OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

FAIR USE POLICY

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

19415

iii, 57p.
graphs

United Nations Industrial Development Organisation

The Photovoltaic Market in Developing Countries

A Methodology Study

IT Power

Reference 90388
November 1991

Consultant: Mr. Bernard McNelis
Backstopping Officer: Mr. Bromley

United Nations Industrial Development Organisation

The Photovoltaic Market in Developing Countries

A Methodology Study

IT Power Ltd

The Warren, Bramshill Road
Eversley, Hants. RG27 0PR, UK
Telephone (0734) 730073
Telex 846852 POWER G
Fax (0734) 730820

Reference 90388
November 1991

METHODOLOGY FOR SURVEYS OF THE MARKET FOR PHOTOVOLTAICS IN DEVELOPING COUNTRIES

CONTENTS

Preface

This Report has been compiled by I T Power Ltd under contract to the United Nations Industrial Development Organisation (UNIDO). Its prime objective, as defined by the Terms of Reference, is to establish a methodology for the identification of the potential market for photovoltaics in a developing country, and to specify a short-list of 4 to 6 countries in which intensive survey is recommended.

These recommendations are in no way definitive, as this is a very preliminary study, undertaken with a very limited budget provided by UNIDO. IT Power therefore disclaims any responsibility for actions taken as a result of this preliminary Report on the Methodology for Surveys of the market for Photovoltaics in Developing Countries.

1. Objectives and Scope

This Report encompasses the results of work to establish a methodology for identifying the potential of the solar photovoltaics (PV) market in developing countries. As such, its scope is global, and covers Africa, Asia and the Pacific, the Caribbean and Latin America. Clearly no single survey could hope to cover all of these areas equally to any degree of detail or certainty. Therefore several steps are recommended, each becoming increasingly detailed as the more promising countries are identified.

The task falls into three main sections:

Section I: This looks at the world PV market, taking into account historical factors as well as present trends and future predictions. It also looks at the market characteristics for PV in developing countries.

Section II: IT Power have used their comprehensive library and long experience of the PV market to conduct a preliminary analysis of the countries in each region. This serves to identify a number of countries in each region as having a good potential market for PV. These countries are then further reviewed to a short-list of 4 - 6 countries, earmarked for further detailed investigation by visiting teams of experts and researchers.

Section III: This section outlines the methodology proposed for the detailed market surveys that are to be performed in the short-listed countries. To perform an effective survey in the necessary detail requires a great deal of organisation, and a sound understanding of the objectives beforehand. The methodology set out here covers a wide range of factors that must be considered to gain a meaningful picture, including economic and demographic factors, the solar resource, the in-country PV experience, possible applications and competing technologies. To this end the survey must be performed on several levels, with activities ranging from desk survey to field visits. The latter of these is of more concern, bringing the greatest benefits, but also requiring the most planning to make use of limited time.

The resulting methodology aims to provide a comprehensive framework for the assessment of the total potential PV market in any developing country. It is hoped that the use of such a framework will enable UNIDO to form a sound basis for its future decisions concerning the application of photovoltaics in the developing world.

SECTION I: THE WORLD PV MARKET

Introduction

For this Report, IT Power has collected and compiled data on the world market for PV. This is divided into historical developments, present status and future prospects.

1.1 Historical Development

The market for photovoltaics is a diverse and ever increasing market, with annual production doubling in the last five years, as illustrated in Fig. 1.

The technological developments within the PV industry are also developing rapidly, with regular reportings of increased cell and system efficiencies and continuing cost and price reductions, which are shown in Fig. 2.

1.2 Present Status

The 1990 world PV market was approximately 50 MWp - other estimates include Maycock 46 MWp and SIER 48 MW, but these estimates are considered to underestimate production in the USSR and developing countries. The IT Power estimate of module production in 1990 is presented in Fig. 3.

In order to make projections of the future PV market, it is necessary to take into consideration segmentation of the current market.

The segmentation of the market by application is shown in Fig. 4. From this it can be seen that remote area power applications make up the bulk of the present market, with the PV grid connected market currently being small.

The value of the remote area power market is difficult to determine precisely because distribution is done by various systems houses and original equipment manufacturers, very few of whom report their activities. The IT Power estimate for the 1990 remote area power market is presented in Table 1 below.

Application	MWp	%
Telecommunications	9.8	32
Building power	5.7	18
Transportation Sector	4.7	15
Water Supply/Irrigation	3.4	11
Cathodic protection	0.9	3
Area Lighting	0.6	2
Agriculture Sector	0.5	2
Data Acquisition	0.4	1
Other	5.0	16
Total	31.0	100

Table 1. 1990 Remote Area Power Market by Application

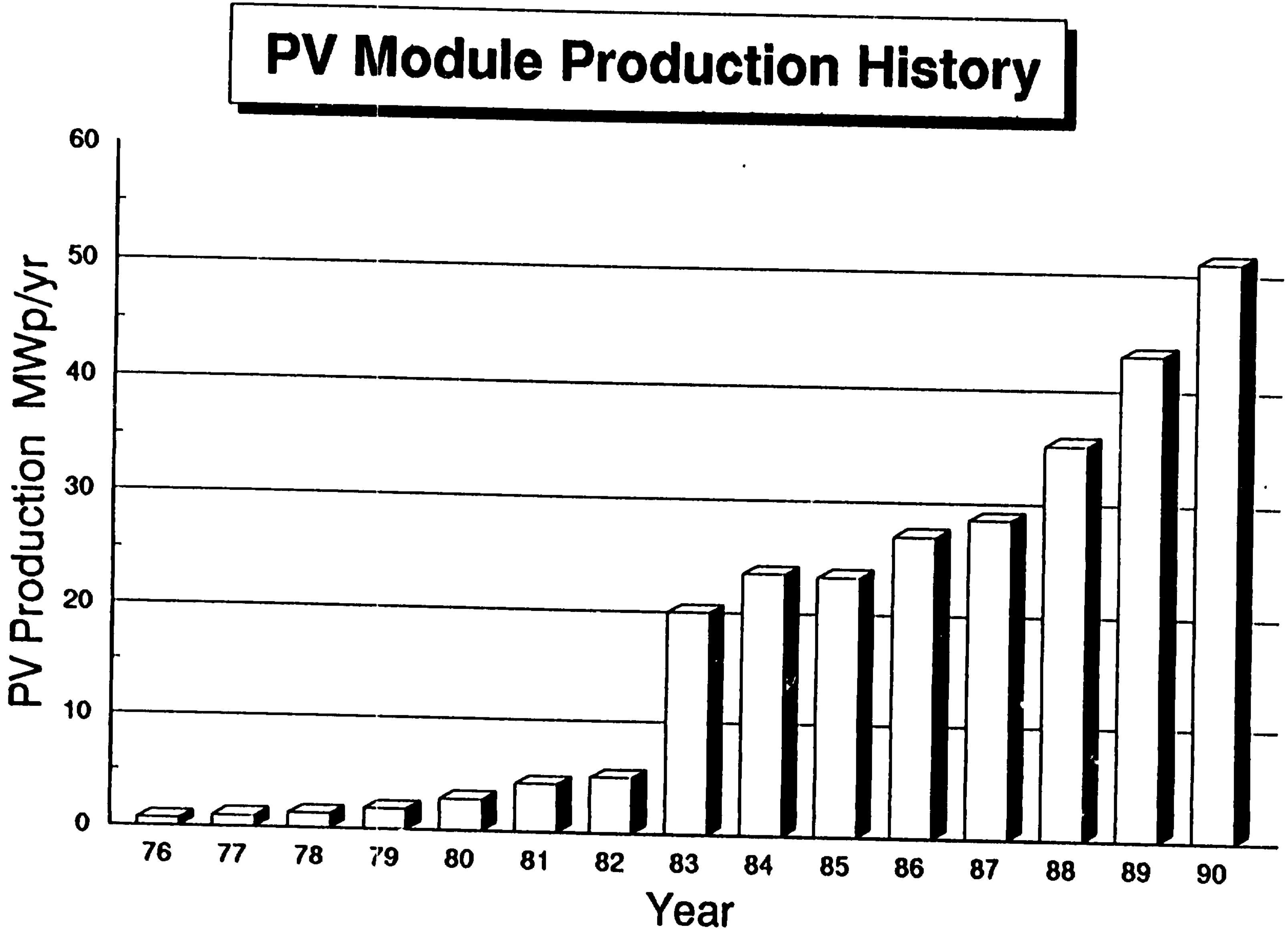

PV Module Production History
PV Production MWp/yr
60
50
40
30
20
10
0
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
Year

FIG. 1

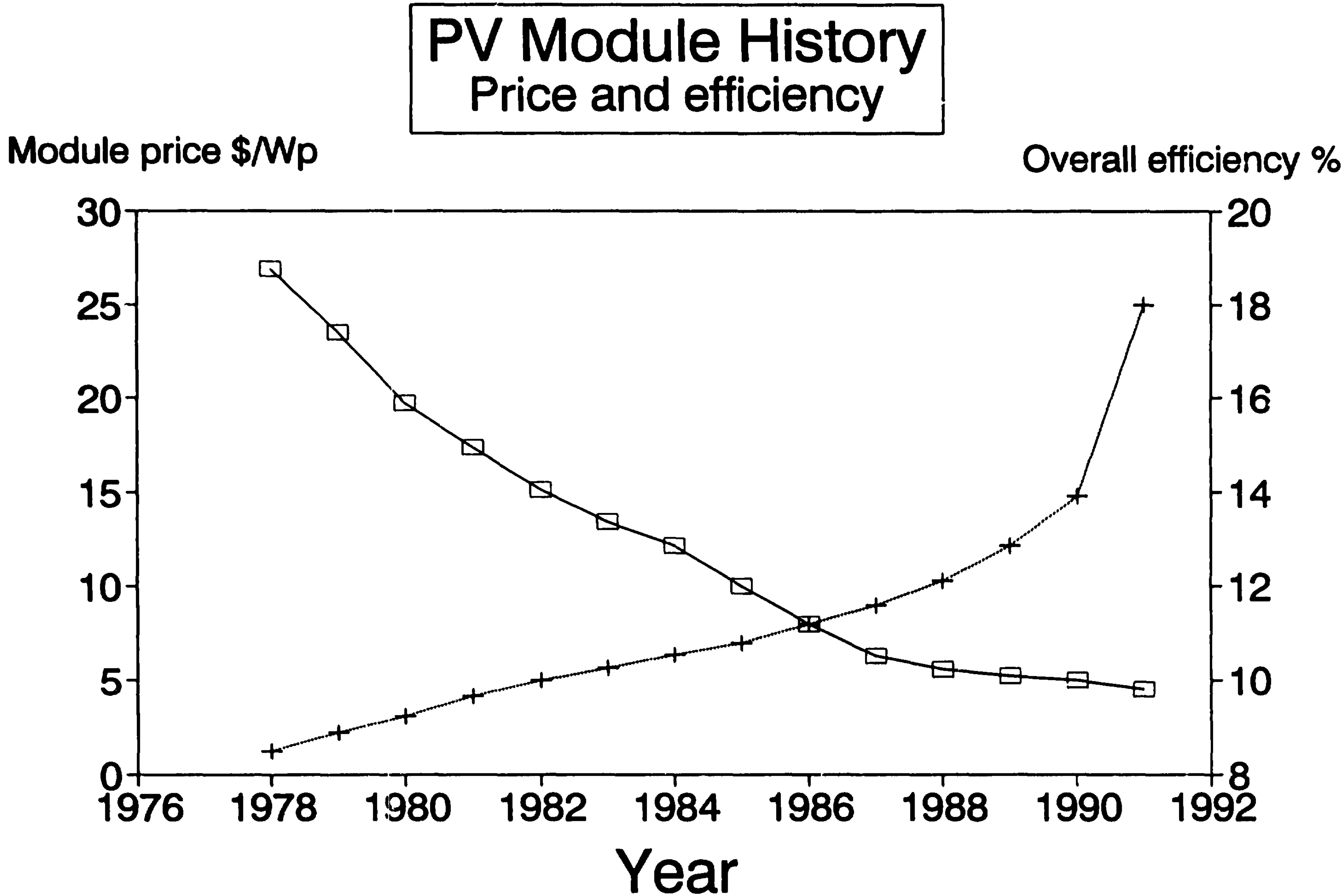
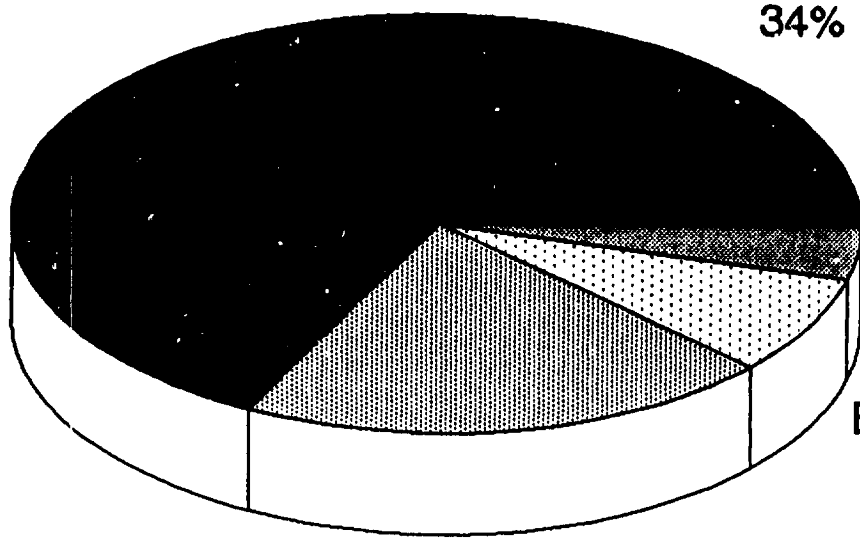

