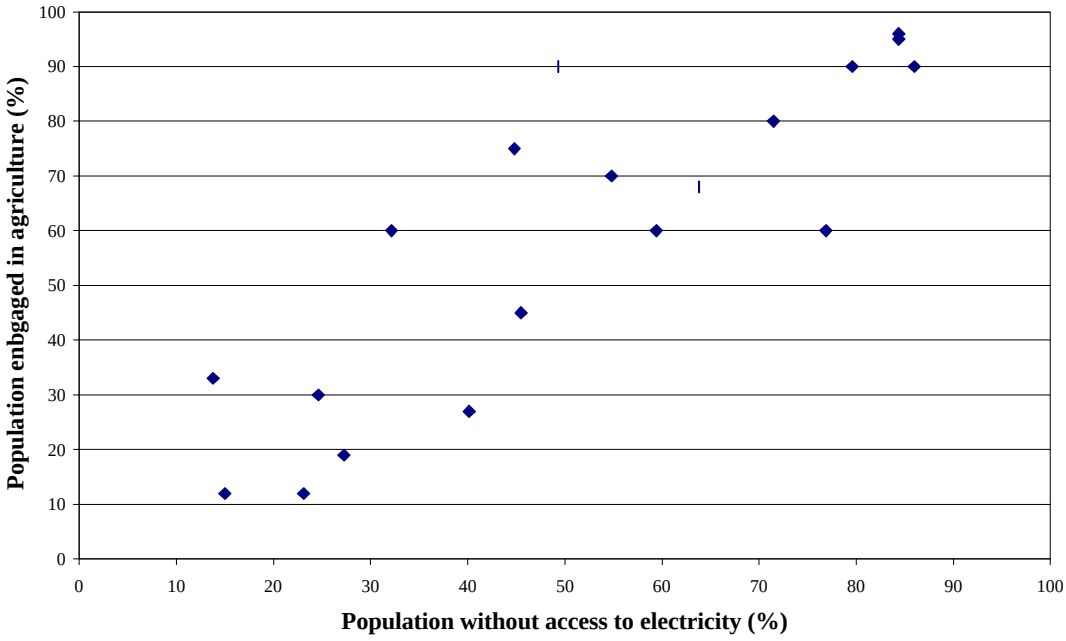


Figure 4: Population without electricity versus population in agriculture

There was also a correlation between the unelectrified population and GDP per capita as can be seen from Figure 5 demonstrating that the poorer countries were more likely to have larger, unelectrified populations working in agriculture.

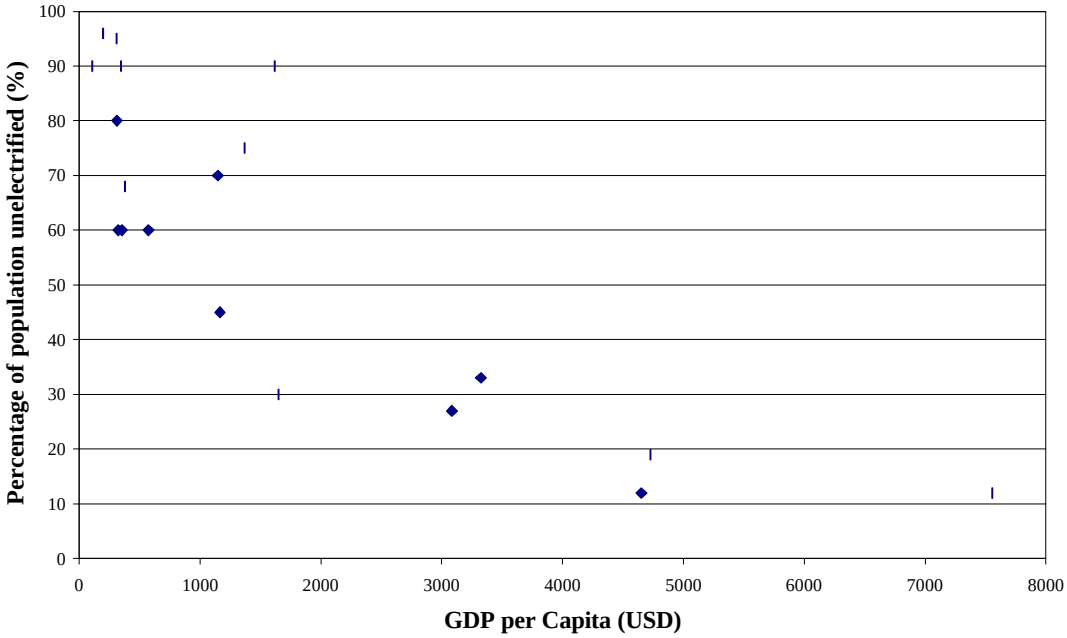


Figure 5: Population without electricity versus GDP per capita.

