1. A GENERAL OVERVIEW OF THE WORLD PV SECTOR

1.1 OBJECTIVES, STRATEGIES AND INCENTIVES OF THE INTERNATIONAL ORGANISATIONS

1.1.1 International Energy Agency - IEA

In 1993 the International Energy Agency - IEA established the PVPS Photovoltaic Power Systems programme, involving 15 member countries and other potential participants in a co-operative programme for the research, development, analysis and information exchange addressing specifically the application of PV power by electric utilities.

The IEA PVPS programme is task shared: each participating country devotes its own resources and personnel to carry out its part of the common work programme.

Objectives

The primary objectives of the IEA - PVPS programme are:

- to promote development and demonstration,
- to enhance acceptance,
- to foster market deployment of reliable, cost-effective photovoltaic power system applications by utilities and other public and private users.

Strategies:

The main strategies identified by IEA for the purpose have been:

- to undertake a wide international collaboration on high priority projects for identified market applications;
- to monitor the operation of photovoltaic power systems and subsystems to analyse their performance and to provide guidelines for design improvements;
- to improve the design, construction and operation of photovoltaic power systems and subsystems;
- to introduce planning methods for evaluation of the true value and the benefits of photovoltaic power systems.
- to involve utilities and other public and private users, as well as manufacturers, in the process of identification, selection and management of high priority activities;
- to widely disseminate appropriate information of successful photovoltaic power system applications, including technical economic and environmental assessments.

In addition, this co-operative IEA activity is intended to work on aspects of photovoltaic power systems such as operational performance of components and information exchange on photovoltaic technology economics, and impacts which are relevant in all potential markets.

1.1.2 World Bank

Specifically solar PV technology suffers the lack of adequate financing and loan/credit schemes allowing potential small-scale energy user categories living in non electrified areas, such as rural families and small communities of usually low level of economic development, to overcome the consistent investment initially required for the installation of a Renewable Energy system.

Although, in many regions throughout the world, such potential user categories do face today much higher energy expenses (e.g. for the fuelling of kerosene lamps, for throwaway batteries, etc.) than what would be required to improve their living conditions significantly by purchasing a small-scale solar PV or wind-energy system, they are unable to face the required initial investment since no appropriate loan/credit schemes are offered by the local banks and/or the national financing system.

To face this problem, in August 1989, the Energy Sector Management Assistance Program (ESMAP) of the World Bank, in association with the U.S. Department of Energy (USDOE) and the Netherlands Ministry for Development Co-operation initiated a programme denominated **FINESSE** on **Financing Energy Services for Small-Scale Energy-Users**. This programme was intended to address specifically the above presented financing problems of small-scale energy consumers who traditionally have no direct access to financing possibilities.

Currently, the key sponsors of the FINESSE programme are ESMAP and the U.S. Department of Energy. The Asian and Pacific Development Centre (APDC), the Netherlands Ministry for Development Co-operation, the U.S. Environmental Protection Agency (EPA), the U.S. Agency for International Development, and the U.S. Department of Treasury are participants and co-sponsors of FINESSE, and discussions with other multilateral and bilateral donors over their participation in FINESSE are presently under way. ESMAP is the principal executing agency for the programme as a whole, while APDC is responsible for co-ordinating ASEAN region-specific.

The FINESSE programme focused initially on the ASEAN countries and specifically on **Indonesia, Malaysia, Philippines and Thailand**. If successful, the programme was intended to extend to additional countries in Asia, the Pacific and in other regions world-wide. The promotion of energy conservation and renewable energy sources forms an integral part of the energy development program of these four ASEAN countries. The importance of these objectives derives from continuing uncertainties over fossil fuel availability, recent concerns with the environmental impacts of conventional energy systems and the high energy demand growth rates caused by rapid industrialisation and modernisation of these economies.

Objectives:

The primary objectives of FINESSE are to examine ways of using Intermediary organisations in the developing countries (development finance institutions, commercial banks, utilities, private sector firms, non-government organisations, etc.) to channel multilateral donor funds more effectively for the provision of energy conservation and renewable energy services to small-scale energy end-users. Since these consumers constitute the bulk of energy users in a country, the FINESSE project is expected to have far-reaching benefits through the expanded use of energy efficient and renewable energy technologies.

The goal of FINESSE is to identify "bankable" projects for multilateral development bank (MDB) financing. FINESSE programme activities include:

- Analysing the experiences of intermediary organisation in small consumer lending;
- Assessing market opportunities for energy conservation and renewable energy technologies in the household, commercial, small industrial and agro-processing sectors;
- Preparing business plans for establishing energy conservation and renewable energy enterprises;
- Developing a brochure on cost-effective applications of energy conservation and renewable energy technologies; and
- Preparing a project assistance handbook to assist MDBs and intermediary organisations in designing, developing and implementing energy conservation and renewable energy projects geared to small-scale energy users.

Strategies:

The target beneficiaries of FINESSE are small-scale energy users requiring typically less than about 100 kW electric power or 1 MW of thermal power, although these limits may vary between different countries and/or sectors. Beyond these limits in terms of energy usage, the typical energy user targeted by FINESSE would traditionally not have access to conventional sources of financing for implementing energy conservation or renewable energy projects.

In spite of considerable technical and economic advantages, implementation of energy conservation and renewable energy technologies at the small-scale user level is affected by a number of hindering factors, including lack of familiarity with the technology; inadequate mechanisms to promote consumer awareness; market barriers imposed by subsidised prices for conventional energy and other disincentives; and not adequate in-country supply, distribution and maintenance networks.

Affordable financing is one of the crucial factors inhibiting energy conservation efforts and adoption of renewable energy technologies or services at the small-scale user level. Small-scale energy consumers in both urban and rural areas lack access to affordable credit for acquiring these technologies or services which have low operation and maintenance costs, but require relatively high initial capital investments. Affordable credit availability is hindered by ineffective branch networks of financial institutions in rural areas, bias towards large-scale projects, perceived risks on the part of potential borrowers, and high administrative costs associated with small loans. The willingness to pay for these technologies has also been limited as loan repayment methods have differed significantly from the ways consumers usually pay for energy. Availability of funds for the purchase of alternatives would enable these technologies to be considered on a broader and more equitable basis.

The FINESSE programme recognised that, for many new energy technologies to take off, there is a need to examine existing governmental policies (for example, towards pricing) and institutional arrangements for both energy and financing. The primary concern of the programme is therefore not only to provide for affordable credits to small-scale energy users, but also to catalyse policies, institutional and infrastructural changes that are prerequisites to render such credit effectively deliverable to the end-users.

Financing strategies

The FINESSE programme considers a number of innovative financing strategies such as, financing the establishment of manufacturing plants for energy-efficient appliances; electric utility-led programmes for distribution of energy-efficient fluorescent light bulbs; private sector manufacturing/distribution enterprises for the sale of domestic solar water heaters; micro-hydro or agricultural residue-fired power plants providing electric power to rural communities; co-operative or private sector ventures for the assembly and distribution of photovoltaic systems for rural households; and companies offering shared savings programs in energy conservation to commercial and industrial customers.

The key factor determining the eligibility of a project for financing under FINESSE is that the ultimate user of the supplied energy should be a small-scale energy consumer. If this main eligibility criterion is met, the actual recipients of initial credit may include a series of intermediary organisations, including commercial banks, energy utilities, rural co-operatives, private sector equipment manufacturers, energy service companies and others. Wherever it is necessary to provide secondary credit to the end-user level, the financing strategies for such intermediary organisations will have to provide viable schemes for the purpose.

1.1.3 Africa

1.1.3.1 The Sahel Region Solar Programme (RSP)

The EC Regional Programme for the Use of PV technology in Sahelian Countries was started in 1991 and was intended to harness the only natural resource really abundant in the Sahel, viz. PV Energy.

The Programme aimed at a large-scale introduction, in rural areas, of PV equipment with proven reliability and to prepare thereby the ground for the spontaneous development of a private market for PV applications.

Objectives

On the whole, the Sahel RSP was intended to improve not only the living conditions of rural dwellers by providing them with increasing quantities of water (which could have been harnessed by development of income-generating activities: irrigation, livestock breeding, etc.) but also the overall living conditions of the rural people.

The programme pursued two ultimate goals:

- Short-term improving living conditions and food security in rural areas through water pumping and small-scale electrification schemes.
- Long-term promotion of new production systems more suitable to the needs of environmental preservation and strengthening of the capacity of rural people to organise themselves to overcome environmental constraints

Actions

The programme involved all nine CILSS Countries and was intended to reach out to nearly one million rural dwellers:

- Regarding the supply of safe drinking water, it enhanced the capacity by 30 to 40% of currently existing boreholes with water extraction capacities exceeding 5 m^3/h;
- As regards irrigation, the project made it possible to supply irrigation water to some 300 ha of vegetable farms and 1000 ha of orchards.

Furthermore the Programme was to foster widespread Community use of PV solar energy for such purposes as rural lighting and medical refrigeration and to promote small-scale accumulator recharging plants.

After-sales services

The orderly establishment of after-sales services was a decisive factor for the implementation of the programme and was therefor strongly considered already in the bid appraisal phase as follows:

- Suppliers of PV equipment had to appoint, in each state, a representative in charge of after-sales services;
- The representative had to be a stable and officially registered local company;
- *Package guarantee of maintenance contract*: under this arrangement, the supplier had to give a five-year guarantee for continuous functioning of the equipment, against payment of a fixed lump-sum amount usually on an annual basis. Accordingly he had to take care of all remuneration and transport of maintenance personnel as well as required spare part supplies. Repairs of breakdowns had to be done *within 48 hours after notification* by the village water committee. Payments were to be made by the village water committee *directly* to the local representative;
- Last not least, suppliers were obliged to make available to their representatives a minimum stock of spare parts, to be inspected at any moment by the administration.