PV Module History
Price and efficiency
Module price $/Wp
Overall efficiency %
30
25
20
15
10
5
0
20
18
16
14
12
10
8
1976 1978 1980 1982 1984 1986 1988 1990 1992
Year

Fig. 2

PV Module Production - 1990

By Region
Total 49.6 MWp



ROW = Rest of world

5

Fig. 3

1990 World PV Market

By Application
Total 49.6 MWp

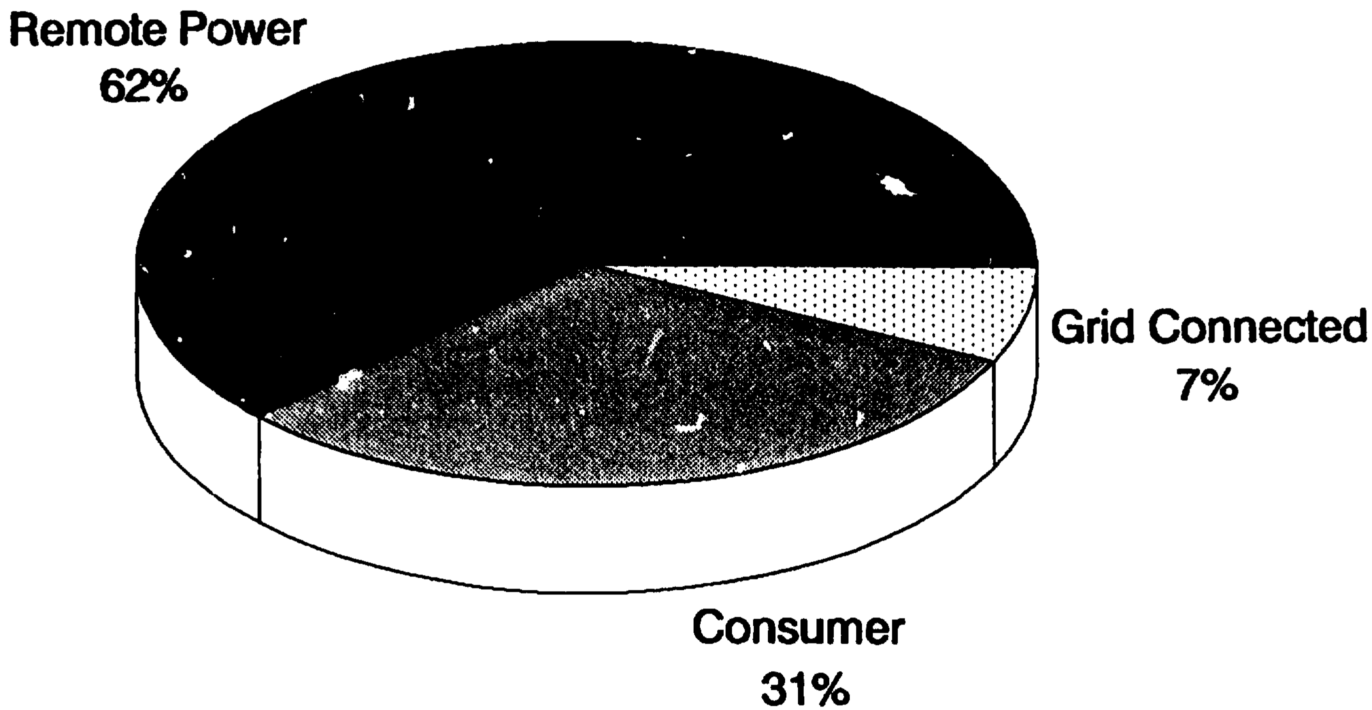


Fig. 4

1.3 Future Prospects

Predictions of future scenarios for the world PV market are routinely made by the PV industry and leading PV experts, such as IT Power.

Projected PV module efficiencies for both high cost (crystalline silicon) and low cost (amorphous silicon) technologies to 2040 are presented in Fig. 5. Module cost projections are presented in Fig. 6. High efficiency modules correspond to crystalline silicon and low-efficiency modules are made from thin-film.

The growth of the world market to 2025 is illustrated, for baseline and accelerated scenarios, in Fig. 7. The borderline (conservative) estimate is based on past trends and reaches 1840 MWp/year in 2025. The segmentation of the market by application - again based on past trends - is illustrated in Fig. 8, and segmentation by region in Fig. 9.

By 2025, it is conservatively expected that the market for PV in developing countries will be around 700 MWp/year. In the accelerated case and beyond 2025, it is expected that large-scale grid-connected plants will form the largest segment, and in the long term this application will be predominant in both developed and developing countries.

The predicted price of PV electricity is illustrated in Fig. 10, where it can be seen that around 2025 it is expected that PV will compete with baseload fossil fuel electricity generation.