Furthermore, from Figure 6 a loose correlation between the unelectrified population and the urban population was apparent, providing further evidence that unelectrified populations tended to be those in rural areas.

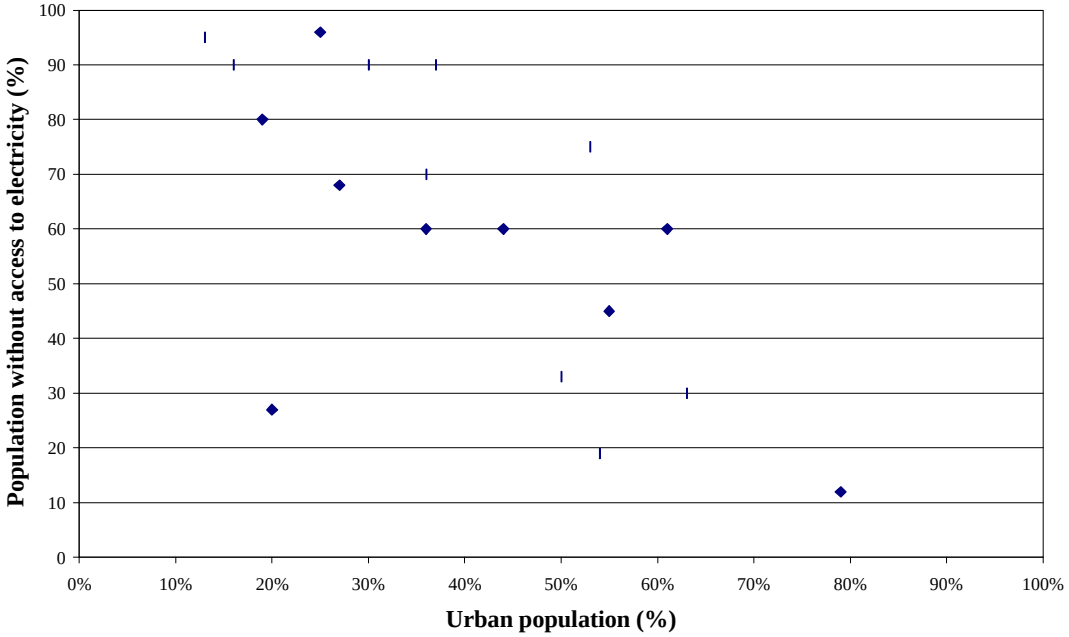


Figure 6: Unelectrified population versus urban population.

4. PV Programme Experiences and Policy Issues

4.1 PV Applications and Installed Power

All of the countries included in the survey had had some experience with stand-alone photovoltaic power systems. For many of the countries, this was largely been for social / health / educational applications, often funded by international agencies and installed as demonstration or pilot programmes. However, a number of countries had developed a commercial PV industry independently of large scale aid projects. Particularly important from this perspective were the industries in Kenya, the Dominican Republic and Namibia.

The installed PV power as of the end of 1996 is shown for each of the surveyed countries in Table 8. It was estimated that the total PV power installed in the surveyed countries is in the region of 53 MWp with over half of this installed in India. Figure 7 shows the installed power per capita. For reasons of scale, the data for Tuvalu has not been included in the Figure as it equates to 5.05 Wp/capita.

Table 8: Estimated installed PV power at the end of 1996 in the surveyed countries.

Country	PV Power installed at the end of 1996 (kW_p)	Country	PV Power installed at the end of 1996 (kW_p)
Brazil	2 000	Morocco	1 000
Cook Islands	NA	Namibia	800
Dominican Republic	225	Philippines	133
Ethiopia	NA	Senegal	800
French Polynesia	NA	South Africa	5 500
Ghana	350	Tanzania	NA
India	35 000	Thailand	2 500
Indonesia	1 800	Tuvalu	50
Kenya	2 000	Uganda	150
Malaysia	640	Vietnam	100
Mongolia	80	**TOTAL**	53 078

The countries with the highest total peak power installed at the end of 1996 were Brazil, Kenya, India, South Africa and Thailand, which accounted for 47 MWp.