Recurrent expenses

To render the RSP sustainable, the operational costs including cost of equipment replacements was to be borne by beneficiaries, with special reference to the following recurrent costs:

- *operational expenses*: salaries of watchmen and caretakers;
- *maintenance and repair costs*: cost of the after-sales service contracts;
- *Replacement costs*: for inverters and electrical pumps. Costs of PV module replacements (if required) were expected to be borne by the beneficiary governments, likewise boreholes and water distribution networks, which have roughly the same life span.

Initial contribution

Right after the formal designing of the project the principle of a substantial initial contribution payment was underlined as one of the bedrocks of the operational strategy of the RSP: this contribution was indeed an effective means of building up a sense of ownership and for ascertaining, even prior to installation of the equipment, that the beneficiary community was effectively motivated and financially capable of shouldering subsequent maintenance

responsibilities. Looking at it from the viewpoint of the supplier or his representative, the initial contribution of the end-users offered also a guarantee that maintenance will be subsequently paid for.

Concentration areas

Installation of a certain number of PV equipment in a given area facilitated the implementation of operational after-sales services at affordable prices for the rural end-user population. As a general rule, the concentration area selected in each country was the operational area of the Village Water Supply programmes under the 6th EDF. On the basis of the specific peculiarities of each country, other concentration areas were then added. The programme covered:

- Supply and installation of 829 PV pumps and 538 community systems including organised provision of aftersales services in each country;
- Conduct of supportive activities identification studies, studies on financial schemes, motivation, training and information, follow up and monitoring.

The RSP supplies were subdivided into three geographical batches, each of which corresponded to one contract:

- batch 1: awarded to SIEMENS Solar, covered Cape Verde, Gambia, Guinea-Bissau, Mauritania and Senegal for a total peak power capacity of 539 kWp;
- batch 2: awarded to PHOTOWATT-TOTAL ENERGIE, covered Burkina-faso and Mali for a total peak power capacity of 490 kWp;
- batch 3: awarded to PHOTOWATT, covered Niger and Chad for a total peak power capacity of 228 kWp;

In view of the total installed peak power capacity of 1257 kWp, the RSP may be considered as one of the largest PV programmes on the globe, specifically as regards stand-alone applications. The supply scheme for each country in terms of number of systems and installed peak power capacity is illustrated in the following table 1.1

Table 1.1- Total peak power capacity (in kWp) and number of systems per type installed in each country

Country	*Installed Peak Power kWp*	*Submerged pumping systems*	*Surface pumping systems*	*Community Systems*
Cape-Verde	67	40	1	37
Gambia	99	50	0	57
Guinea-Bissau	55	42	0	40
Mauritania	119	61	47	39
Senegal	200	61	28	166
Burkina-Faso	211	111	52	55
Mali	279	141	28	40
Niger	124	73	32	39
Chad	104	62	0	65
Total	**1.258**	**641**	**188**	**538**

The main technical characteristics of the proposed systems are provided in table below.

Table 1.2 - Technical characteristics of the installed systems (in Wp)

Application	*Peak Power Wp*
Water pumping	
Irrigation	360-400
Irrigation	540-700
Water supply	700-1080
Water supply	1400-1600
Water supply	2520-2700
Water supply	3240-3800
Community systems	
Lighting: 3 fluo lamps	45-50
Lighting: 8 fluo lamps	135-150
Medical refrigeration	180-300
Ni-Cad R20 accu charger	45-100
Pb battery charger	135-200

Funding

The RSP was financed by the Commission of European Communities for an amount of 34 million ECU, as a non-refundable subsidy. 25,5 million of ECU of the amount were allocated to equipment supplies.

The programme starting in January 1991 and had a foreseen total duration of 4 years. The total cost involved in the provision and operation of the RSP equipment is shared as follows:

- **RSP funding** used for:
  - supply and installation of equipment
  - establishment of after-sales services
  - Regional activities for co-ordination of and support to the implementing agencies.
- **National Host Programme** funds are used for:
  - required local infrastructures such as boreholes, reservoirs, pipeworks and water distribution systems;
  - motivation/awareness raising;
  - monitoring and field execution of the Programme;
- **The End-Users** have to bear the cost of equipment operation, maintenance and replacements.

The costs of equipment are illustrated in the following table 1.3 for each RSP batch and for each type of pump. As an average estimate the following figures may be given:

- Average PV system cost per Wp delivered at the country capital: 5.000 CFAF/Wp (14 ECU/Wp)
- Average Wp cost of installed systems: 7.000 CFAF/Wp (20 ECU/Wp)

Above costs included:

- The supply of all required mounting and assembly accessories including fencing work and outlet Pipes as well as the establishment of aftersales services;
- Prices remained fixed throughout the duration of the four-years contract.

Table 1.3 - Type of equipment, Average cost per Wp of supplies (CIF price), of on-site installation and total cost (in ECU)

Batch	*Type*	*CIF Cost*	*Installation*	*Total*
1	Water supply 700-1080 Wp	22	10	32
	Water supply 1400-1600 Wp	16	7	23
	Water supply 2520-2700 Wp	14	4	18
	Water supply 3240-3800 Wp	12	4	16
2	Water supply 700-1080 Wp	14	5	19
	Water supply 1400-1600 Wp	11	4	15
	Water supply 2520-2700 Wp	12	3	15
	Water supply 3240-3800 Wp	11	3	14
3	Water supply 700-1080 Wp	15	9	24
	Water supply 1400-1600 Wp	12	6	18
	Water supply 2520-2700 Wp	12	5	17
	Water supply 3240-3800 Wp	12	4	16

The table below illustrates the annual maintenance costs for each country and for each type of pump.

Table 1.4 - Country, annual maintenance contract cost for pumping systems (in ECU)

Country	*Water supply 700-1080 Wp*	*Water supply 1400-1600 Wp*	*Water supply 2520-2700 Wp*	*Water supply 3240-3800 Wp*
Gambia	629	720	783	877
Mauritania	809	1.011	1.114	1.317
Senegal	394	483	543	634
Burkina-Faso	503	671	714	757
Mali	849	934	1.049	1.149
Niger	374	406	429	503

Chad	234	617	963	1.691

1.1.4 Asia

1.1.4.1 The Philippines, an outstanding market potential for stand-alone PV applications

Located in South East Asia, the Philippines is an archipelago of more than 7,000 islands, of which 2,500 are populated. The 11 biggest islands comprise 93.15 % of the country's total land area of approx. 300,000 km^2. The majority of the population reside in these islands; the rest is scattered in smaller ones, where population densities are much lower.

The Philippines have a population of about 63 million people; the annual population growth equals 1.9%. The country is a predominantly agricultural nation with its population concentrated in the low land areas. Primary crops are rice, coconut, sugar and maize.

The Filipino archipelago is situated between 6° and 20° north latitude and has steady warm humid temperatures, typical of a marine tropical climate. In the Luzon area, for which measurements of the daily solar energy on a horizontal plane are available, the monthly average values range between 2,7 kWh/m^2 day in to 5,6 kWh/m^2. The lowest value of is reached in August during the rainy season. During the remainder of the year, solar radiation values are rather stable.

In the Philippines, urban centres, especially the capital area, are very modern and have electricity, telephones, cinemas, department stores, restaurants, hospitals and factories. In contrast, the rural areas are still unchanged today. In 1989, only 35 out of 2,500 populated islands had an electricity grid. Consequently, 51 % of the population was not supplied with electricity. Electrification by conventional means is becoming increasingly harder as more remote areas with less dense population are reached by the network.

- **Rural Electrification in the Philippines**

  Rural electrification is a major infrastructure programme of the Philippines government. As a priority programme, rural electrification aims to accelerate socio-economic development in remote areas by providing new and better opportunities for increasing income, facilitating communication and mobility as well as improving the general awareness and self reliance of its people.

  More than 60 % of the total Filipino households live in rural areas. The productive sectors found in the rural areas are agriculture, fishery, forestry and mining. The combined output of these activities constitutes almost a third of the country's total output in terms of GDP. Nevertheless, rural incomes are very low, simply because the rural economy is chained to subsistence. Ultimately, rural development or progress will depend on the provision of infrastructures, such as roads, water, health services, electric power and, of course, education.

  Several observations can be made about the rural energy sector, namely:

  * The biggest energy user is the household sector.
  * The main energy source for the household sector is biomass, especially wood (e.g. firewood, charcoal, coconut shells).

* In agriculture, the main energy source is animate power, both human and animal, whose original source is also biomass and which therefore competes for land.
* Most traditional energy conversion devices have very low efficiencies.
* Most household energy is obtained and used by women.

The rural energy problem is compounded by the following factors:

* a growing population;
* increasing demand for natural resources and thus for land;
* increasing gap between the availability of resources to rich and poor;
* deteriorating state of the environment;
* migration of young people from rural areas to urban centres.

In recent years, the **National Electrification Administration (NEA)** and 118 **Electric Co-operatives** have administered and continue to extend rural electrification to most remote areas of the Philippines. In 1989, they supplied electricity to 2.9 million Philippine households or to 15.8 million Filipinos. Electric co-operatives cover an average of 10 municipalities each with a total population of 100,000 people. Electric services are extended by co-operatives to all prospective consumers in the franchised area, not only in town centres, but also to outlying barrios, provided that the supply of such services does not impair the financial feasibility of the utility's operation.

The weaknesses of the Electric co-operatives may be attributed to the following factors:

* Application of technical and reliability standards which are too costly to be appropriate in rural areas;
* Area coverage philosophy too costly to fulfil;
* Insufficient tariffs to provide revenues;
* Inadequate attention to maintenance;
* Constraints on qualified man-power and material;
* Too many "minimum bill" residential users;
* Resistance of industrial consumers to be connected to co-operatives, prefer connection to National Power Corporation;
* Decaying physical plants;
* Lack of spare parts, tools and service materials.