Projected PV Module Efficiencies

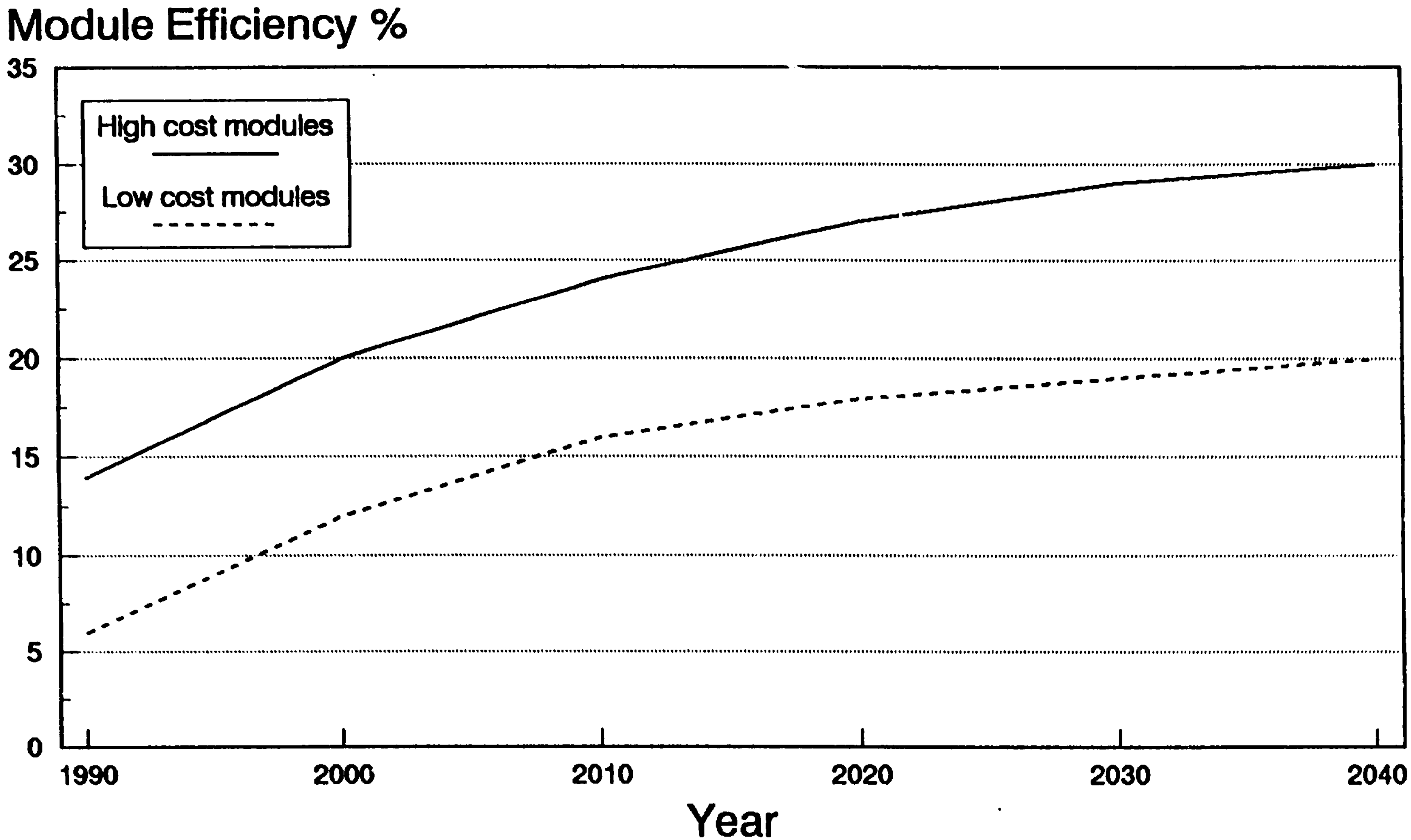


Fig. 5

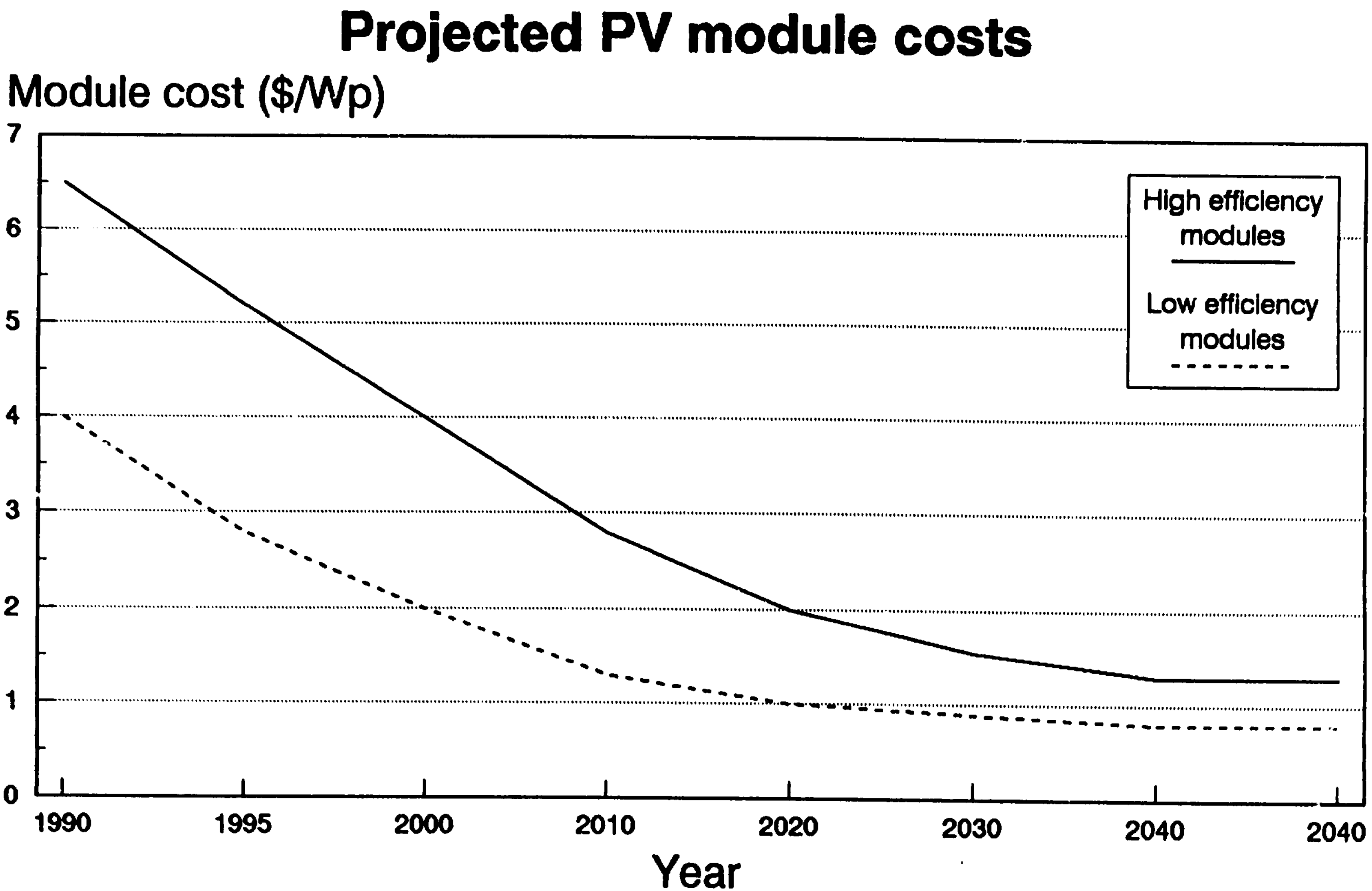

Projected PV module costs
Module cost ($/Wp)
7
6
5
4
3
2
1
0
1990
1995
2000
2010
2020
2030
2040
2040
Year
High efficiency modules
Low efficiency modules

Fig. 6

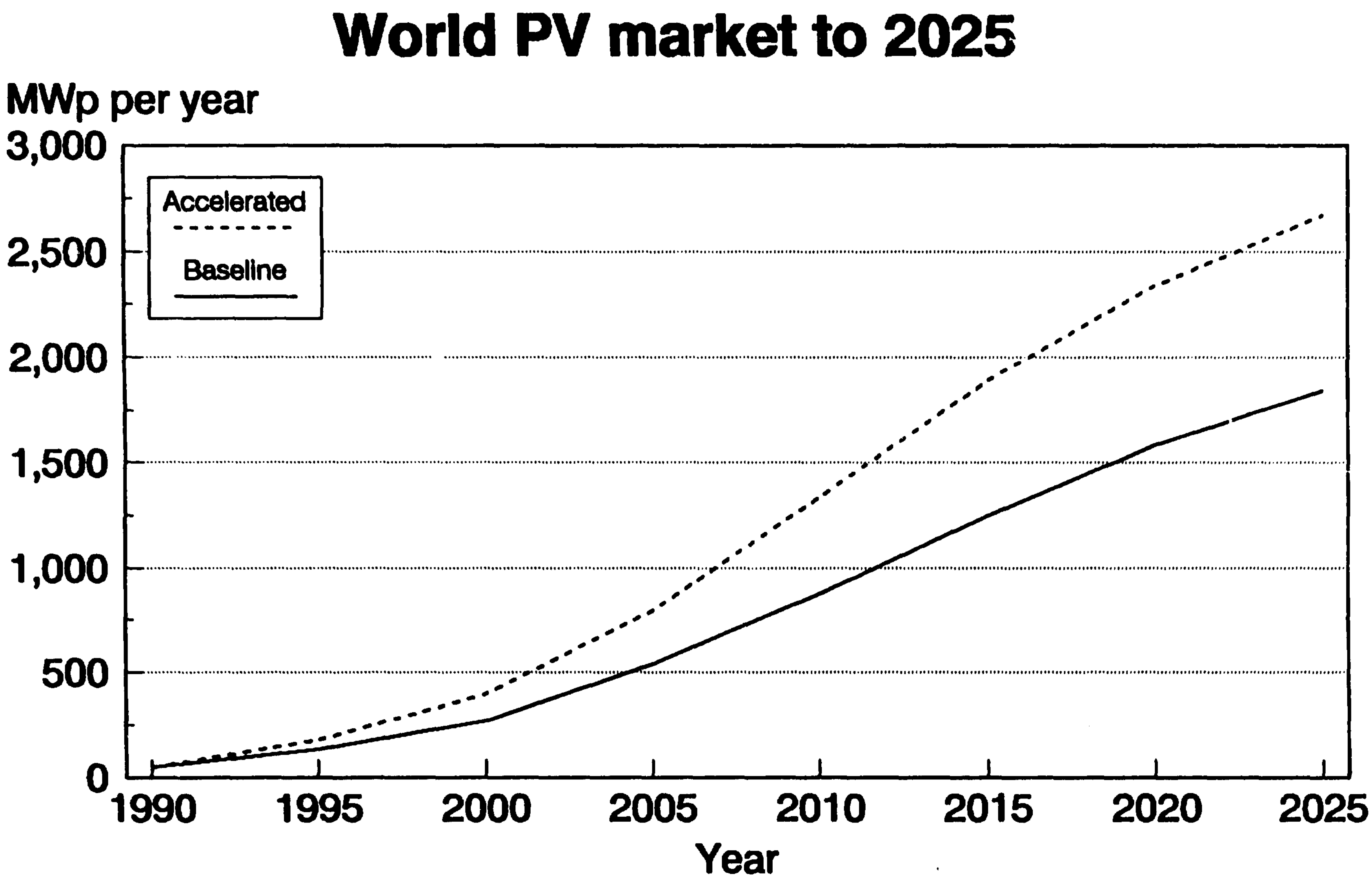

World PV market to 2025
MWp per year
3,000
2,500
2,000
1,500
1,000
500
0
Accelerated
Baseline
1990
1995
2000
2005
2010
2015
2020
2025
Year