In India, PV had been used in many applications including water pumping, street lighting systems, solar home systems and solar lanterns as well as large scale

(>100 kWp) PV power plants and telecommunications. PV in South Africa had been largely used in solar home systems, water pumping, electrification of schools and clinics as well as in professional applications such as telecommunications. In Thailand, PV had been installed for village battery charging stations, schools and clinics and water pumping applications. In Brazil, the first PV applications were for telecommunication relay stations but since 1992, PV had been used in solar home systems, schools and water pumping. In Kenya, PV had been largely used for solar home systems and solar lanterns, almost entirely in the private sector.

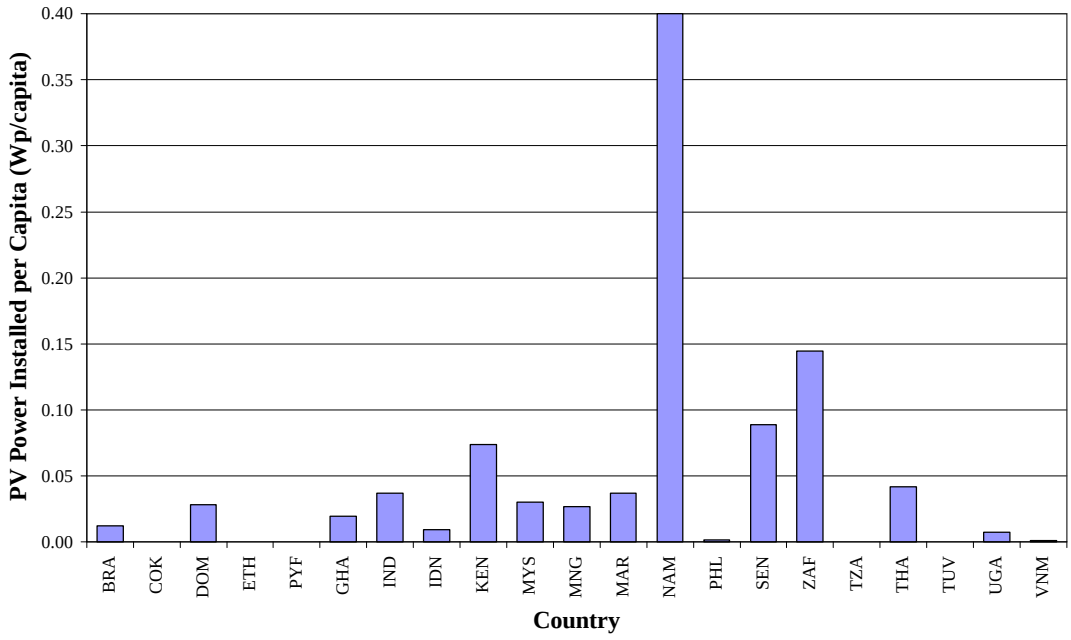


Figure 7: Installed PV power per capita in the surveyed countries

From Figure 7 it can be seen that the countries with the highest per capita figures were Namibia, South Africa, Tuvalu, Kenya, Senegal and Morocco. It is interesting to note that the governments of these countries were actively supportive of PV and, with the exception of Senegal, had an active private sector PV industry. In Morocco, Senegal and Tuvalu, large PV programmes funded by bilateral agencies had been implemented and these had been generally successful in ensuring continued government support. In Namibia and Thailand the PV industry had developed mainly through the active support of the national governments and in the absence of large aid programmes.

Table 9 shows the uses of stand-alone photovoltaic power systems in the survey countries. It must be noted that as information was often difficult to obtain there may be examples of particular applications that are not listed for a particular

country. Every effort was made to ensure the accuracy and completeness of the data although there were inevitably areas where data were lacking.

Table 9: PV applications in the surveyed countries

Country	Domestic	Schools	Clinics	Water	Telecoms	Other
Brazil	✓	✓	✓	✓	✓	agriculture
Cook Islands	✓		✓		✓	
Dominican Republic	✓					agriculture
Ethiopia			✓	✓	✓	PV radios
French Polynesia	✓					Pearl farms, hotels
Ghana	✓				✓	battery charging centres
India	✓	✓	✓	✓	✓	industrial, agriculture, larger scale plants
Indonesia	✓		✓	✓		public lighting, hybrid mini-grids
Kenya	✓		✓	✓		industrial, agricultural
Malaysia	✓	✓	✓	✓	✓	military, large scale plants for village power
Mongolia	✓				✓	
Morocco	✓	✓		✓		battery charging stations, mosques
Namibia	✓	✓	✓	✓	✓	shops, farms, railway stations, navigational buoys, TV relay stations
Philippines	✓	✓	✓	✓		village grid and battery charging stations, hotels, community centre lighting
Senegal	✓		✓	✓		village battery charging stations
South Africa	✓	✓	✓	✓	✓	Navigational buoys
Tanzania	✓		✓	✓	✓	
Thailand	✓	✓	✓	✓		PV-hybrid mini-grids, industrial, village battery, charging stations
Tuvalu	✓				✓	
Uganda	✓		✓	✓	✓	
Vietnam	✓		✓		✓	Navigational aids, height indicators, community centres, village battery charging stations, street lighting