- **PV implementations in the Philippines**

In 1990, approximately 170 PV systems were installed and operating in the Philippines. These totalled about 40 kWp of installed peak power and cover most known PV applications, such as:

* a 13.3 kWp centralised village PV power plant;
* a domestic water supply system for an island;
* a battery charging facility for a remote village;
* several telecommunication facilities (relay stations) on mountain tops;

* a PV airport marker system;
* various pumping systems for irrigation and drink water supply;
* PV vaccine refrigerators;
* a PV poultry incubator;
* an electronic repair shop supplied by PV;
* a PV video system for educational purposes and use as village cinema;
* PV street illumination;
* PV rural electrification units.

Especially the distributed stand-alone and individual systems (e.g. solar home systems) proved successful in rural villages with scattered populations, where electricity consumption is much lower than what is generally believed. Majority consumption falls in the range of 10 to 30 kWh per month. This basic demand for electricity power can competitively be covered by solar power systems. A Solar Home System of 50 Wp and a daily average yield of 180 Wh suits the electricity needs of a typical rural household, by feeding direct current for 2 fluorescent tubes, a radio cassette recorder and a small B&W television or electric fan. In remote rural areas such PV electrification competes economically much better than the conventional options of a sea cable or an autonomous diesel gen-set.

- **National and International PV programmes in the Philippines**

Since 1977, the Filipino Non-conventional Energy Division (NCED), under the then Ministry of Energy (now Department of Energy), in co-operation with both public and private research institutions, has embarked on studies of various renewable energy applications, including photovoltaics. These were also sponsored by the United Nations Development Programme (UNDP), the United States Agency for International Development (USAID) and the German Agency for Technical Assistance (GTZ).

A first experimental programme aimed at investigating the potential of PV technology was initiated in 1981 and completed in 1989 by the NCED with foreign assistance. It yielded useful information on suitable applications and technologies for "off-the-ground-practical-utilisation" of solar energy systems. The programme's results are the following:

* Installation, monitoring, optimisation and evaluation of a 13.3 kWp central village PV power plant. After the successful implementation, the plant was dismantled.
* First example of dissemination of PV rural electrification units through the formation of a local solar power co-operative.
* Technology promotion through the media, which generated a high public awareness and resulted in curiosity, increased participation and support of government agencies.

- **Lessons learned**

These projects illustrated both the potential and limits of photovoltaic systems in satisfying energy demands, especially in rural areas. In particular, the comparison between the operational results of the 13.3 kWp central PV power station and those of individual, small scale systems have led the NCED to orient future developments mainly towards diffused and individual, small scale applications. The reason for this choice may be summarised as follows:

* **Centralised PV power plants** are economically not competitive as compared to conventional (diesel) power plants. In addition, large PV power plants within the distribution grid present technical complexities similar to that of comparable conventional power plants, requiring skilled personnel for their operation and maintenance.
* **Individual user systems** are simple, entirely autonomous and independent from any external service facility. They are easy to install and operate, therefore requiring little skilled man-power. They are reliable, since they are simple and produce direct current. They are safe, as only low voltage is employed. Most maintenance can directly be performed by the user. In case of failure, only one single user and not an entire distribution grid is affected. All systems are standard, so that spares, installation and maintenance are the similar for all systems.

On the basis of this experience, two major PV dissemination programmes have been implemented since 1990:

* *Filipino-German Photovoltaic Pumping (PVP) Project*

  Within a project period of 4 years, up to 15 PVP systems will be installed to improve water supply conditions in unelectrified rural areas. At present, eight PVP systems have already been installed in selected communities. The technical and socio-economic data will be closely monitored to further develop the technology and to control its impact on rural communities. The project implementors are the Filipino Department of Energy (DOE), the German Agency for Technical Co-operation and the University of San Carlos (Water Resources Center).

* *Filipino-German Special Energy Programme*

  The programme regards the installation of Solar Home Systems and battery charging stations in various unelectrified barangays. Further details are provided in Table 1. The programme implementors are the Filipino National Electrification Administration, the German Agency for Technical Co-operation (Special Energy Programme) and the local Rural Electric Co-operatives.

Other projects commenced since 1990 comprise the following:

* DOE-UP Solar Laboratory
* The Solar Laboratory is an R&D facility supported by the DOE, the University of the Philippines and the National Engineering Center. It also provides technical support for the development and installation of PV systems as well as the testing and quality control of the Balance of System (BOS) components for PV systems.
* Demonstration projects of DOE
* The Department of Energy, Non-Conventional Energy Division (DOE-NCED) provides through its Affiliated Non-Conventional Energy Centers (ANECs) technical and other services to actual and potential users of renewable energy systems in the country-side. Small Home Systems have been installed by the ANECs in selected sites to demonstrate the techno-economic viability of the technology.

Private sector and financing institutions also contribute to the commercial dissemination of PV in the Philippines. In the spring of 1994, the BEL-SOLAR Project was financed by the

Development Bank of the Philippines in co-operation with the Dutch Director General for International Co-operation and the St. Joseph Credit Union of Belance, Nueva Vizaya. Hundred Solar Home Systems and five street light systems were purchased and installed in Belance.

Following the experience gained in the Experimental Programme of 1981-1989, the focus of DOE was shifted to the decentralisation of PV systems and commercialisation. Particular attention was given to viable decentralised energy systems, such as Solar Home Systems (SHS) and PV for telecommunications. These two systems showed the most promising in terms of commercialisation.

Commercialisation of PV systems was first introduced in the Burias Islands; the results demonstrated that PV has a market potential in the Philippines.

The Burias model was also the first established solar power co-operative in the country. PV is now entering the commercial phase of penetration.

- **Factors affecting the use of PV technology**

  The main factors favouring PV technologies on islands result from the high costs of conventional power sources, which are strongly affected by **Remote locations,** the **loss of scale-economy effect,** and the frequently **prohibitive price of fuel and spare part supplies.**

  The dominant factors inhibiting PV technologies are mainly initial investment cost and skill requirements of users, although environmental conditions, location, land acquisition and data availability can be major issues in particular cases.

  * **Initial investment costs** for large PV installations are prohibiting for the majority of the rural population. Therefore, the end users' requirements should be careful analysed before proposing a particular system.
  * **Skilled man-power** is not abundant in remote areas. Therefore, systems having complex operating or maintenance requirements are generally unsuccessful, as the local small population cannot provide or spare skilled man-power.
  * **Land acquisition** can be particularly problematic in the South East Asia, where there exists a customary ownership of the land.
  * **Data** of good quality are essential not only to estimate potential demand, but also to establish the right conditions for site specific technologies. Insolation may vary considerably even on the same island and the viability of solar power projects may critically depend on specific site conditions.

  Social acceptance refers to a whole set of different beliefs, traditions and mentalities not only for a country, but also for each region within it. The acceptance of photovoltaics depends first on human criteria before acknowledging technical ones:

  * The different applications of photovoltaics do not appear to be accepted in the same way.

* By introducing even minimal financial conditions to rural populations, the choice of an adequate target group becomes unnecessary beforehand. Households wishing to buy the technology define the target groups themselves.
* The population's degree of concern for the reliability of PV technology is proportional to the price they will have to pay for it and to its individual or community oriented character.
* A link exists between the social behaviour of the implementors of a project and the degree to which a new, unusual energy source will be accepted.
* Foreign sponsored projects usually face a dual reaction:
* Apparently sceptical and disinterested inhabitants, when they have already experienced unsuccessful development projects.
* Expressions of interest, if not through the goals they may offer, then through the income possibilities they may present. This foreign currency effect could bias the projects' perception of social acceptance.

The degree to which a project is accepted can be measured through:

* The village's assessment of which land could be donated.
* The landowner's agreement and the paper processing of the land donated to the community's project.
* The population's willingness to spend some of their income on one of the project's activities.
* The future trend of the households' attitude towards the loan they contracted.
* The trend of the demand for solar home systems and battery package loans.

- **Conclusions**

Programmes for the development and promotion of using PV technology should consider the following:

* Non-conventional energy systems find their most viable applications in rural and/or remote areas.
* The intended beneficiaries of the projects must be involved in the planning and implementation of the projects.
* A thorough socio-economic and social implantation analysis must be made to obtain valuable inputs for the design of the project.
* In view of the novelty of the technology, mechanisms to provide maintenance and repair service support to rural users should be established.
* In addition, continued research and development to further improve the appropriateness of systems for local environmental and social conditions should be conducted.
* Application of non-conventional energy technologies should be implemented in "free competition" with both conventional and traditional energy systems.
* The local manufacture of non-conventional energy equipment and devices should be encouraged.
* A favourable market environment for both buyers and sellers of non-conventional energy systems should be induced.

* Projects which can bring desirable social and environmental impacts to the country, especially rural areas, should be supported.

1.2 TECHNICAL REGULATIONS AND STANDARDS

Due to the very wide application range of PV technology, the technical regulations potentially applicable to PV technology embrace a large variety of subjects including the specific regulations applicable to each specific envisaged application.

Generally speaking the following general regulations may be expected to be somehow correlated and applicable to PV technology:

- specific PV technology standards;
- general safety and specifically electrical safety;
- technical quality standards;
- building standards;
- utility grid interfacing;

As with any conventional technology, it is growing market demand which usually generates the need for norms, reference standards and regulations allowing to evaluate the technical quality and performance of a technology device.

As regards PV technology, related developments of standards and regulations have concentrated, until today, on the following issues:

a) Module Qualification Testing

b) PV System Monitoring.

There are, however, still other subjects requiring the development of reference standards and regulations, such as:

- PV system design quality, configuration selection and sizing appropriate for application;
- PV BOS (= Balance Of System) component quality standards

1.2.1 CENELEC

An agreement on Co-operation between the European Committee for Electrotechnical Standardisation (CENELEC) and the European Photovoltaic Industry Association (EPIA) was signed in Brussels on July 7th 1995.

The Agreement was made possible by the intervention of DG XVII's C.2. Unit responsible for ALTENER activities.

1.2.1.1 IEC - International Electrotechnical Committee

IEC as the ultimate international body responsible for norms and standards concerning electrical components and systems, in its meeting in Tokyo 1992, decided to create a special Technical Committee denominated TC82, to deal with all aspects of Photovoltaics. As a result, TC82 immediately set up the following three Working Groups:

- WG1 for PV technology,
- WG2 for PV cells and modules
- WG3 for PV systems.