Fig. 7

2025 World PV Market
By Application
Total 1840 MWp

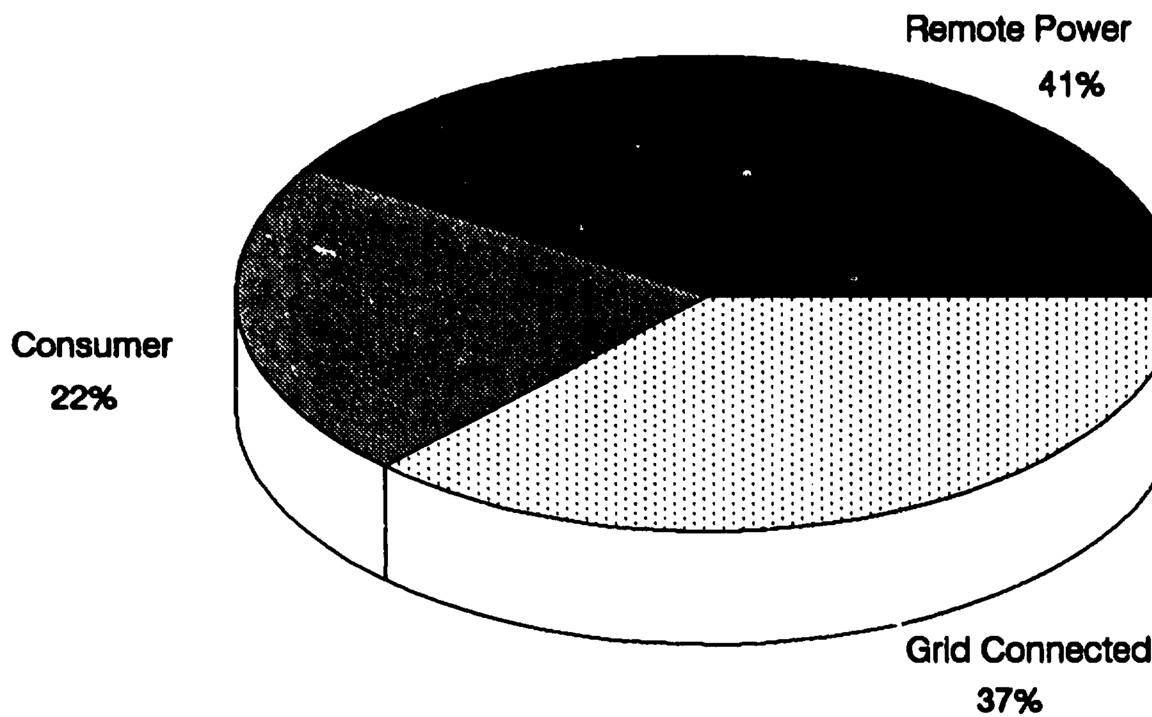


Fig. 8

2025 World PV Market

By Region

Total 1840 MWp

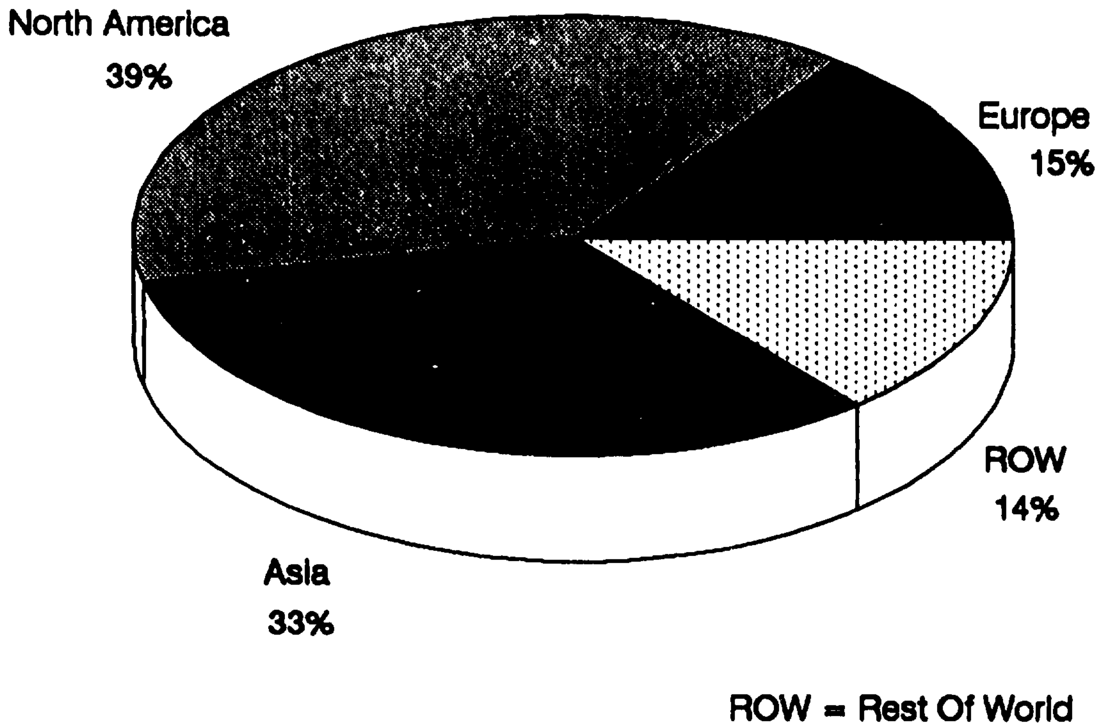
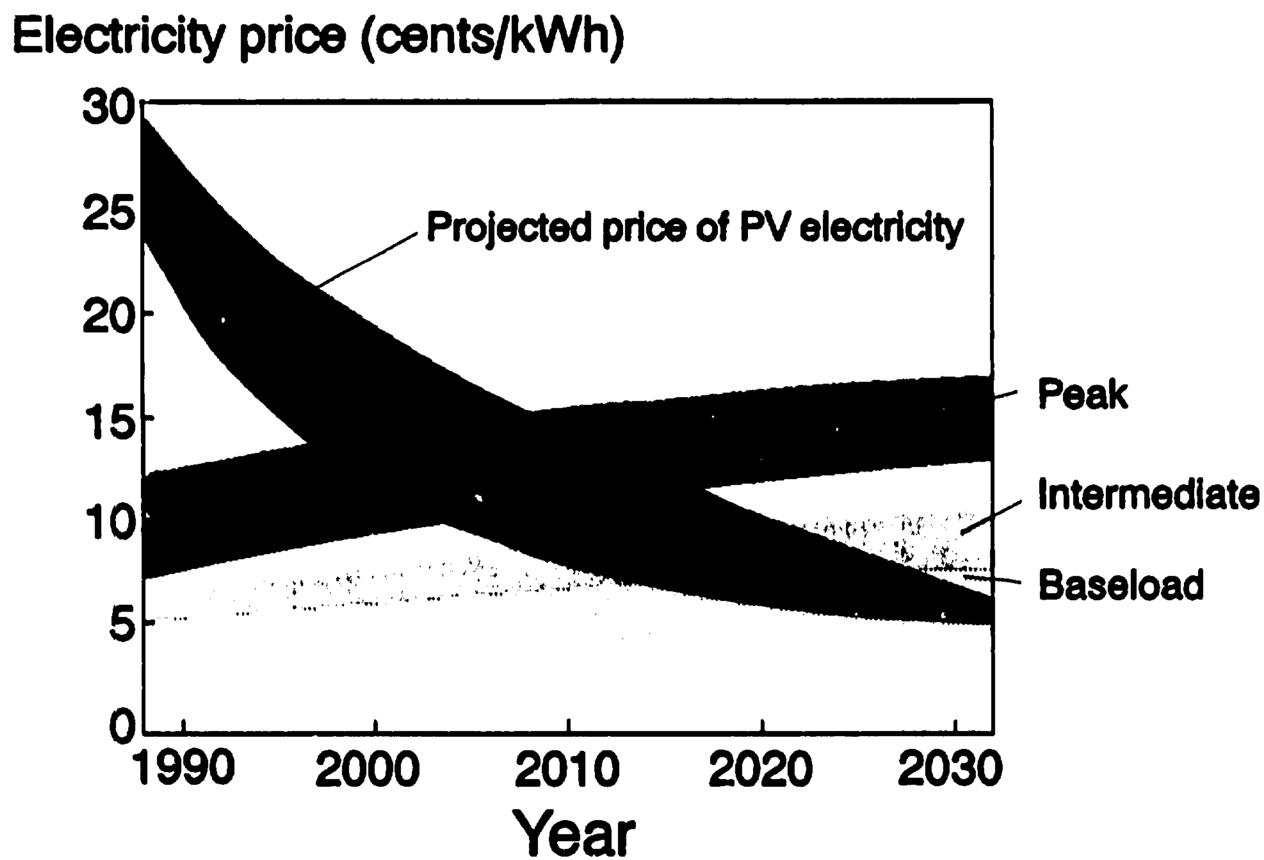


Fig. 9

Future Price of Electricity from PV



Source: National PV Program, U.S. Dept of Energy

Fig. 10

SECTION II: COUNTRY ANALYSIS

2.1 Analysis by Region

The 1990 PV market, defined by end-use location, is illustrated in Fig. 11. From this diagram it can be seen that markets in developing countries - particularly in Africa - represent a relatively small market share to date.

The countries with high disposable incomes, such as the USA, Japan and Europe, dominate the PV consumer goods market. Particularly successful products have been path lights (several million sold) and car ventilator fans. One UK supplier of an 'auto-vent' has sold over 1 million units and has a weekly production of several thousand per week.

There is also a strong market for remote area power in the USA, Europe and Australia. In Europe the remote habitation market is often underestimated as it is not widely known that there is more than 2.0 MWp/year of modules sold in Scandinavia, almost 0.5 MWp in the Alpine regions and over 2.0 MWp in southern Europe.

The PV markets in developing countries have been slow to develop, with South America believed to be particularly underdeveloped from the international trade viewpoint. The Brazilian market is the most diverse,and demand is currently met by the home supplier, Heliodymanica. The market in other South American countries is principally within the telecommunications sector, with relatively little power building or water pumping activity. The Pacific region remains an active market for remote habitation as a result of several projects supported by the European Development Fund, the French Government and the United Nations.

The PV irrigation pumping market will go down in history as the market which never materialised (some US past forecasters predicted hundreds of thousands of PV-powered irrigation systems in use in Asia by the 1990s).

The United Nations Water Decade did little to stimulate the solar-powered water supply market, with most of the approximately 3,000 systems sold in 1990 being for the stock watering markets in the USA, Australia, Canada and The Netherlands.

1990 marked a flurry of interest in the USA, Germany, Switzerland and Japan for grid-connected PV systems, particularly for distributed power building, although it will take some time to see the results of this activity translated into module sales. Interest in this sector has also increased in other European countries since the beginning of 1991.

1990 PV Market by Region
Total 49.6 MWp

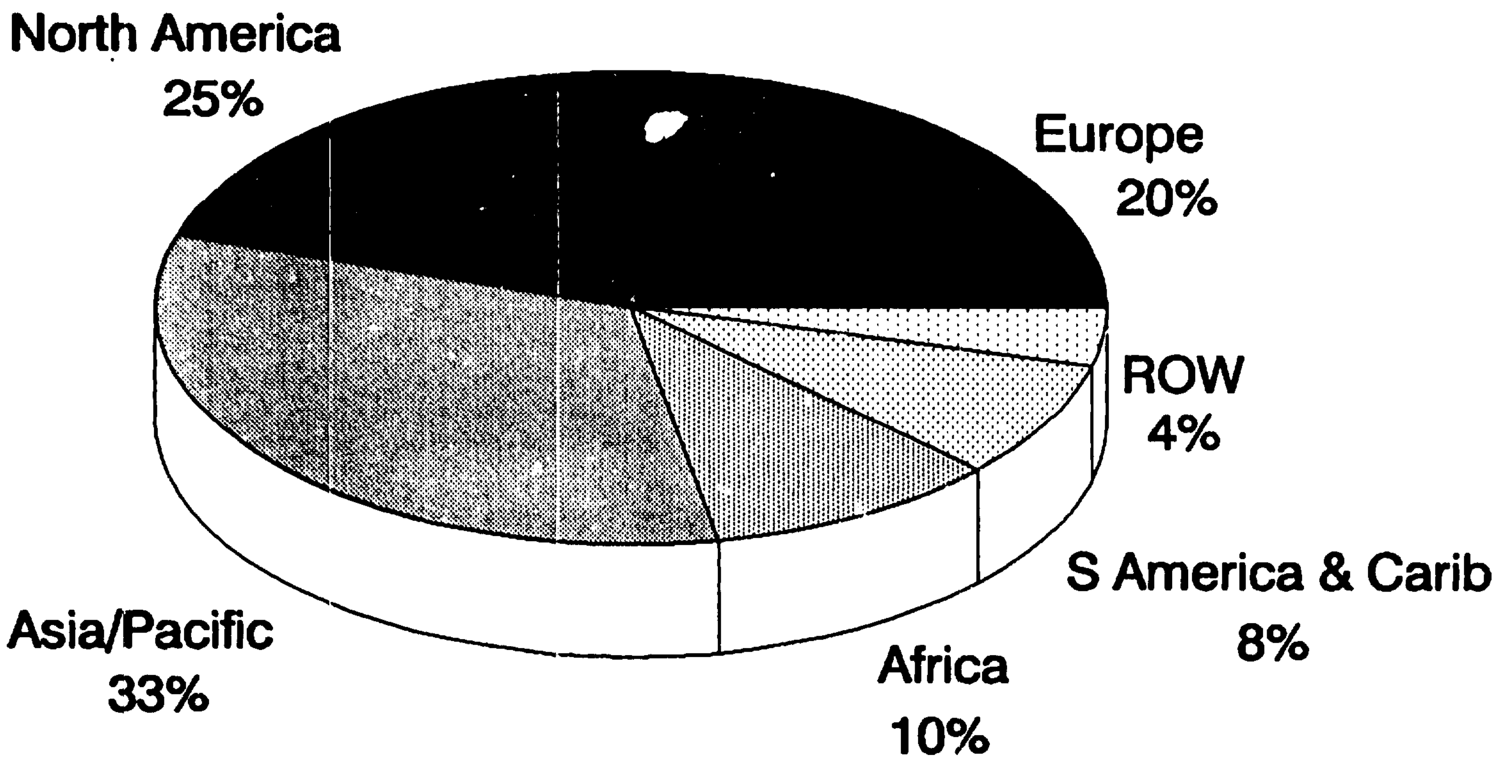


Fig. 11

2.2 Possible Countries Selected for Survey

The Terms of Reference request that a short-list is made of potential countries, for consideration as part of a future intensive phase of work. Due to the limited nature of this Report (as outlined previously in the section on Objectives and Scope), to undertake this exercise in detail, based on quantitative data would require an extensive professional effort which is far beyond the scope of this project. It is indeed recommended in Section III of this Report to undertake an in-depth country analysis as part of the next phase of the project.