The use of PV water pumping and other agricultural applications use had been piloted widely, as this was seen as a primary market for systems. The private sector purchase of systems for agricultural use was limited by the expense involved. Even as a community co-operative venture, the capital accumulated from subsistence agriculture was generally not enough to provide the down-payments necessary for developing a photovoltaic powered irrigation system.

Other agricultural applications, such as solar-powered electric fences were also being piloted, especially in areas of Brazil where animal husbandry was widely practised.

In the Pacific islands of French Polynesia and the Cook Islands, economic activity based upon photovoltaic electrification included pearl farming and 'eco-hotels', catering to environmentally conscious tourists.

Domestic lighting appeared to be the primary use of photovoltaic systems purchased in the private sector, mainly because these systems were the least expensive. Three different types of system were commonly used: a small (~50 Wp) solar home system providing power for three of four lights and a radio; a solar lantern, providing a small (5 Wp to 10 Wp) module and a single light; or a co-operative venture in which a battery charging station was set up and each member either rented or was given a light and battery, which was returned to the charging house for recharge.

In urban areas, which were relatively affluent but had an unstable power distribution system, such as the Dominican Republic, photovoltaic power systems were used for back up power supplies.

The immediate effects of photovoltaic projects, as with other power supply projects, focussed upon either economic or social benefits. Projects providing power to remote health clinics and schools addressed social problems, which may lead to secondary economic improvements in productivity. Solar pumping projects providing increased irrigation water addressed the necessity of increasing productivity to break the population free from subsistence agriculture.

One of the most important social aspects of stand-alone photovoltaic power systems in areas without access to electricity was the provision of lighting. Private sector purchases focussed upon domestic lighting followed by radios and televisions, all of can provide immediate social benefits as well as secondary economic benefits. These immediate improvements in quality of life and status were often seen as more important than the possible long term increases in productivity available with systems aimed at small enterprises.

Electrification programmes based upon the use of photovoltaic systems have begun to focus upon providing domestic electricity in response to this demand. Solar Home Systems (SHS), designed to meet domestic lighting requirements are becoming the typical stand-alone system.

An alternative to SHS is the installation of a village battery charging stations, renting out batteries and lights. These systems were reported as having been quite successful, both in ease of cost recovery and in satisfaction by the end users.

4.2 Policy Issues

Many countries had plans with regard to the electrification of rural areas. A number of countries had policies and targets for rural electrification that explicitly included reference to the use of PV and/or other renewable energy sources. A summary of existing programmes on rural electrification and PV and the status of import duties and tariffs in the surveyed countries is given in Table 10.

An important policy issue affecting the implementation of photovoltaic power systems was the imposition of import duties and tariffs charged on photovoltaic components. The decision to charge import duties on system components was often based upon a need to collect revenue, as well as to protect any home industries for these products.

Many of the countries had developed and implemented coherent plans focused on encouraging the growth of the photovoltaic industry. The various programmes were not comparable, as the size of the populations being served were very different and the goals of the programmes quite different. Indonesia was attempting to develop a rural infrastructure for both supplying electrification and supplying credit on a massive scale, while Tuvalu and French Polynesia, with small populations, were attempting to achieve electrification with PV almost entirely as a demonstration project. The Malaysian government, in contrast, was leaving the development of the industry almost entirely to the private sector in the belief that PV should only be implemented on an economically justifiable basis.

In countries with limited governmental interest in promoting PV systems on a wide scale, private sector interest and internationally funded Aid projects can support industrial activity to some degree. Kenya had a thriving private sector photovoltaic industry, although it was supported by Aid projects throughout the region and its success was largely due entirely to the private sector. The Dominican Republic had also developed a successful private sector industry despite confusing government policies and tariffs, although the industry suffered from some difficulties in the development of customer finance mechanisms. The PV industry in Namibia had also developed independently of large scale aid programmes, although there had been government support for the technology.