The Working Groups produce draft standards, which are circulated by the TC82 Secretariat to National Standard Committees for comment.

On the basis of these comments, TC82 (which meets every 18 months) either approves the draft for final voting by the National Committees or returns it to the WG for further elaboration.

If the final voting (for which there is a 6 month period) is favourable, the draft is released for publication.

Due to this lengthy procedure, it is often necessary that a draft is used as a de-facto standard in the mean time.

At present such TC82 draft releases address specifically two fields within PV technology:

a) Module Qualification Testing
b) PV System Monitoring.

CENELEC holds the institutional responsibility (Directive 83/189/EC) for proposing, adapting and editing the European Electrotechnical Standards for products and services brought on the European market. CENELEC and EPIA agreed to co-operate in all fields of electrotechnical standardisation related to the applications of PV technology.

1.2.2 European Community - ESTI- JRC Ispra

Already in 1978, i.e. long before TC82 was created by IEC, module testing activities were started at the ESTI (European Solar Test Installation) at the JRC (Joint Research Centre) Ispra.

At first, procedures developed by the Jet Propulsion Laboratory (JPL) in Pasadena (USA) for space applications were adopted.

However ESTI very soon identified the need for qualification standards appropriate for terrestrial applications.

Since then ESTI has given a substantial contribution to PV standardisation as regards specifically PV module qualification testing and PV system monitoring as described below.

1.2.3 PV module qualification testing

As regards PV module qualification testing, throughout the years, several important official documents and draft standards have been developed for the purpose, which include (by order of publication):

- "Jet Propulsion Laboratory, Block V"-USA.
- "Norme française NFC 57-101,102,103, relative aux modules photovoltaiques au silicium cristallin pour applications terrestres" (1982).
- "Qualification test procedures for crystalline silicon photovoltaic modules", specification n° 503 CEC-JRC- Ispra.
- "IEC 1215", The International Electrotechnical Commission, Technical Committee 82, Working Group 2: joint efforts from USA, Canada, France, Germany and Japan have allowed to issue this document, very similar to spec. 503 CEC-JRC.
- "Interim qualification tests and procedures for terrestrial Photovoltaic thin film flat-plate modules" NREL, USA.

Except for the last mentioned reference standard, all the previous ones refer specifically to **crystalline silicon photovoltaic** modules, whereas the last mentioned refers for the first time to thin film flat-plate PV modules.

As mentioned above ESTI - JRC Ispra, already in the early eighties, identified the need for a PV module qualification standard appropriate for terrestrial uses and started therefor to develop a procedure and a related document (Specification 501) for the testing of crystalline-Si flat-plate modules. Spec. 501 was then accepted by the CEC as the official test procedure for modules to be used in EC financed projects.

All module qualification work up to 1984 (in particular, for the first PV Pilot Programme of DG XII) was performed using Spec. 50l. In 1984 IEC/TC82/WG2 took over the work for the drafting of an international standard on module testing, and this resulted in some modifications of the original ESTI Spec. 501, which was substituted by Spec. 502 and finally (in 1989) by Spec. 503.

This latest version became at the same time became the IEC/TC82 draft, which was officially accepted in 1993 as IEC Standard 1215 for the qualification testing of flat-plate crystalline Si--Modules.

Other new drafts are expected to be introduced as a result of the development of new module technologies, such as concentrator devices, new thin film materials, etc. ESTI has already proposed its Spec. 701 for the qualification testing of thin-film modules (a-Si) to be circulated as IEC draft.

However, it has to be emphasised here that **amorphous silicon modules have caused serious problems to standardisation Committees**, as for their tendency to degrade under natural sunlight conditions (light induced defects in a-Si:H, also called Staebler-Wronski effect).

Special groups of researchers are therefor presently investigating the subject throughout the world, to stimulate experiments and to co-ordinate interpretations, such as SMART in the US, SESAME in Germany, and EMMA in France.

1.2.4 PV system monitoring

The importance of PV system monitoring was already recognised during the first EC PV Pilot Programme. The main objectives of this first programme were:

- to demonstrate that PV systems are a reliable energy source,
- to identify weak system components,
- to improve system design methods (optimising a PV plant for given site and application),
- to identify operational procedures (such as battery and load management) that optimise the efficiency of an existing installation, and
- to establish evaluation methods for comparing PV systems with other energy sources in economic terms.

To facilitate the implementation of PV monitoring and to produce sets of comparable data, ESTI founded (under EC financing) the European Working Group for PV Plant Monitoring, consisting of a group of selected PV experts.

This group has developed (and updated) a set of Guidelines for the Assessment of Photovoltaic Plant performance consisting of two documents:

- **Document A**: Photovoltaic System Monitoring, which specifies the technical requirements to be followed for:
  - the type of data recording to be implemented on site (analytical or global),
  - the set of parameters and measurement procedures, and
  - the modalities for data transfer to the collecting centre (medium and format);
- **Document B:** Analysis and Presentation of Monitoring Data, which gives recommendations for the analysis and evaluation of recorded data, defining 'Figures of Merit' and specifying a standard format for periodic summary reports.

In 1990 Working Group WG3 on PV-systems of IEC/TC82 circulated a draft on PV Monitoring guidelines, revised several times in the following.

Since, however, this draft has not yet been accepted as a definite standard, the European Working Group for PV Plant Monitoring has updated its Guidelines by including the generally accepted parts of the IEC-draft.

Thus until the final version of the IEC document are available, Documents A and B of the European Guidelines continue to be used as a de-facto standard within the EU, as well as by many researcher groups outside the European Union.

1.2.5 Missing quality Standards for PV systems, typical application designs and BOS components

Unfortunately, since Photovoltaics is still a young technology branch, and most commonly used conventional (non-PV) norms and standards have been developed prior to the development of this new technology, they usually do not take into account the specific requirements of PV applications and particularly those addressing appropriate system design, configuration and BOS (Balance of System) components.

The result is that, since reference standards are missing, in may cases, it is difficult for non-PV-experts to evaluate the technical appropriateness of solutions being proposed for a PV application.

Specifically, the evaluation of alternative bids offered by different competing suppliers requires the evaluator to examine also, whether the technical quality of the offered system configuration, and specifically of BOS components, satisfies the envisaged needs.

Actually, in the large majority of cases, **poor performance of PV systems is not caused by non mature PV module technology, but due to cheaper and apparently equivalent low quality BOS components**. Once installed, such **lower quality BOS components become, during operation, the weakest link of the chain,** but their failure induces people to believe that PV technology is not yet mature.

Since non-expert purchasers are frequently unaware of the implications deriving from the selection of low quality BOS components, they do not define sufficiently severe requirement specification for these, but focus only on the PV modules.

The result is that, during competitions, suppliers often tend to offer BOS components of cheapest and lowest possible quality, just sufficient to satisfy the purchasers' requirements, since otherwise their competitor will be able to make a better price and have the contract awarded.

Once the relatively short guarantee period for the BOS components has expired (typically 1 year or even less - PV modules are instead guaranteed for several years), in case of a BOS component failure the purchaser is frequently left without assistance with his broken down PV system, although his high cost PV modules are perfectly operating.

Norms and reference standards facing this specific problem of PV technology **are presently still missing.**

1.2.6 Electrical safety standards applicable to PV technology

Electrical safety standards govern the erection of electric installations in buildings with respect to electric safety. They define requirements for procedures to be followed as well as for components and equipment covered also by other standards. Most related national standards comply and are harmonised with the international standard IEC 364, the most important issues of which are the following:

- protection of human beings against electric shock;
- protection of equipment and immediate surroundings from fire hazard due to overload and short-circuit conditions;
- protection from overvoltage;
- requirements for equipment and components;

Electrical safety standards distinguish generally between installations accessible to laymen, and electrical facilities accessible only to technically qualified personnel. To the latter (e.g. utility owned plants) less stringent requirements apply. However, since PV technology is intended to reach widespread and diffused application in locations accessible to the public, the more stringent requirements are necessarily to be applied.

1.2.6.1 Protection of human beings against electric shock

Standard considers provisions to ensure general safety under normal operation and it gives provisions to ensure personnel safety in case of faulty equipment or installation.

For safe operation under normal conditions it requires protection from *direct contact*, as well as (in case of an insulation failure) protection against *indirect contact*.

Details may be found in IEC 364-4-41 or the German VDE 0100 Section 410.

According to these standards, any electrical equipment and appliance must be marked with a label stating clearly the *protection class* of the device and, accordingly, which *protective measures* are to be applied.

The protection classes of interest to PV technology are the following:

1. *Extra-low voltages (SELV/PELV - protection class III)*

   Defines the voltage limits within which it is possible to touch a life circuit part without risk to human life (50 Vac or 120 Vdc maximum voltage level). Accordingly, for equipment and electrical system operating within such voltage limits, no protections means are required to protect human life against shock hazard.

2. *Protective insulation (protection class II)*

   Under this class, electric safety relies on a double or reinforced insulation. Generally electric equipment and components classified under safety class II have to withstand a high test voltage (approximately 4000 V for equipment rated for 230 V design voltage) and their mechanical durability must be appropriate for the intended use. Most household appliances

having a plastic casing or enclosure fall under this category (hairdryer, razor, power drill, etc.).

3. *Automatic disconnection or warning (protection class I)*

   Equipment classified hereunder relies for safety on a grounded, metallic enclosure which, even in case of an insulation failure, ensures voltage levels near to ground potential. Furthermore, the resulting short-circuit current trips a fuse or other protective switching device. All equipment for this protection class needs a metallic enclosure and a terminal to connect the PE (grounding) conductor. Larger household appliances with a metal housing (e.g. washing machines) fall under this category.

4. *Electrical separation*

   In case of utility grid connected equipment, protection is ensured by a safe electrical insulation between grid and equipment, for example by means of a special isolating transformer. Switches, relays, etc. located in the main power path must fulfil the same specification for electrical separation as the transformer.