However, as a preliminary step to assist in this identification and selection process, IT Power has used its direct experience in the field to select a number of credentials to indicate possible candidates in the following regions:

* Africa
* Asia/Pacific
* Caribbean
* Latin America

The selection of possible country candidates has not been made on any political or other grounds of preference, simply on the immediate availability of in-house data gained from recent experiences.

In arriving at a short-list, IT Power has made informed guestimates relating to the parameters listed below:

Solar Regime: Reasonable solar conditions are required for the successful operation of PV systems. In larger countries (eg. China), there are wide variations in the solar radiation levels recorded across the country. In other countries there are wide regional variations caused by geographical features.

Population without Electricity: The principle markets for PV in the near and medium term will relate to people not connected to the electricity grid. Some countries (eg. Indonesia) have large numbers of islands and other remote areas without electricity, or where it is supplied soley by diesel generators.

Potential PV Purchasing Power: For a PV market to develop, the potential users need to be able to pay for the systems. This parameter takes into account private purchasing power, government programmes and international aid received.

Price of Commercial Energy: If commercial energy is very cheap or subsidised (eg. in Egypt), the penetration of the market by PV is made more difficult. Conversely, high prices for energy make PV more economically attractive.

Level of Development Aid: In many developing countries (eg. Mali), development aid is a major factor in the national economy, and a likely source of funding for PV projects.

PV Experience: The potential market for PVs will be easiest to assess in countries with a relative large experience in PV, either as importers of such systems (eg. Morocco) or with an indigenous manufacturer (eg. India).

Likely Size of Market: The absolute size of the potential market will ultimately depend on the size and population of the country. Thus China and India will, in the long term, become major world markets. However, in the short term, smaller countries have more immediate prospects which are important for the PV industry. Some smaller countries (eg. the Caribbean Islands) are small markets in absolute terms, but can represent immediate business (eg. the Dominican Republic).

Approximate ratings for a selection of countries against the above parameters have been made. The results are summarised in Fig. 12. If added together (though it is suggested that no benefit will be derived from doing this), the total number of points for each country do not represent an absolute figure. Rather they correspond roughly to the potential market for PV in each country, taking into account the factors listed above and the comments listed in the summary sheet.

From the above empirical approach, the following countries have been identified for a detailed study:

2.1.1 Brazil

Brazil has an indigenous manufacturer, Heliodynamica, who has been in operation for a number of years now. There are also a number of companies who import PV systems into the country.

However, despite this and other factors such as the high price of energy within the country, and the current government's more positive attitude to renewable energy technologies, the market to date for PV has remained small.

With increased political will and stimulation from other sources, Brazil should provide a large potential market for PV.

2.1.2 Dominican Republic

There have been a number of successful PV projects operated in the Dominican Republic. The most successful of these has been with rural lighting systems. The country has a good level of solar radiation, a high relative price for commercial energy and also receives substantial amounts of development aid. These factors should combine to present a good potential market for PV.

2.1.3 Malaysia

Malaysia has been identified as a good potential market for PV as it has good solar radiation levels, a government committed to the implementation of renewable energy technologies and especially PV, and a potential adequate level of purchasing power for PV. Malaysia also has a high proportion of its population living without grid-connected electricity.

Indonesia was also identified as a good potential market in Asia, but was discounted in favour of Malaysia. The factors which influenced this initial decision included the Indonesian government's commitment to grid extension, and the work currently being proposed for its island communities by the World Bank.

2.1.4 Mexico

Mexico has had quite a varied experience with PV systems to date. However, the current government is committed to the implementation of renewable energy systems - especially using PV for remote areas. Mexico also has a very good level of solar radiation and an adequate level of private PV purchasing power.

2.1.5 Morocco

Morocco has had many years experience with PV-powered systems, projects, ranging from rural lighting to health refrigeration schemes.

The potential purchasing power in the country is good for PV, and the price of commercial energy is relatively high. Morocco also receives substantial development aid, which is a likely source of funding for PV projects.

2.1.6 Zimbabwe

Zimbabwe has been identified as the African country with the most potential for PV for a number of reasons, the major ones being its relatively high level of potential purchasing power for PV, the level of development aid received and the amount of experience with PV to date.

Preliminary Identification of Countries with the Most Potential for

	Solar regime	Population without electricity	Potential PV purchasing power	Price of commercial energy	Level of developme aid
AFRICA					
Egypt	QQQQQ	QQQ	QQQ	Q	QQQQQ
Kenya	QQQQQ	QQ	QQ	Q	QQQQ
Mali	QQQQQ	QQQ	QQ	QQQ	QQQQQ
Morocco	QQQQ	QQQ	QQQ	QQQ	QQQ
Nigeria	QQQQQ	QQQQQ	QQ	QQQ	Q
Zaire	QQQQQ	QQQQ	Q	QQQQ	QQQ
Zimbabwe	QQQQQ	QQ	QQQ	QQQ	QQQ
ASIA / PACIFIC					
China	QQQ	QQQ	Q	QQ	QQQ
French Polynesia	QQQ	QQ	QQQ	QQQ	QQQQ
India	QQQQ	QQQQ	QQQ	QQQ	QQQ
Indonesia	QQQQ	QQQQ	QQQQ	QQ	QQ
Malaysia	QQQQ	QQQQ	QQQ	QQ	Q
Pakistan	QQQQ	QQQQ	QQ	QQQQ	QQ
CARIBBEAN					
Barbados	QQQQ	Q	QQQQ	QQQ	Q
Dominican Republic	QQQQ	QQQ	QQ	QQQ	QQQ
Haiti	QQQQ	QQQQ	Q	QQQQ	QQQ
LATIN AMERICA					
Argentina	QQ	QQ	QQQ	QQ	Q
Brazil	QQQ	QQQ	QQQ	QQQ	Q
Colombia	QQQ	QQQ	QQQ	QQQ	QQ
Mexico	QQQQ	QQQ	QQQ	QQ	QQ

ntial for Adopting PV

❑❑❑❑❑ Most potential for PV
❑ Least potential for PV

Level of development aid	PV experience	Likely size of market	Comments
❑❑❑❑❑	❑❑❑	❑❑❑❑	*Grid-connected wind power more economically attractive, fuel price low*
❑❑❑❑	❑❑	❑❑❑	*Limited PV experience*
❑❑❑❑❑	❑❑❑❑❑	❑❑❑	*Large experience but small market*
❑❑❑	❑❑❑	❑❑❑❑	*Very promising near term market*
❑	❑	❑❑	*Large population, but very small market at present*
❑❑❑	❑❑❑	❑❑	*Large experience with aid projects*
❑❑❑	❑❑❑	❑	*Extensive electrification, but good awareness and purchasing potential*
❑❑❑	❑❑	❑❑❑❑❑	*Vast country: long time req'd for proper study. Large manufacturing capacity, but small market*
❑❑❑❑	❑❑❑❑❑	❑❑	*'Success story' for small-scale PV*
❑❑❑	❑❑❑❑❑	❑❑❑❑❑	*In-country PV manufacture. Strong government interest. Long time required for study*
❑❑	❑❑❑❑	❑❑❑❑❑	*Large number of small islands - good market*
❑	❑❑❑	❑❑❑❑	*Favourable govt energy policy for PV. Good marke potential*
❑❑	❑❑	❑❑❑	*'Failure story' for village PV*
❑	❑❑	❑	*Island fully electrified*
❑❑❑	❑❑❑	❑❑	*Successes with PV lighting*
❑❑❑	❑	❑	*No data on PV available*
❑	❑	❑	*Grid-connected wind-power more promising*
❑	❑❑❑❑	❑❑❑❑	*In-country manufacture of PV, but very small market to date*
❑❑	❑❑❑	❑❑❑	*Large number of small systems installed*
❑❑	❑❑❑	❑❑❑❑	*Large potential market*

Figure 12

SECTION III: SURVEY METHODOLOGY

3.1 Introduction

The purpose of a useful market survey is not just to come up with a numerical result, but to gain a thorough qualitative understanding of the structure and background of the market. Clearly, quantitative data must form a vital part of the final product, but without a qualitative appreciation of the situation the interpretation of figures will be at best inaccurate and at worst dangerously misleading. The most effective way to gain such an understanding is by talking to the relevant people in the country, meeting with the widest possible strata from government to user.

The following methodology therefore concentrates on making effective use of time spent in the field in recommending a comprehensive range of topics for investigation.

3.2 Economic and Demographic Factors

Statistics concerning the overall economic state of the country form an important part of the background work to any country-wide market study. Although not directly related to the PV market, they reveal much about the distribution of wealth, the economic health of the country and the pattern of life of the populace. They are essential factors in determining the potential funders, buyers and users for various PV applications.

Basic information on these items should be gathered previous to any visits, and will enable the researcher to more accurately target geographical regions or sectors of the population for further study. These data should be updated and expanded upon during visits.

3.2.1 Population and Infrastructure

As PV is essentially a technology suited to use in rural areas, the population distribution is of paramount importance. Therefore as a minimum requirement, it is recommended that the following data are determined before the visit:

i) total population;

ii) percentage of rural population;

Where possible, rural population densities for different regions within the country should be found. During visits other useful information would include the typical village size; the primary occupation of the villagers (to assist in ascertaining their disposable income); and the extent of infrastructure connecting those villages.

Cultural factors should also receive some consideration. For instance: rural populations of some countries may be suspicious of new technologies and methods, and quickly revert to their traditional ways when problems occur. In addition, the inhabitants may not regard the provisions of different services with the same priorities as one may think: e.g. some societies may see lighting as more desirable than a convenient, clean water supply.

This type of question can only be answered by a 'bottom-up' approach, i.e., by consultation with someone working closely with the potential end users.

Relevant questions are:

i) How many villages have no road access;

ii) What is the extent of the electricity grid;

iii) What proportion of villages/population have access to electricity. Is it grid connected or locally generated;

iv) To what end use is this electricty put (eg. heating, cooking, lighting);

v) What proportion of the population have no access to clean water;

vi) Are there any areas in which a lack of law and order prevent effective transport or communication;

vii) How willing are the population to change traditional methods, and accept new technologies.

3.2.2 Industry

The type and distribution of industry will give some indication of the indigenous ability of the country to support a PV market. It will also be closely linked to infrastructure and the distribution of wealth. A potential PV market will be greatly assisted by the existence in-country of workshops with the capability to manufacture or repair balance of system components.

The possession of basic electrical or engineering skills within the rural population is also a factor in ensuring the proper installation and maintenance of PV equipment. Specific types of industry may affect certain parts of the PV market: for example the project cost of PV pumping in hard-rock areas depends greatly on the cost and availability of borehole drilling plant.

Relevant questions are:

i) Are there main centres of electrical or electronic industry;

ii) Where, if any, are there centres of engineering industry and to what products are they geared;

iii) To what extent does the rural population have mechanical or electrical skills.

3.2.3 Economics

Under this heading two main areas are relevant: the macro- and the micro-economic situation. These terms are not used here in their strictest sense, but more to differentiate between general and more specific data.

As defined in this Report, macro-economic details concern the country as a whole and help to form a background to potential market penetration. Much of this type of information can be found pre-visit.

Useful information includes:

i) Per capita GNP and GDP;

ii) Outstanding national debt;

iii) Political and economic stability;

v) Mean inflation rate;

vi) Applicable discount rate.

Point (vi) above, the *discount rate*, is necessary if you wish to perform any life-cycle cost analysis as part of the study. This gives the rate at which future costs and benefits should be discounted in economic analyses, and is a rather nebulous figure. However, for developing countries a figure of around 10 or 12 % is not uncommon.