Table 10: Existing policies, initiatives and tariffs for PV components

Country	Policies and Initiatives	Tariffs on PV
Brazil	The Ministry of Energy & Mines had an ongoing project, PRODEEM, to install demonstration PV systems in every state in Brazil.	VAT and import duties - under review.
Cook Islands	Involved in energy discussions with other countries in the area in an effort to capitalise upon any opportunity to increase the electrification of the islands.	No.
Dominican Republic	Negligible policy making in support of solar energy, although PV modules counted as electricity generation equipment and were free of import duties. Left to private sector.	No duties on PV modules, 100 % import duty on batteries.
Ethiopia	Indications were that the government was supportive of solar power systems, but lacked the resources to implement them.	NA.
French Polynesia	Private sector expected to sustain the local PV industry.	NA.
Ghana	Committed to electrify the whole country by the year 2020. This commitment was being realised within the framework of a National Electrification Programme, initiated in 1980. PV was included as part of NEP.	NEP projects attractedno duties; private project attract 15 % VAT.
India	The Government of India was committed to renewable energy development. The Ministry of Non Conventional Energy Sources was responsible for the specific policy, legislation and support programmes for renewable energy, with the aim of achieving a 6 % contribution to power generation from renewable sources by 2002. Numerous programmes were planned and ongoing, including the construction of high capacity power plants to electrify entire regions, small scale domestic lighting / power production, credit provision to encourage market development, and subsidy schemes. In 1998, the GEF/IFC “Photovoltaic Market Transformation Initiative” programme was launched.	Yes.
Indonesia	Government had made rural electrification a priority and the Suharto government gave considerable support to photovoltaic applications. In 1997, the GOI set a target for 50 MWp of PV by 2005 to install 1 million SHSs nationwide. World Bank and GEF funding was secured for 200 000 homes (10 MWp) in West Java, Lampung and South Sulawesi.	Equipment not manufactured locally were exempt from import taxes and duties.

Country	Policies and Initiatives	Tariffs on PV
Kenya	Rural Electrification Master Plan should re-stimulate rural electrification activities. It was anticipated the plan will give specific attention to PV. In 1998, the GEF/IFC "Photovoltaic Market Transformation Initiative" programme was launched.	Yes.
Malaysia	Supportive of PV for rural electrification providing it was economic. Ministry of Rural Development established a rural community initiative encompassing the Sabah, Sarawak and Peninsular Malaysia Provinces in 1996. The 34 MUSD programme will run for 5 years in 2 phases to improve rural village services.	NA.
Mongolia	PV systems are seen by the Mongolian government as providing a possible method of providing electricity for nomadic herders.	NA.
Morocco	Government was committed to electrifying most of the remainder of the country (1.6 million households) by 2010, and had indicated that approximately 5 % of those households should be electrified using off-grid solar and wind technologies. In 1998, the GEF/IFC "Photovoltaic Market Transformation Initiative" programme was launched.	Import duty on modules, 2.5 %, BOS: 25 %; inverters: 17.5 %. VAT levied on all components at 20 %.
Namibia	By 1996, a basic infrastructure for rural electrification in the north and east of the country had been completed. The current focus was on the south of the country. The Ministry of Mines and Energy had given photovoltaic applications high priority for rural electrification.	NA
Philippines	The government aimed to achieve 100 % electrification of all villages by 2010 and connect all potential customers by 2018. BP Solar Australia had been contracted to design, supply and install 1 003 PV systems to provide electricity to 387 villages electrifying over 1 million people in one of the biggest solar projects world-wide.	Equipment not manufactured locally is exempt from import taxes and duties.
Senegal	Government was actively promoting the use of renewable energy resources and equipment for all PV systems was exempt from VAT and import duties.	PV equipment exempt from all import duties and sales taxes.