1.2.6.2 Protection against overload and short-circuit conditions

To prevent fires caused by overloads or short-circuits, appropriate protective measures are defined by IEC 364-4-43 and IEC 374-4-473 (German VDE 0100 Section 430). They essentially require suitable fuse or circuit breakers to be installed on each circuit to be protected. In some application, disruption of current under normal operation is not desirable or feasible, e.g. excitation circuits of electric motors, current transformers, connections from batteries to control boards. In such cases the installation has to be done in a way to virtually exclude the occurrence of an overload or short-circuit condition. In such case, standards explicitly define permitted wiring concepts called *ground-fault-proof and short-circuit-proof* wiring by means of:

- Rigid conductors, where mutual contact and contact to grounded conductive parts is excluded e.g. by sufficient distances or by mechanical fixtures.
- Single-conductor cables, where a mutual contact and contact to grounded conductive parts is excluded e.g.:
- Single-conductor cables built for higher insulation capabilities (e.g. H07RN-F).
- Accessible cables placed apart from combustible materials, where the hazard of mechanical damage is excluded by appropriate measures (e.g. installation in locked electric facilities).
- Cables and wires which may burn without a hazard for their surroundings are considered to be equivalent to ground-fault-and short-circuit-proof installation (e.g. underground cables).

1.2.6.3 Lightning and overvoltage protection

General requirements for lightning protection are also usually defined by standards, intended to limit damage to electric installations due to lightning strikes by reducing surge voltage across the cable insulation.

This is achieved by a through *potential equalisation bar,* to which all active parts are electrically connected

1.2.7 Conflict areas between electrical safety standards and PV technology

1.2.7.1 Peculiarities of PV technology

For better understanding the main peculiarities and differences between a PV generator and common practices resulting from the power supply characteristics of the public utility grid (mains) are recalled as follows:

- A PV generator acts like a *current source,* while the public grid mains provides a *voltage source*. As a result, a **PV generator is intrinsically short-circuit-proof** and cannot overload its connection wires. Furthermore, since its nominal short-circuit current (I_{sc}) is only 1.2 time higher than its nominal operating current (I_{mpp}), **it cannot trip common overcurrent protection devices like fuses or circuit breakers.**
- During daylight conditions, **a PV generator cannot be switched off**. If a PV generator is disconnected from its load (apparently switched off), full open circuit voltage will be present during daylight. For this same reason, leakage currents due to insulation failure are very difficult to be disrupted.
- **A PV generator is a DC source**. There is no zero crossing of current (like in AC-systems), which supports all interrupting actions and helps to extinguish electric arcs. In combination with the aforementioned *current source* characteristics PV systems present a specific risk of stable arc development (which usually causes fire), if an insulation fault develops.
- According to interpretations adopted in some countries **PV modules cannot comply with the double or reinforced insulation requirements of protection class II** since the front glass layer is considered a single and not reinforced insulation means.

Accordingly, latest standard developments in Germany, and specifically as related to VDE 0100 Part 7xx, address these issues specifically as follows:

1.2.7.2 Protective measures for Personal safety

- In case of very small PV systems (below 1 kWp) protection by low voltages (protection class III), i.e. maximum voltage limit of 50 Vdc and 120Vac is preferably to be applied to the generator's Voc at standard reporting conditions (SRC). In case of grid connected (e.g. small-scale rooftop) applications, to classify the system under same protection class III, the inverter needs a special isolating transformer as specified in IEC 742 (VDE 0551), and compliance with this requirement must be declared in the manufacturer's data sheet.
- Protection by automatic disconnection (e.g. in case of an insulation fault) is difficult to realise since, as mentioned above, a PV generator cannot be switched off during daylight.
- In all cases where SELV and PELV low voltages according to class III are not reasonable as for resulting too high current ratings (i.e. PV generators of more than 1-2kWp power rating), protection class II appears to be most reasonable and convenient for PV systems and components. PV module manufacturers are therefor discussing with standardisation authorities how to develop PV modules in compliance with protection class II, and how to interpret the relevant requirements.

- Combination of ground-fault and short-circuit-proof wiring allows to exclude virtually the occurrence of ground faults and shorts in the PV generator, permitting thereby simplifications in overload and short-circuit protections.
- Protections against indirect contact may be considered not required (regardless of operating voltage) if a PV generator is placed out of reach. In Germany, this criterion is interpreted as applicable to rooftop installations since "out of reach" is considered fulfilled in case that the system is installed at least 2.50 m above the plane of access. People who have access to the roof must however be cautioned by warning signs.
- In Germany, if the above requirement (Out of reach) is fulfilled, PV modules having only basic insulation (not corresponding to protection class II) may be used for PV generators rated above 120 Voc. However, since some elder PV module types presented non-negligible risks of ground faults during normal services, at present this concept is not recommended without further safety device, i.e. specifically a continuous isolation monitoring.
- As compared to conventional electric installations, a PV generator presents special risks of hazard for maintenance workers, since it cannot be switched off. Therefore, if the nominal open-circuit voltage of the system is above 120 Vdc, during cabling as well as during maintenance, measures must necessarily be taken to reduce this risk as follows:
    - Working at night
    - Effective covering of the PV generator (complete and reliable darkening of PV cells must be achieved) to reduce significantly the open-circuit voltage;
    - Splitting strings into sections of individual Voc below 120 Vdc. This is achievable by providing disconnectable terminal blocks at the envisaged string intervals.

Protection class II defines certain insulation test voltage levels depending on maximum permissible system voltage according to the formula presented below.

Both these parameters must therefor be clearly stated on module label.

$$V_{test} = 4 * Voc, max + 2000\ V$$

Another important requirement for protection class II modules is a sufficient mechanical durability. While glass-glass-modules are usually considered in compliance with this requirement, PV modules with Tedlar backsheet are more prone to incidental damage. To assess their susceptibility to cutting, the *cut test* specified in the US standard UL 1703[1] is adopted as *protection class II* test specification.

Class II equipment must not have a PE (grounding) connection. Nevertheless, a protection class II module may have a metallic frame. If this frame is considered not a part of the active module, but simply an external mounting facility, the protection class II requirement of having no ground connection is not infringed.

The issue of class II requirements for PV modules have therefore been brought to the concern of the IEC Committee TC 82.

1.2.7.3 Overcurrent and short-circuit protection

Conventional overcurrent protection means (fuses or circuit breakers) do not work in PV systems, since the PV generator is inherently current-limiting. Accordingly, if correct sizing of all source conductors is assumed, it is not possible to overload a wire under normal operating conditions. Proper sizing means: string cables must be rated for the module Isc (at RSC), and the main PV generator connection to the inverter must be rated for the Isc of the entire PV generator.

Only in case of an insulation fault in a string cable, which shorts the current generated by more than one string of same PV generator, the involved string cable will be overloaded. **Ground-fault-proof and short-circuit-proof wiring,** together with a string fuse allow to prevent the system from this kind of risk. Accordingly, ground-fault and/or short-circuit proof wiring according to VDE 0100 Section 520 are to be employed, which means that "+" and "-" wires are to be kept separate, either by an appropriate spatial arrangement or by mechanical barriers along cableways as well as inside junction boxes and electrical cabinets.

String blocking diodes are commonly used in battery buffered stand-alone PV systems, since they allow to avoid reverse current flow from the battery through the PV generator during the night, and to prevent thereby the battery from undesired discharge. In case of grid connected PV systems without battery, there are doubts regarding the need For string blocking diodes. If ground-fault and short-circuit-proof installation wiring are applied, under normal operating conditions the blocking diodes are useless. Only in case of a multiple ground-fault a blocking diode can prevent reverse current flow into this partially shorted string. As a consequence the draft code permits to omit string diodes under certain defined conditions.

1.2.7.4 Overvoltage protection

According to German regulations, a PV generator installed on the roof of a building does not increase the risk for same building to suffer a lightning strike. The additional installation of an external lightning protection system is therefore considered not necessary. However, likewise any other metallic structure, the mounting structures of a PV generator on a roof must be included into the potential equalisation system of the building.

Although a direct lightning strike is very unlikely for most PV installations (this is therefor not a stringent requirement.), a protection against induced overvoltages should be foreseen by installing Varistors towards ground in every leg of the PV generator

It should be noted, however, that Varistors may change their characteristics under overload conditions. on the long-term, this may result in a permanent loss of current through the Varistor, which again may lead to overheating and fire. This hazard should be accounted for by regularly monitoring the leakage current or by adopting Varistors with an internal overheating protection.

1.2.8 Utility grid interface regulations

1.2.8.1 General considerations

To protect their contractual interests as well as own technical facilities (the electric grid) from risks of harmful interactions between the grid and connected consumers and self-producers, utilities throughout the world commonly adopt precise standards and regulations, which define how and under what circumstances consumers and self-producer facilities are to be connected to the utility grid.

The grid interface represents the contractual battery limit between the facilities of the utility and those of any consumer and/or self-producer connected to the grid. The technical requirements defined by the utility for the purpose have different aims and purposes as follows:

- **Contractual**: They define the terms, conditions and technical devices to be installed at the interface, allowing both parties (the utility and the connected consumer/self-producer) to measure and monitor exactly the active and reactive energy flows going in and out from the consumer/self-producers facility.
- **Protection of consumer's/self-producer's facilities** from disturbances, damages and/or danger to human beings originated by the electric grid. A typical example may be a lightning strike entering a transmission line of the electric grid, which may affect the equipment and facilities connected to the relevant electric grid section.
- **Protection of electric utility grid** from disturbances, damages and/or danger to human beings originated by the **facilities of the consumer** and/or **self-producer**. A typical example may be again a lightning strike, but entering the facility of a consumer, the propagation of which to the electric grid as well as to other consumers must be avoided.