The micro-economic factors, as defined in this Report, are those which directly affect the potential user, manufacturer or importer.

These factors include:

i) Structure of import taxes and government policy towards foreign imports (also availability of hard currency);

ii) Structure of taxes and subsidies affecting the purchase of renewable energy equipment in general or PV in particular;

iii) Taxes or subsidies affecting the competing technologies, ie diesel and kerosene price, electricity pricing structure;

iv) How easy is it to borrow money for investment in energy/development projects;

v) What are the typical terms for lending and how do they vary for private industry, individuals and communities;

(v) What are the attitudes to borrowing money within different stratas of society.

The above list covers a large and complicated area of analysis and different aspects should be given more priority depending on the required depth of the research.

The question of taxes and subsidies is a vital factor in determining market size. In this respect it is advisable to talk to various persons in government concerned with rural energy policy.

Regional energy agencies are also an important source of information as they often operate autonomously and will often aim in a different direction to the national office. Here more than anywhere it is important to gain an appreciation of the 'feeling' on the ground, and the extent to which various energy sources are favoured within each region.

The survey should also try to determine:

i) Have there been any PV projects or initiatives in the past;

ii) Were they successful and if not why not;

iii) What is the future direction of government policy likely to be.

3.2.4 Development Aid

The level and distribution of development aid may be a key factor in determining certain areas and aspects of the PV market. For instance, development projects such as PV water pumping or vaccine refrigeration are often funded by aid agencies. Aid may come from various sources and each donor will have its preferred projects in a country or region.

Before the visit, the survey should find out which agencies operate in the country. Discovering their attitudes to funding PV projects may best be done by contacting either their chief representative in the country or at their head office.

Useful information includes:

i) What is the total development aid to the country in question;

ii) What is the financial contributory breakdown of the donor and implementing organisations;

iii) What percentage, if any, of their current aid budgets presently goes to projects which include PV;

iv) What percentage of their aid programme goes to potential PV areas such as power supply for water pumping or rural health care;

v) What is the level of awareness concerning PV among donor/implementing organisations.

3.3 Assessment of the Solar Resource

Most developing countries are fortunate in that they tend to be in the more tropical regions of the world, and thus tend to have an abundance of available solar energy. This, however, is not something which should be taken for granted. Monthly means of daily solar insolation should be obtained for as many recording stations as possible. The means used should be over as many years as are available. The quantity most useful for solar energy calculations is kWh/m^2/day. This should be measured as the total daily energy (direct and diffuse) falling on a horizontal surface. In remote areas meteorological stations may be very far apart, and data must be interpolated.

Care must be taken that far flung data points are not averaged over an area to which they are inappropriate, and advice should be sought from someone with knowledge of the regional topography and meteorology of the country in question. In general most care must be taken in regions where changes in topography or nearby coastal effects cause local anomalies in the pattern of cloud-cover.

The World Meteorological Organisation (WMO) in Geneva co-ordinates a global network of climate data. This database is also kept by the UK, US and German Meteorclogical Offices. However, not all stations are defined as climatological stations and so may not be featured. In this case the data must come from the country's national meteorological office.

Some solar atlases exist, but their coverage is patchy and interpolation is likely to hide small features.

3.4 In-Country PV Capability

3.4.1 PV experience to date

Clearly, if PV has already gained some penetration into the country, this will help pave the way for further opening of the market. Perhaps more importantly, the experiences to date will give some idea of the likely problems that may beset future market development. On the other hand, past successes with PV may indicate a receptiveness to PV technology. Either way there is much to be learned, and discussion with those involved in project management would be most valuable. It is unlikely that there will be any private market for PV systems, but foreign and indigenous PV systems firms should certainly be visited.

The following questions should be answered :

i) What, if any, PV installations exist in the country. Who funded and installed them, and how successful are they;

ii) Are there any companies currently manufacturing PV arrays or balance of system components in the country;

iii) Are there any companies currently importing/selling PV arrays or balance of system components;

iv) If such companies exist, what are their sales and to whom do they sell;

v) What is the level of awareness/education concerning PV among decision makers in government departments.

3.4.2 Distribution and maintenance capability

For PV installations that are part of a monitored development programme, independent local expertise is not a problem, as the project may have several persons trained in maintenance, and all parts can be imported directly.

However, the presence of an indigenous company able to import or otherwise supply parts and spares will be a great advantage. For the development of any independent PV market, the presence of such a supplier is practically a prerequisite. In terms of maintenance, the existence in rural areas of persons with enough technical background to effectively repair PV equipment may also make a difference to market growth. In very remote rural areas in which there is virtually no penetration of anything but the most basic technology, the lack of distribution and maintenance capability could present a problem in the acceptance of PV.

The points to consider are similar to those in sections 3.2.2 (Industry) and 3.4.1 (PV experience to date).

3.5 Estimation of Demand

For products which are already established in the market-place, it is possible to collect quantitative data such as numbers of units sold per annum, the annual sales figures and associated trends. Armed with this, it is possible to estimate fairly accurately the future demand for the product, and to predict how a new and improved product might displace sales of existing products.

Because PV is not yet a mature or established product, the conventional approach to market prediction cannot be applied. This makes converting the available market information, and often qualitative and rarely quantitative data into accurate hard figures for potential demand extremely difficult.

PV is a power source of great versatility, and as such there are a considerable list of applications that must be accounted for in any estimation of the potential market. The market for PV may be regarded as roughly consisting of two components:

i) Replacing existing power sources;

ii) Providing power for new services.

The replacement market is the easier to quantify, as a 'demand' for the services can be said to exist. Thus any load for which replacement of the traditional power source with PV makes sense is part of the potential PV market. This has a huge range, and the probable actual market will be only a fraction of the total. The points discussed thus far are the factors that will help to make possible a realistic estimate of the size of that fraction.

The potential market for PV to provide previously unavailable services is more difficult to quantify, as no 'demand' has yet been established, and therefore also no theoretical limit (unlike the replacement market). Because no/little demand has yet been perceived by the potential user, the initiative to use PVs in the market place is more likely to come from aid agencies or from the government.

Two such technology areas are power for rural health care and village electrification. The size of this market can only be extrapolated from information on the distribution and policy of aid spending and government schemes. For each application, the typical size of array required should be calculated to enable the estimated number of systems to be turned into a figure in MWp per year.

Clearly, the two perceived market types for PV, as outlined above, are not completely separable, and in time replacement will lead to the use of PV for new applications. For instance, a village electrification scheme may be intended to replace kerosene lighting. As awareness of the versatility of PV develops, demand for more electrical services could lead to an expansion of the PV array.

Thus initially it is estimated that the potential market for PV will be almost completely a replacement market, with the market for new applications increasing with time.

3.6 Applications and Potential Users

The principal applications for PV are discussed below:

3.6.1 Lighting

Lighting in developing countries is predominantly by kerosene lamps or candles in off-the-grid areas, thus providing a vast potential replacement market for PV. In some areas electric lighting is currently powered by automotive batteries that are periodically taken for recharging.

PV is a very large technology step up from candles and so the initial market will be quite small in real terms, and not limited by the potential market.

However, past experience has shown that there is an increasing demand for systems in areas where PV lighting has been installed.

For example:

* In French Polynesia more than 1000 homes have PV lighting installed in a scheme with a 25% government grant.

* In the Dominican Republic a PV lighting project started by USAID has now become self-financing, with over 1000 systems installed.

* In areas presently using DC lighting from batteries (eg. in Thailand) people already have familiarity with electric lighting.

The move to PV is therefore not always such a large step (if its implementation is managed correctly), thus making the achievable potential market larger.

In the least developed areas only community buildings such as schools and health centres are likely to be suitable for PV lighting, due to potential barriers to implementation as outlined above.

As part of the project assessment a brief life-cycle cost comparison should be performed between traditional lighting means and PV lighting. However, results should be viewed with caution, as non-economic factors are important where lighting is concerned. This is because PV gives a higher quality of lighting and so one is not necessarily comparing like with like. For instance, the obvious improvement in lighting may mean that a householder is prepared to pay more. This scenario tends to be more true of lighting than many other areas, because the service provided is literally much more 'visible', and will have a marked effect on the uptake of PV systems.

Fig. 13 shows the Cost of Rural Lighting, in the scenario PV vs Kerosene as the energy source for lighting systems. These calculations are based on 1991 module prices of $4.50 per peak watt and future projections of $2.00 per peak watt.

Salient points in assessing the PV lighting sector include:

i) How many PV lighting systems are already installed in the country? If there are any, who has them and how are they funded;

ii) What is the present main mode of lighting;

iii) What are the costs involved (ie. cost of lamps, fuel, candles, battery recharging etc);

iv) What is the mean family expenditure on lighting fuel, and what quality of lighting do they receive;

v) What importance do people place on lighting;

vi) How many community buildings are there without adequate lighting;

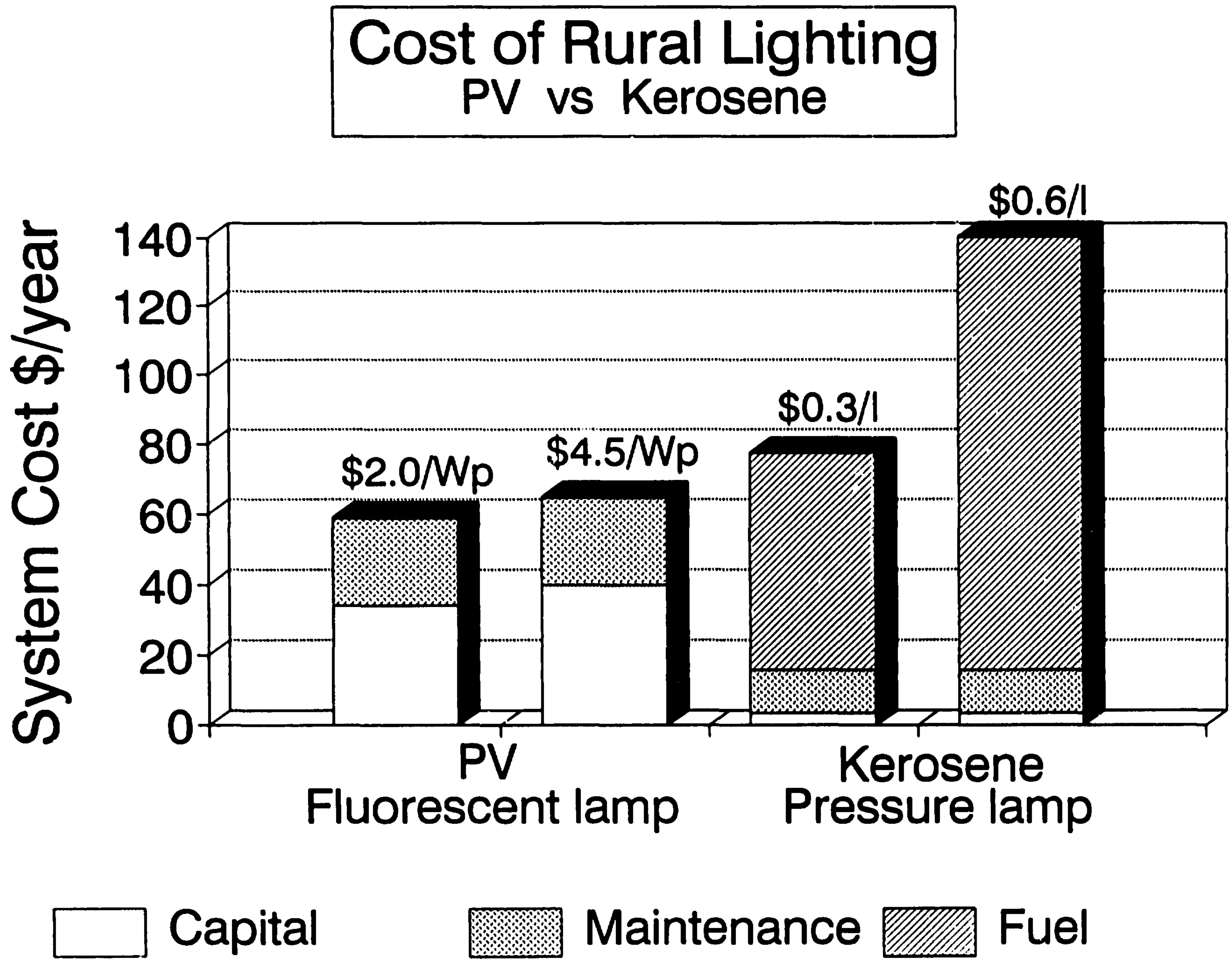

Cost of Rural Lighting
PV vs Kerosene
System Cost $/year
140
120
100
80
60
40
20
0
$2.0/Wp
$4.5/Wp
$0.3/l
$0.6/l
PV
Fluorescent lamp
Kerosene
Pressure lamp
Capital
Maintenance
Fuel

Fig. 13

vii) With what priority do the government/aid agencies view the provision of lighting;

viii) If possible try and ascertain the regional lamp/candle market.