Country	Policies and Initiatives	Tariffs on PV
South Africa	The National Electrification Forum aimed to increase dwellings connected to the grid from 45 % to 67 % by 2000 and to 79 % by 2012. REFSA established and charged with developing PV SHS programme. Subsidy of 1 500 ZAR per system for approved pilot projects. ESKOM committed to manage the electrification of 16 400 schools that will not be connected to the grid under the RDP. 4 000 health clinics had been targeted for PV electrification.	NA.
Tanzania	Rural electrification did not seem to be a high priority. All PV programmes had been aid programmes.	NA.
Thailand	There was no distinct rural energy plan, but rural energy issues had a high priority under the rural development component of the National Economic and Social Development Plan	Yes.
Tuvalu	After initial scepticism about the use of PV systems, the government was enthusiastic about their use. Three programmes had been initiated, installing over 300 more systems and funded by the E.U. and French bilateral aid	NA.
Uganda	The NRSE (New & Renewable Sources of Energy) within the Department of Energy in the Ministry of Natural Resources activities included facilitating the development of renewable sources of energy and this had ensured government involvement. Funding had been secured for a 1.76 MUSD GEF funded PV for Rural Electrification Project. The project aimed to install 2 000 SHS and solar lanterns in rural communities.	No import duties levied but sales tax of 17 % imposed in 1995.
Vietnam	The Government had already played a major role in establishing PV industry and energy policy. The National Program for New and Renewable Sources of Energy (NRSE) was established by a government initiative to improve living conditions in rural areas. The World Bank and DANIDA had recently provided funding for a Rural Electrification Masterplan to identify regions to be supplied by the grid, and those which would be supplied by a variety of other energy sources, including micro-hydro and PV.	No import duties levied on PV related materials and equipment.

5. Domestic PV Industries

Many of the survey countries lacked the industrial base and trained technicians required to produce all of the components of a photovoltaic power system. However, the production of PV modules from cells bought on the international market or manufactured by parent companies overseas took place in a number of countries including South Africa, Thailand and Vietnam. There were three companies in India involved in the manufacture of PV cells, as well as module manufacture. Facilities for module manufacture did exist in Brazil but these were no longer in production.

Table 11 displays the production capability of PV system components in the countries surveyed.

Most of the countries had the ability to produce some, if not all, of the components for a stand-alone PV system. These typically included charge controllers, batteries, DC lamps, wiring etc. Most of the batteries that were manufactured were automotive batteries rather than the more expensive solar batteries.

Demonstration programmes had encouraged the creation of photovoltaic firms for assembling and installing components in all of the countries surveyed; however, many of these firms were dormant between projects, as the local market volume was too low to sustain employment. Those countries that were known to have private sector firms providing photovoltaic power systems on a continual basis were Brazil, Dominican Republic, French Polynesia, India, Indonesia, Kenya, South Africa, and Thailand.

Table 11: In-country manufacture of components

Country	BOS Components	Module Manufacture	Comments
Brazil	✓	×	Cell & module manufacturer ceased production. Established market for professional systems. At least 2 national commercial distributors of PV systems.
Cook Islands	×	×	All components imported from French Polynesia.
Dominican Republic	✓	×	PV modules imported and a mixture of imported and locally manufactured BOS components used. PV industry reliant solely on private sector.
Ethiopia	×	×	No system components manufactured. University of Addis Ababa involved in PV technology and applications research.
French Polynesia	✓	×	PV industry capable of manufacturing all components except modules.
Ghana	✓	×	Estimated 13 companies working with PV. University of Science and Technology manufacturers BOS components.
India	✓	✓	Several companies involved in manufacture of PV cells and modules (production in 1997/8 estimated at 8.2 MWp) and numerous companies involved in design and installation of systems.
Indonesia	✓	×	Most international PV manufacturers have either subsidiaries or local dealerships. Most BOS components manufactured locally.
Kenya	✓	×	Estimated 50 000 SHS installed on a commercial basis. As many as 15 module distributors and a further 20 companies involved in BOS component manufacture.
Malaysia	✓	×	Most components imported.

Country	BOS Components	Module Manufacture	Comments
Mongolia	✓	×	Institute of Physics and Technology had manufactured cells from imported wafers and assembled modules on a laboratory scale. 1 commercial company involved in PV for telecommunications sector.
Morocco	✓	✓	As many as 30 organisations involved in manufacture, systems design and installation. 6 modules distributors and one local module manufacturer using cells purchased on international market.
Namibia	✓	×	Most BOS components manufactured locally or imported from South Africa. Modules sourced from South Africa or direct from manufacturer.
Philippines	✓	×	Modules and charge controllers imported. Other BOS components manufactured locally. At least 15 suppliers dealing in PV, supplying modules from most international manufacturers.
Senegal	✓	×	Most PV components imported, although automotive batteries manufactured locally.
South Africa	✓	✓	All components manufactured in country. Most major international module manufacturers have dealerships in south Africa.
Tanzania	×	×	Perhaps 9 firms involved in system installation. All components imported and systems are purchased privately.
Thailand	✓	✓	Joint ventures in PV module assembly have been established and module production capacity estimated at 1 MWp.
Tuvalu	×	×	All components imported from French Polynesia.
Uganda	×	×	System components imported and assembled locally. Estimated nine companies involved in PV installation.
Vietnam	✓	✓	Five companies involved in design and installation of PV systems. three dealers of international companies. BOS components also manufactured locally. Two companies involved in small scale PV module manufacture.