Particular care is paid by utilities to this second aspect, since relevant non adequate performance of protection devices may not only cause damage to the facilities (properties) of the utility but, what is more, be harmful (lethal) to maintenance staff of the utility working on grid sections apparently isolated from any power source of the utility but, if connected to a self-producer, unexpectedly may become energised.

1.2.8.2 Critical subjects as related to PV technology

The critical areas, where common practice and grid interfacing regulations may be considered somehow in conflict with the requirements of PV technology may be summarised as follows:

- Grid interface regulations allow mostly only for **large size rotating generators:** Since grid interfacing requirements and standards developed by utilities have followed the historic evolution of usually large scale generating facilities, they are generally designed taking into consideration the technical peculiarities of larger size rotating generators such as turbogenerators, diesel-, hydropower turbine driven generators. Inverter connection to the grid (as required by grid-connected PV installations) is therefor either not foreseen at all, or else limited to the traditional inverters of natural commutation type (triggered by external utility grid frequency reference).

- **Islanding prevention/safety**: To protect the maintenance staff of the utility working on grid sections isolated from any utility power source of the utility, self-producer facilities are allowed to be connected in parallel to the grid only if intrinsically unable to operate as an island grid. This means that, as soon as the reference voltage and frequency coming from the utility grid are no more available (due to failure or switch-off on the utility side) the selfproducer facility must switch off simultaneously. This is the reason why in many countries, at present, only traditional natural commutation type inverters are accepted to be connected to the utility grid.

- **Harmonics injection**: The subject of harmonics being injected into the grid by many types of user appliances such as fluorescent lamps, dimmers, controlled rectifiers, etc. is presently being discussed between utilities and electric equipment manufacturers. Same subject applies also to inverters connected to the grid, whereas naturally commutated inverters are characterised by much higher harmonics as compared to modern self-commutating inverters (which, however, are not accepted by many utilities as for the above mentioned safety reasons).

- **Connection to 380Vac/220Vac low-voltage grid not accepted**: Grid interface requirements of many utilities do not foresee the possibility to connect a small-scale self-producer facility to the low voltage grid, but foresee **only connection to the medium voltage grid** (typically above 10.000 Vac). Furthermore, **three-phase connection is usually required.** As a result small-scale self-producer facilities of only few kW generation capacity (e.g. typical grid-connected PV rooftops) are either simply not allowed to be connected, or else discouraged by such stringent (and costly) technical requirements, that grid connection becomes economically not reasonable.

The result is that, in many countries, the lack of adequate grid interfacing regulations becomes an **insurmountable barrier** for a private customer of a utility, who wishes to install a small grid connected PV system on his roof.

1.2.8.3 Newly developed German regulations

At present only utilities in Germany, Austria, Switzerland and Netherlands are known to **have developed draft requirement specifications allowing small scale self-producers to be connected to the low voltage grid**. Specifically the German VDEW (Vereinigung Deutscher Elektrititaetswerke = Association of German Utilities) has issued in 1991 a first document called "Richtlinien fuer den Parallelbetrieb von Eigenerzeugungsanlagen mit dem Niederspannungsnetz des Elektrizitaetsversorgungs-unternehmens (EVU) (Guidelines for operation of selfproducer facilities in parallel to the low voltage Utility grid). These guidelines face the above presented problem areas, and have created the basis for the **German 1000 PV roof programme,** as well as for the development of similar PV rooftop programmes in the above mentioned countries.

1.3 OVERVIEW OF THE PV INDUSTRY (SUPPLY SIDE) IN THE WORLD

1.3.1 PV manufacturer status 1994

The following tables and graphs provide a synthetic overview over the development status in 1994 of the PV sector (supply side) in the world.

Table 1.5 - Number of PV Manufacturers per geographical areas (1994)

	Number of manufacturing producers							
	Crystall. silicon	*Ribbon*	*A-Si*	*CdTe*	*CIS*	*Other*	***Total***	*Only Module Assembly*
Europe	11		6		1	1	**19**	4
USA	7	1	5	2	4	5	**24**	4
Japan	9	1	5	1		4	**20**	4
Rest of the world	14		3				**17**	17
TOTAL	**41**	**2**	**19**	**3**	**5**	**10**	**80**	**29**

Table 1.6- Production Capacity of PV Manufacturers per geographical areas (1994)

	Production Capacity of PV Manufacturers in MWp							
	Crystall. silicon	*Ribbon*	*A-Si*	*CdTe*	*CIS*	*Other*	***Total***	*Only Module Assembly*
Europe	26,7		5,0				**31,7**	4,1
USA	28,0	1,0	22,0	10,0		0,3	**61,3**	
Japan	10,2		14,0	1,0			**25,2**	
Rest of the world	7,0		5,0				**12,0**	12,0
TOTAL	**71,9**	**1,0**	**46,0**	**11,0**		**0,3**	**130,2**	**16,1**

Figure 1.1 - Distribution of number of PV manufacturers per geographical area (1994)

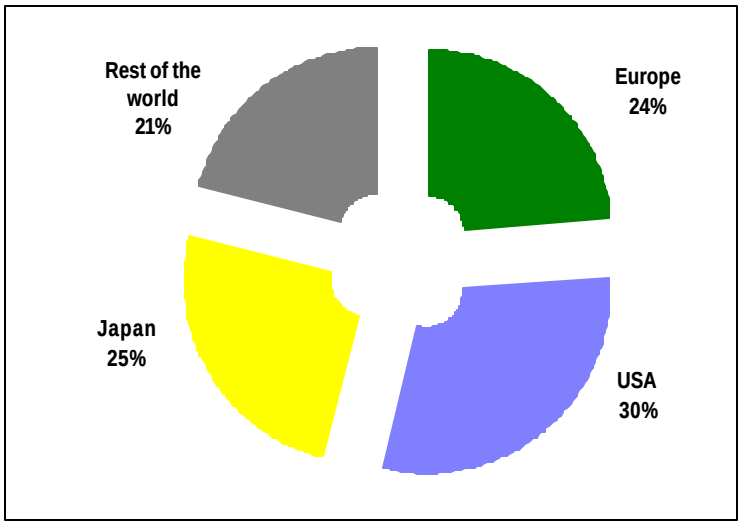


Figure 1.2 - Distribution of production capacity of PV Manufacturers (excluding only module assembly manufacturers) per geographical area (1994)

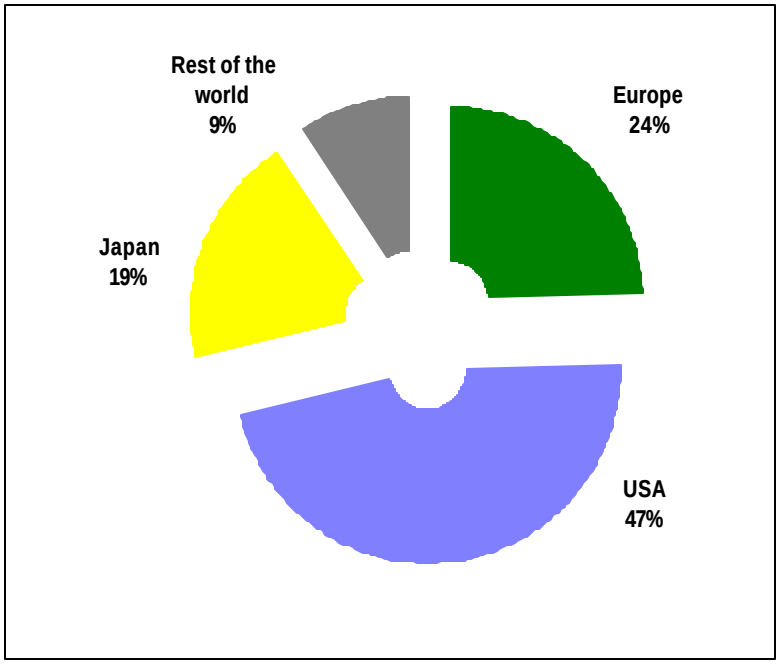
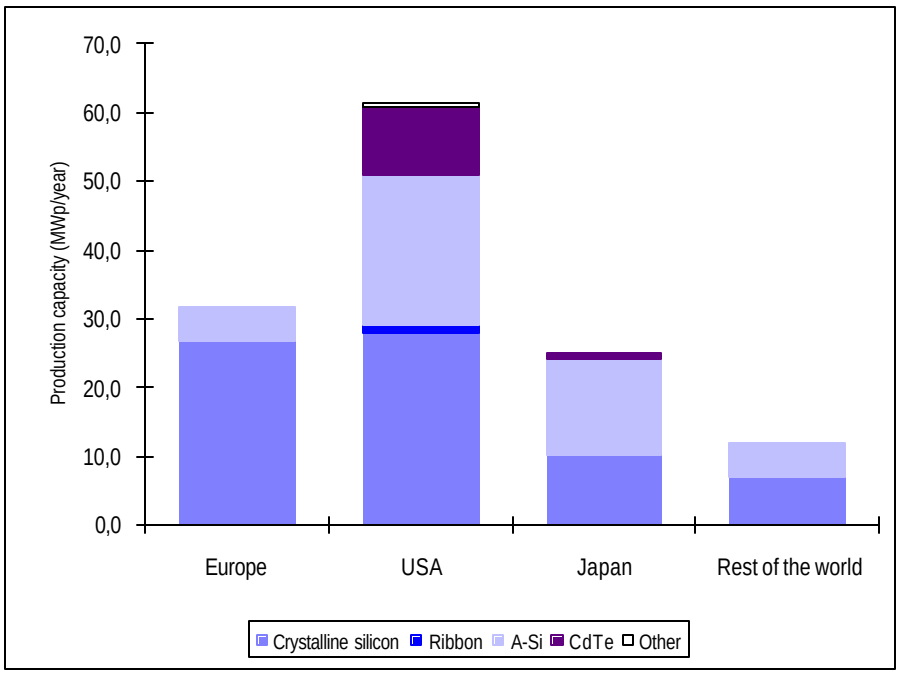


Figure 1.3 - Production capacity of PV Manufacturers (excluding only module assembly manufacturers) per geographical areas and technology (1994)