3.6.2 Water Pumping

PV water pumping systems in developing countries are mainly installed as community water supply projects. The market is likely to be regional, as in some areas access to a clean and convenient water supply may not be a problem. In other areas, such as the hard-rock areas of Africa, clean water is to be found deep below the surface, but the only available source for villagers may be far away from the village and available only from polluted surface water sources.

Alternatively, their supply of water may be from handpumping systems, which may not yield enough water for their needs. Being quite a specialised technical field (ie. usually is implemented into an aid agency, NGO or government programme rather than installed by individuals), the market for PV pumping is easier to estimate than other areas such as lighting.

Funding for PV pumping systems is most likely to be through aid agencies, as part of a larger programme. Because of the expertise needed in siting and sizing a PV pumping installation, private or one-off sales will be minimal. PV pumps are essentially replacing handpumps or competing with diesel pumps, and the two major factors affecting the size of the potential market are cost and reliability. Villagers themselves may not put a very high priority on a nearby clean water supply, the men often being happy to have the women continue to use traditional sources. If PV pumping is to succeed, they must be convinced of the advantages, which means that pumps must be cost effective as well as reliable.

Whilst a single community will be very unlikely to be able to pay the capital cost of a pump (usually 80-90% covered by aid agency funding) they will probably have to pay running costs. However, any donor agency will be interested in the total cost of providing water to a certain standard, making the life-cycle cost analysis very important.

If borehole drilling is required, the cost of hiring plant (if it is even available) may be as much as the PV system. Open wells are much cheaper to dig but cannot be excavated to such depths. If diesel pumping is the main competing technology, then the increased reliability of PV pumping will serve to make PV more desirable in cases which are borderline economically.

The acceptance of PV pumping by the aid agencies is a key factor to market penetration, as they will provide virtually the whole market - especially at the initial stages. Some agencies have found that PV pumping can be extremely successful, such as the programme in Mali where over 200 PV-powered pumps have been installed. Others will not be as knowledgeable about PV pumping systems; or may have had bad experiences in the past.

PV pumping has attracted the attention of UNDP and the World Bank, such that there is more data available on the technology, economics and market than for other PV applications. The growth of the PV pumping market to 1990 is illustrated in Fig. 14.

Clearly, those agencies and NGOs who have had any experience with PV pumping systems would be well worth talking to.

PV is rarely suited to irrigation pumping due to the large volume of water required, making this application unlikely to form a significant part of the market. Naturally, if there is an existing PV irrigation market, extrapolation should be made from this.

To assist in defining the potential market for PV pumping systems, the following information should be obtained where possible:

i) How many villages have inadequate domestic and agricultural water supplies;

ii) What are the typical water supply conditions - eg. wells, boreholes, surface water;

iii) What are the normal lifting means - eg. hand, diesel. Are there any data available on numbers of systems in operation;

iv) Gather what hydrological data is available for different regions (depths of water tables, rock types etc). Data for existing pumps (diesel or PV) may give useful information concerning well yield, drawdown etc. to assess suitability for PV;

v) Do any aid agencies or NGOs have community water supply projects in any of the regions. Could PV pumping be used in any of these circumstances;

vi) Are there any PV pumping installations in the country. If so who installed them and how many. What are their experiences;

vii) What is the level of knowledge concerning PV pumping among aid agencies/government;

viii) What priority do people/government/aid agencies put on access to a clean, nearby water supply;

ix) What are the relative costs of alternative water supply methods - eg. Handpumps, diesel pumps, diesel fuel, borehole/well excavation;

x) Are there any PV pumps used for irrigation at present? If so how many, what size and funded by whom.

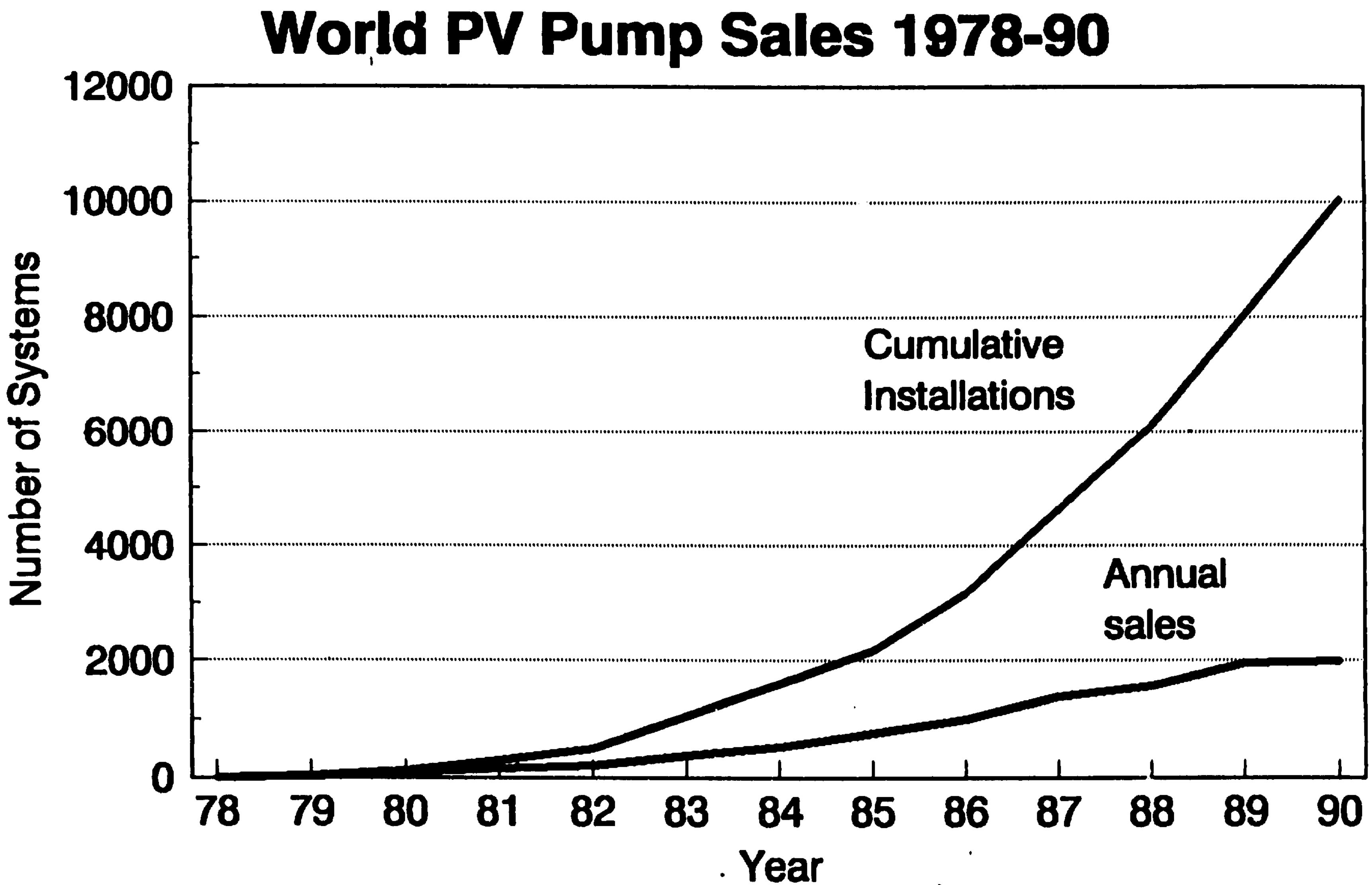

World PV Pump Sales 1978-90
12000
10000
8000
6000
4000
2000
0
Number of Systems
Cumulative Installations
Annual sales
78
79
80
81
82
83
84
85
86
87
88
89
90
Year

Fig. 14

3.6.3 Village electrification

Village electrification may be either centralised or decentralised. Some projects executed by governments in developing countries have attempted to provide a mini-grid in remote villages, using a central PV array from which the whole village derives its supply.

While this may appear impressive, experience has shown that a decentralised system works better, with each house having its own modules to provide lighting and a few other low-power services. A program of this sort is expensive and is more likely to be taken on by a government rather than an aid agency. If the modular approach is adopted, there will be some interest from private householders, and the systems used become identical to those for PV lighting. A little extra capacity would be provided for other appliances, such as a radio or television.

In addition to the points considered in the PV lighting case (section 3.6.1), one should consult the relevant persons in government and regional energy offices to discover their policy on rural village electrification. This will often be restricted to extension of the grid.

To illustrate these points, Fig. 15 illustrates Electricity Cost against Load, PV vs Diesel; Fig. 16 shows Electricity Cost against Load, PV vs Grid Extension.

3.7.4 Telecommunications

The principal users on a large scale in the telecommunications sector will be government-based (both civil and military). Many developing countries are large and sparsely populated and remote repeater stations are an ideal application for PV where reliability is at a premium. Although repeaters will be few, a single installation is likely to be several kWp.

On a smaller scale communications can play a role in rural development, particularly in terms of radio transceivers, radio telephone links, and community television. The actual market for private telecommunications use will be quite small in terms of Wp per year. For instance a radio station in Panama runs from just a 180 Wp array; another in Liberia on 360 Wp. In terms of PV radio receivers, a domestic portable radio set would need only a 1 or 2 Wp cell, most likely built into the receiver itself. The potential number of these could be very large. Estimation of numbers should consider for which areas there is radio coverage, and whether there is an indigenous manufacturer capable of assembling such a device.

There is also a potential market for radio transceivers (30-50 Wp), perhaps one per village or per health centre. In remote regions these may be the only reliable means of fast communication.