6. Financing Options

One of the common features among the survey countries was the lack of finance available for the purchase of PV systems, either through cash sales or through affordable credit. This was especially problematic in rural areas, where the population was often reliant upon subsistence agriculture and informal employment. As this demographic group represented the largest market for stand-alone photovoltaic power systems, the problem of finance needs to be addressed in order to develop the potential market.

In general, many of early demonstration projects were not implemented with any intention of recovering costs, and many public sector projects follow this tradition. Electrification of medical clinics and schools was usually performed on a grant basis, and only recently had solar pumping projects begun to attempt cost recovery. Cost recovery was seen as both inducing a sense of ownership on the part of the people paying for the system and providing funds to sustain the project beyond initial installation.

Cost recovery had become especially important as national budgets in the developed world tighten and aid funding was stretched tighter; by achieving full cost recovery for capital costs as well as operation and maintenance costs, the same initial funds can be reinvested in subsequent installations. An effective cost recovery system requires administrative infrastructure to disburse and collect funds and keep records of transactions.

Three main methods of developing the necessary infrastructure were being used in the survey nations: strengthening local lending bodies, expanding state owned enterprises, and encouraging private sector development. As shown in Table 12,Table 12 the majority of the projects covered by the surveys relied upon funding from Non-Governmental Organisations (NGOs) and bilateral grants.

Attempts to either strengthen traditional lending mechanisms or introduce culturally sympathetic mechanisms among the local population had achieved a level of success. With the assistance of NGOs, revolving credit schemes and local credit co-operatives were both used frequently as a means of distributing available funds to the consumers. The advantages of these schemes included the strengthening of social ties within the community and the minimal administration costs.

Official encouragement of private enterprise to provide credit at the local level for photovoltaic power systems was an option that was promoted in a number of countries. In Indonesia, providing local dealers with access to finance to provide credit to consumers was incorporated as part of the World Bank /GEF programme.

Table 12: Sources of project funding

Country	Local co-operative	Government	Aid Agencies and NGOs	Bank/Private	Utilities
Brazil	✓		✓	✓	✓
Cook Islands			✓		
Dominican Republic	✓		✓	✓	
Ethiopia			✓		
French Polynesia		✓	✓	✓	
Ghana	✓		✓		
India	✓	✓	✓	✓	
Indonesia	✓	✓	✓	✓	
Kenya			✓	✓	
Malaysia				✓	
Mongolia		✓	✓		
Morocco		✓	✓	✓	
Namibia				✓	
Philippines	✓	✓	✓	✓	
Senegal	✓		✓	✓	
South Africa	✓	✓	✓		✓
Tanzania			✓		
Thailand		✓			
Tuvalu	✓		✓		
Uganda			✓	✓	
Vietnam	✓	✓	✓	✓	

Despite the firm commitment of the previous Indonesian government to the use of PV for rural electrification, implementation was still hampered by a lack of financing mechanisms. While the central government believed that the overall economic growth of the country was dependent upon electrification, the immediate ability of the population to pay for system installation was limited. The limited resources of the end-users required appropriate credit arrangements in order to achieve full cost recovery. With a large population to provide for, this time delay in cost recovery resulted in credit funds being prohibitively expensive to set up and offered little return on the investment. For the original pilot scheme, the SHS project averaged a cost recovery of approximately 60 %, and it was not expected that follow on projects would achieve 100 % cost recovery.

The rather slow response in private sector investment in Indonesia is indicative of the problems encountered during attempts to instigate economic development in low income areas. Although the initial solar project in Indonesia was set up

using aid funding with a low down-payment and a 10-year, zero interest financing scheme, procuring photovoltaic systems on a private basis required a large down-payment, 2-3 year financing, and ~18 % interest. Clearly the purchase of photovoltaic systems in the private sector was limited to either those with a large disposable income, or those whose income would be significantly enhanced by the addition of electrification.

The success of photovoltaic systems in Tuvalu can be partially attributed to the small population and the relatively large amount of development aid from which it had benefited. Tuvalu had managed to successfully develop an operating photovoltaic electrification scheme. As in Indonesia, the island nature of the country does not lend itself to centralised power distribution grids. In this scenario, photovoltaic systems can be expected to provide the most cost effective method of providing electricity to a widely dispersed population, and the success of an electrification project rests upon the provision of financing mechanisms which can be afforded by the local population. In Tuvalu, the initial down-payment and monthly payments were kept low by not actually selling the photovoltaic systems to the end-users, who pay a flat rate for the systems depending on the size to the Tuvalu Solar Electric Company. While this increased the possible client base to include those households with very low income, the co-operative itself was only able to cover short term operating costs; it has been unable to purchase new units to increase the electrification of the population, nor to purchase replacements as units fail.