1.3.2 PV shipments 1987-1994

The following table 1.7 and graph 1.4 provide a synthetic overview of the development of PV shipments from 1987 till 1994

Table 1.7 - Estimate PV Industry shipments per year and cumulative period 1987-1994

Geographical Area	*Production Capacity of Cells Manufact.*	*Estimated annual Shipments in kWp*									
	Mwp/year	*1987*	*1988*	*1989*	*1990*	*1991*	*1992*	*1993*	*1994*	*Cumulative 1987-1994*	
										kWp	*%*
Europe	31,7	4.700	7.100	7.900	9.800	12.100	16.000	16.900	21.700	96.200	24,6%
USA	54,0	9.300	13.000	14.400	16.100	17.000	18.400	22.300	25.400	135.900	34,7%
Japan	25,2	11.000	10.800	15.100	17.700	18.500	17.300	16.900	16.500	123.800	31,6%
Rest of World	12,0	2.900	3.000	3.500	4.500	5.700	5.000	5.100	6.200	35.900	9,2%
TOTAL	**122,9**	**27.900**	**33.900**	**40.900**	**48.100**	**53.300**	**56.700**	**61.200**	**69.800**	**391.800**	

Figure 1.4 - Annual PV industry shipments

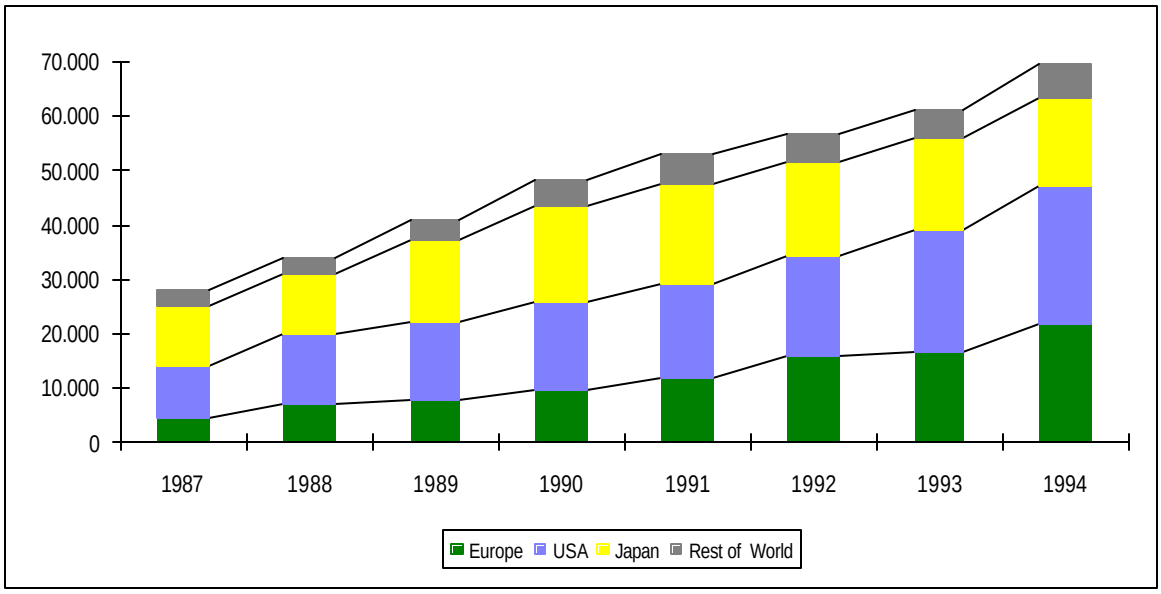


Table 1.8 - PV Industry market shares period 1987-1994

	BEHAVIOUR IN TIME OF MARKET SHARES								
	1987	*1988*	*1989*	*1990*	*1991*	*1992*	*1993*	*1994*	*Average 1987-1994*
Europe	17%	21%	19%	20%	23%	28%	28%	31%	24,6%
USA	33%	38%	35%	33%	32%	32%	36%	36%	34,7%
Japan	39%	32%	37%	37%	35%	31%	28%	24%	31,6%
Rest of World	10%	9%	9%	9%	11%	9%	8%	9%	9,2%

Figure 1.5 - Behaviour in time of market shares of PV producers per geographical area

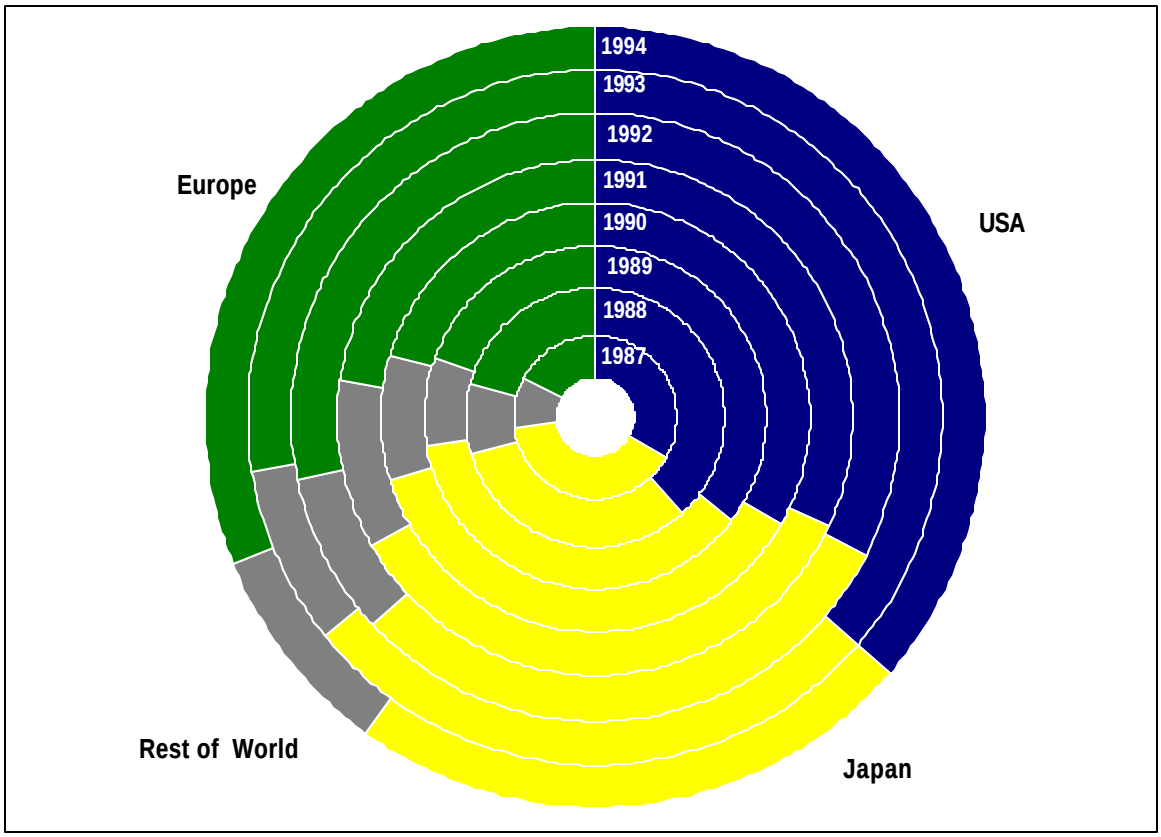
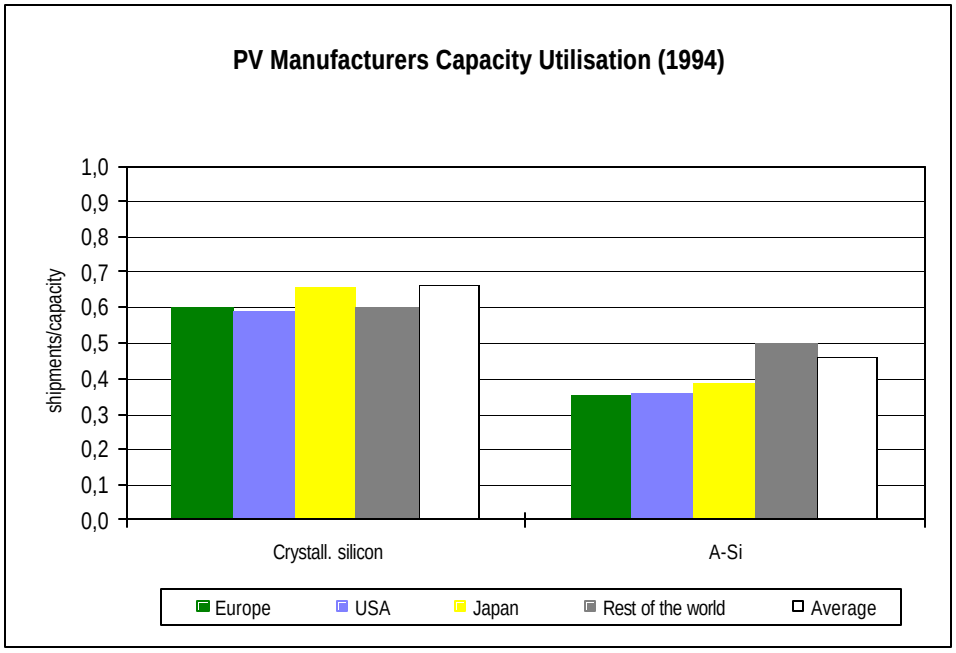


Table 1.9 - PV Manufacturing Capacity Utilisation (1994)

Geograpphical Area	*PV Manufacturing Capacity Utilisation (shipments/capacity)*						
	Crystall. silicon	*Ribbon*	*A-Si*	*CdTe*	*CIS*	*Other*	***Average all technologies***
Europe	0,60		0,35				**0,56**
USA	0,84		0,36				**0,59**
Japan	0,66		0,39				**0,50**
Rest of the world	0,60		0,50				**0,58**
Average	**0,75**		**0,46**				**0,57**

Figure 1.6 - PV Manufacturing Capacity Utilisation (1994)



1.4 MARKET OVERVIEW FOR MAIN APPLICATION SEGMENTS (DEMAND SIDE)

1.4.1 Definitions

For the purpose of the present investigation, the market demand for PV technology has been subdivided into the following three main market segments:

a) Large and medium size PV plants (bulk power);

b) Grid-connected small-scale applications, typically PV rooftops, building facades, etc.;

c) Stand-alone applications;

The reasons for this subdivision may be summarised as follows:

Generally speaking, the **grid connected PV plant market is generally not a free market**, but mostly supported by public financing. This is because, at present, the cost of PV power (expressed in monetary value per kWh of produced electricity) cannot compete with the kWh price paid by electricity consumers to the utility and accordingly, from economic point of view, a grid connected PV facility can never recover the required initial investment.