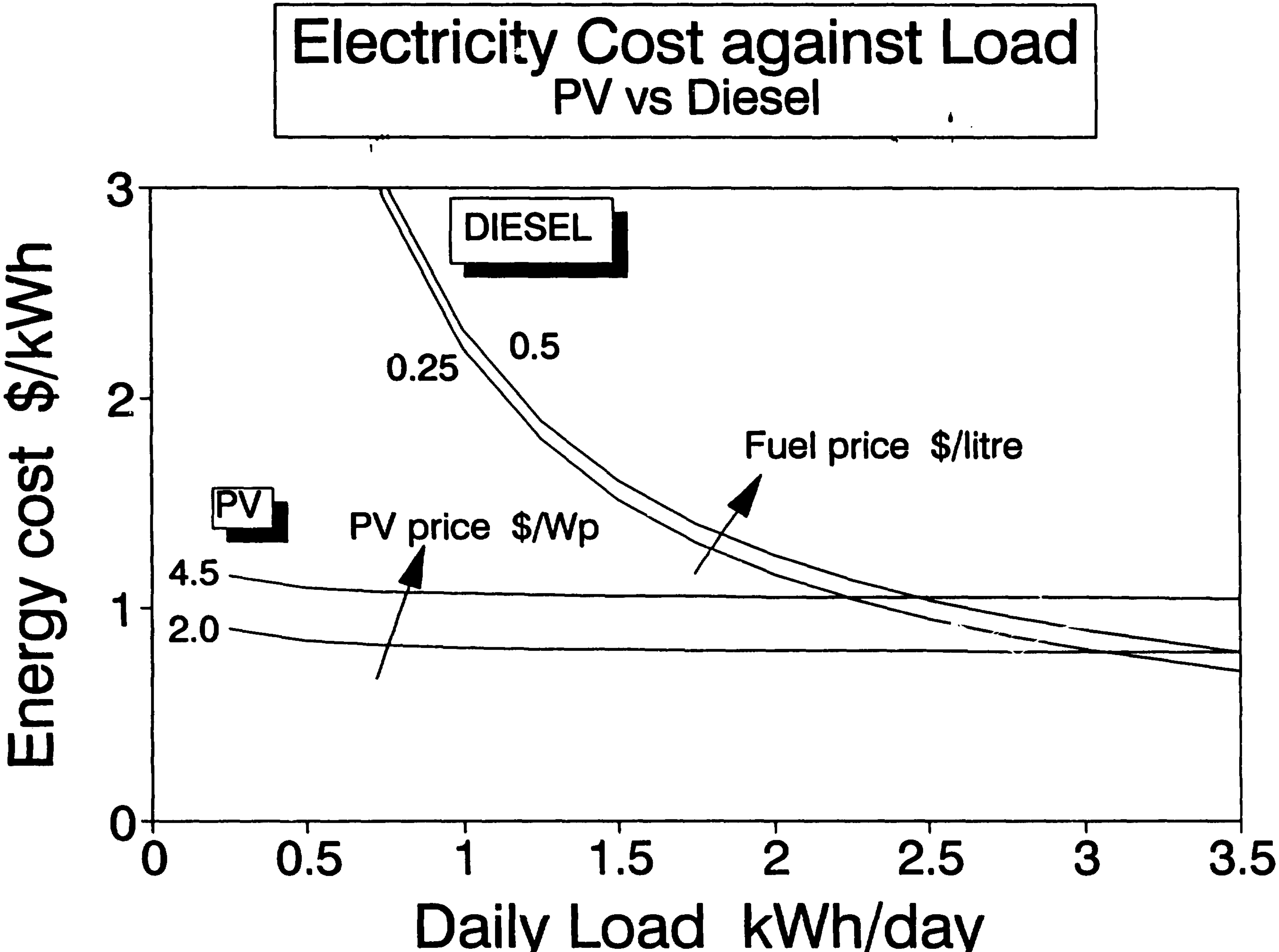
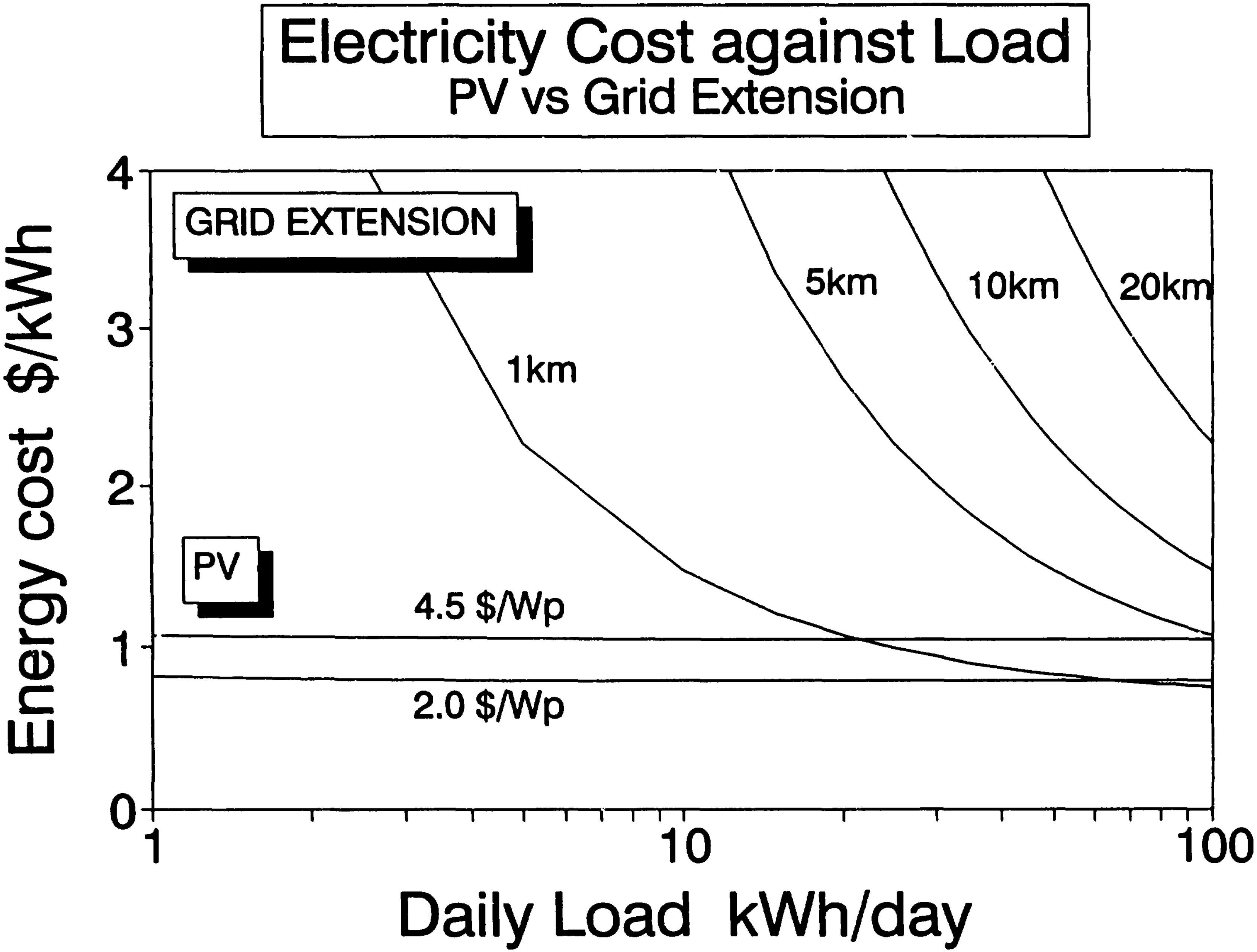

Electricity Cost against Load
PV vs Diesel
DIESEL
PV
0.25
0.5
Fuel price $/litre
PV price $/Wp
4.5
2.0
Energy cost $/kWh
Daily Load kWh/day
0
1
2
3
0
0.5
1
1.5
2
2.5
3
3.5

Fig. 15



Electricity Cost against Load
PV vs Grid Extension
GRID EXTENSION
PV
1km
5km
10km
20km
4.5 $/Wp
2.0 $/Wp
Energy cost $/kWh
0
1
2
3
4
1
10
100
Daily Load kWh/day

Fig. 16

Relevant questions are :

i) Is PV currently used for telecoms in the country. If so in what capacity;

ii) What is the market for battery powered transistor radios;

iii) Does anyone manufacture or import PV radios at present;

iv) What is the extent of radio/TV coverage;

v) Are there any government radio repeater stations and what are their means of power supply;

vi) What is the attitude of the government/military to the use of PV for telecommunications.

3.6.5 Health Care

Health care projects which utilise PVs are similar to water pumping projects in that most installations will be funded and set up as part of a larger programme by aid agencies. A typical installation may be in a rural health centre where PV provides the power for refrigeration and lighting. Refrigeration is essential in immunisation programmes where vaccine must be stored before distribution. Ice packs must also be produced to keep vaccine cool during transit. PV powered refrigerators are highly specialised and it is unlikely that they will be found indigenously. An excellent example of a programme of this nature is the WHO Expanded Programme of Immunisation, which has successfully used many PV refrigerators in Zaire, Uganda, Gambia and other countries.

The market is thus relatively well defined as required by the current and future immunisation and rural health programmes. In this respect PV is acting to replace or compete with kerosene refrigerators, which in comparison are rather unreliable and short-lived.

Relevant questions to be answered are :

i) Who presently runs and funds rural health centres;

ii) How many such centres exist;

iii) What proportion of rural health centres use PV for refrigeration or lighting? What is their typical array size;

iv) What is the level of knowledge/education within implementing agencies concerning the uses of PV;

v) What health programs are currently underway, and what is planned for the foreseeable future.

3.6.6 Navigational aids

This is a niche market and the potential market is relatively small. However, there is scope for PV-powered illumination on buoys and shorebound navigation lights in rivers and harbours. One notable example is a network of navigation lights on the Yangtze River in China. There are also airfields that use PV-powered landing lights.

The size of such market depends very much on the openness of the appropriate government departments to PV, and the need for navigation lights in semi-remote areas. This is likely to be a new market rather than replacement, and so may be more difficult to open. Typical array sizes will be small (ie. 50 Wp or less).

Relevant details may be:

i) How many shore-based and off-shore navigation lights are there in off-grid sites;

ii) Is PV used for navigational purposes by aviation or marine users? If so, how many installations;

iii) Is there a need for more lights? Is the power source a preventative factor;

iv) How receptive to PV are the relevant decision-makers (ie government, admiralty, aviation services).

SECTION IV: CONCLUDING REMARKS

4.1 The PV Market in Developing Countries

An analysis of the present world PV market has shown that the market share of the developing countries is smaller than might be expected. This is particularly the case in Africa, where it can be reasoned that there is the greatest need for PV.

However, the potential market in developing countries is extremely large, but needs assistance in its development. UNIDO (and other international agencies) are in a position to play a major role in opening the market for PV systems in developing countries. As highlighted in the Report, many donor agencies have already financed research, development & demonstration projects. Whilst these activities have not necessarily led to the development of self-sustaining commercially viable markets, it is believed that, with proper research and implementation strategies, it is possible to open up large potential markets in developing countries.

It is thus believed that future activities should give emphasis to:

* making realistic analysis of market potential and requirements;
* identifying and qualifying barriers to market penetration;
* pursuing specific market development actions.

4.2 Market Study Requirements

There is an urgent need for comprehensive market studies to be undertaken in selected developing countries, to assess their market potential for PV. This Report has presented an outline of a methodology which can be developed and used for this purpose.

Power Ltd

The Warren, Bramshill Road
Eversley, Hants. RG27 0PR, UK
Telephone (0734) 730073
Telex 846852 POWER G
Fax (0734) 730820