The success of PV in both Namibia and Kenya was largely a result of private sector demand in the absence of any large scale donor funded electrification programmes. There were no specific financing schemes in either country for solar home systems, although hire purchase schemes finance as many as 2 000 solar home systems per year in Kenya. It was estimated that as many as 50 000 solar home systems had been sold on a commercial basis in Kenya and 2 000 in Namibia, with a further 2 000 systems sold for installation in schools, clinics, community farms and shops. The hire purchase schemes were generally over 12 or 24 month period and interest levels could be as high as 40 %.

More recently the concept of the Energy Service Company or ESCO, has been pioneered in South Africa. These companies can be a PV manufacturer, a local electricity utilities, who own and maintain the PV system and charge either a flat monthly rate or according to the energy consumed.

7. Conclusions

In many of the countries surveyed there was a substantial rural population not connected to the electricity distribution network, either because they lived in areas not covered by the distribution system or because they were unable to afford the price of a connection. This problem was often compounded by the fact that electricity utilities in some of the countries discouraged domestic connections in rural areas due to the low levels of electricity consumption associated with these populations.

Many of the surveyed countries had already experience of stand-alone PV systems for remote service applications such as telecommunications, railway signal and switching devices, television relay stations, and coastal navigation devices. This market was largely a commercial market and operated without the need for direct subsidies. Solar Home Systems (SHS), vaccine refrigerators, school electrification, public street lighting, water pumping and desalination plants can all be considered to bring significant social benefits and represent a huge potential market for the PV industry. Many of the countries in this survey had experience with one or more of these applications, although they were often funded through multi-lateral or bilateral aid programmes.

The technical capability of photovoltaics as a means of rural electrification was demonstrated through the successful implementation of programmes in many of the countries. It must be noted that many of the early programmes suffered from technical problems associated with poor system design and inadequate component specification. The importance of ensuring that the institutional capability to ensure that systems were operated properly and adequately maintained has also been highlighted.

Of the countries surveyed, only India had the facilities to manufacture PV cells where three companies were manufacturing PV cells and others were manufacturing modules from cells bought on the international market or supplied by parent companies. The production of PV modules from cells bought on the international market or manufactured by parent companies overseas also took place in South Africa, Thailand and Vietnam. Facilities for module manufacture did exist in Brazil but these were no longer in production. Most of the other countries had the capability to manufacture some or all of the balance of systems components. Many of the international companies had also established dealerships in the many of the countries.

The key barrier to the accelerated implementation of stand-alone photovoltaic power systems is highlighted in each of the surveyed nations as being the high capital cost of PV systems and the lack of available and affordable finance. The people most able to benefit from the appropriate implementation of PV are those

often most unable to be able to afford the high capital costs associated with PV systems, i.e., the rural poor.

The issue of financing of photovoltaic systems was an issue to be resolved in each of the 20 countries surveyed. This was perhaps inevitable due to the low income levels of much of the population in these countries. However, the problems were not insurmountable and some of the countries had approached the problem of finance with some degree of success. Indonesia, India and Tuvalu each had some success at providing finance to end users. The Dominican Republic, Kenya and Namibia had also had considerable success in providing PV systems on a market basis in the absence of any government subsidies.

Attempts were also being made by various NGOs to develop finance mechanisms within the developing countries in the form of revolving funds and local co-operatives. As a large portion of the potential market for PV was engaged in subsistence agriculture and had only a small disposable income, the start-up of the credit schemes capitalised by external funds was often an appropriate solution. It was also important to ensure continual cost recovery in order sustain the project. Consumers, once educated to the advantages of photovoltaic systems and provided with affordable credit schemes, appeared willing to invest in domestic lighting and entertainment systems. It was important that payment levels were kept to a level that are affordable by the end users. Expenditure on alternative forms of lighting, such as kerosene lamps and candles can be diverted to pay off loans for a solar home system. For every 20 hours of operation of a kerosene lamp, 1 litre of kerosene is required.

Other barriers have been identified as a lack of awareness of the potential of PV as a technology for rural electrification; lack of quality control of system installation and design; difficulties in setting up and maintaining distribution networks over large, sparsely populated areas, lack of provision for maintenance and a lack of end user training.