Similar considerations apply also to **larger stand-alone systems**, since such larger systems have to compete economically either with a grid extension or with a larger diesel-power plant configuration, and both these alternatives present marked scale-economy effect, i.e. the larger they are, the cheaper the alternative conventional electricity will be (while PV power presents very little scale economy effect).

Furthermore, since the market share of larger stand-alone PV facilities is very limited, for the purpose of the presented PV market demand analysis, larger stand-alone PV systems have been grouped together with the same size grid connected systems.

Instead, as regards **small scale** systems, a **clear distinction** has been made **between grid connected systems** and **stand-alone systems**, since the market targets, economics and competitivity of these two categories of PV systems are entirely different.

The following range definitions for small, medium and large scale PV plants have been adopted within the present work:

- below 5 kWp — small-scale systems
- between 5 -50 kWp — medium scale systems
- above 50 kWp — large scale systems

1.4.2 Historical shipments overview for main categories of PV applications

The table 1.10 and figures 1.7, 1.8 and 1.9 given in this paragraph present the results of an integrated computer based PV market model, which incorporates the correlations existing between interdependent market parameters, such as between annual shipments, prices, installed PV capacities, investments required for manufacturing capacity increases, employment, etc. This model has allowed first of all to check for and to detect inconsistencies between available market figures and estimates given by literature, and at the same time to create a sound knowledge base for the estimate of unknown market parameters as well as for the development of scenarios and extrapolations to year 2010.

Table 1.10 - Historical shipments overview for commercial modules (excluding cells sold to other PV manufacturers) in MWp for main categories of PV applications

Year	*PV Stand-alone systems capacity*										*Grid-connected*		*TOTAL*
	Remote industrial			*Remote rural*					*Consumer/leisure*				
	Telecom	*Cathodic protection*	*Military/ signalling*	*Water Pumping*	*Village Power*	*Solar Home Systems*	*Remote houses*	*Other remote*	*Camping Boating Leisure*	*Consumer Indoor*	*Grid-Connect. large-medium scale*	*Grid-Connect. small scale*	*PV module Shipments*
1982	1,9	0,3	0,3	0,4	0,1	0,4	0,2	0,6	0,2	0,9	2,4	0,1	**7,7**
1983	2,2	0,4	0,4	0,7	0,3	0,7	0,3	0,5	0,3	1,7	7,5	0,2	**15,0**
1984	3,3	0,2	0,6	1,2	0,3	0,8	0,4	0,4	1,0	3,4	5,7	0,3	**17,4**
1985	4,0	0,3	0,5	1,6	0,5	1,3	0,6	0,4	1,8	3,5	3,6	0,6	**18,7**
1986	6,3	0,4	0,5	2,1	0,7	2,1	0,9	0,5	2,2	3,8	0,6	1,0	**21,1**
1987	7,4	0,5	0,6	3,0	0,9	2,8	1,2	0,5	2,8	4,1	0,5	0,6	**24,9**
1988	8,9	0,7	0,7	4,2	1,3	4,2	1,7	0,6	4,0	3,9	0,5	1,0	**31,7**
1989	9,8	0,8	0,8	5,4	1,9	5,3	2,3	0,6	5,5	4,0	0,5	2,2	**39,1**
1990	9,8	0,9	0,8	6,4	2,1	6,4	2,7	0,8	6,3	3,7	0,8	2,0	**42,7**
1991	10,9	1,1	0,7	7,3	2,8	7,3	3,1	1,0	7,3	3,2	2,1	3,1	**49,9**
1992	12,4	1,3	0,9	8,0	3,5	9,1	3,9	1,2	8,7	3,4	1,1	2,2	**55,7**
1993	10,5	3,6	2,4	4,0	1,6	9,6	4,1	3,3	9,5	3,7	3,4	2,8	**58,5**
1994	12,6	2,5	2,6	5,4	2,0	10,1	4,3	1,8	8,9	3,5	5,9	7,5	**67,1**
TOTAL	**100,0**	**12,9**	**11,7**	**49,6**	**17,9**	**60,1**	**25,7**	**12,2**	**58,5**	**42,7**	**34,5**	**23,6**	**449,4**

The difference between the total commercial module sales presented in this paragraph (demand side) and the total PV shipments of PV industries (supply side) presented in the previous paragraph 1.3.2 reflects the fact, that **sales of PV cells to other PV manufacturers are excluded** from the here presented demand side analysis.

The outcomes of this PV market investigation may be summarised as follows:

- **Annual PV shipments** have reached world-wide nearly 70 MWp in 1994. In the early eighties, the PV market had been strongly dominated by the large-scale market segment (the impact of the USA Carissa plains plant 1983-1985 is very evident). Since then the Communications market segment, and generally all stand-alone applications have clearly taken the lead.

The presently largest four PV application market segments are (in order of decreasing importance):

* Communications;
* Leisure, boating and caravaning (mainly industrialised countries);
* Solar home systems (major part in developing world);
* Water pumping (developing world);

- On world-wide basis, **the grid-connected market segment** (both large-scale and diffused small-scale together) represents only roughly 10% of the market demand, but in industrialised countries and specifically in Europe its share in sales is significantly higher and, what is more, it is expected to grow strongly in the next decade as a result of widespread building integration and rooftop applications.

The **installed whole world PV capacity** is estimated to total roughly 350 MWp in 1994, of which 70 MWp (20% of world total) are installed in Europe. These figures have been calculated by eliminating the leisure, boating, caravaning and the indoor applications. As regards large-medium scale PV plants, the presented figures are not an estimate but calculated analytically as the sum of all known large-medium PV plants (see relevant paragraph for list of considered plants).

Figure 1.7 - PV Industry shipment shares for main application segments (average 1990-1994)

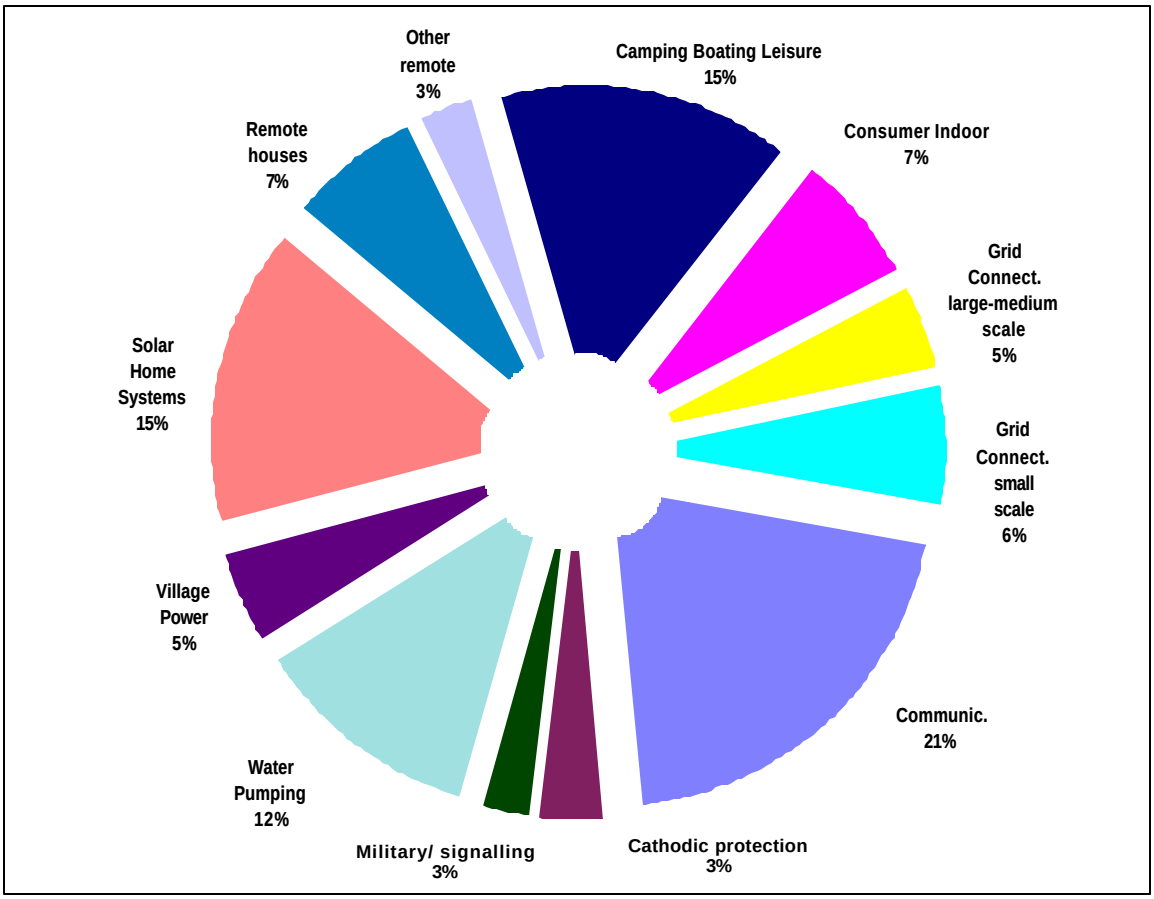


Figure 1.8 - Actual World PV market development for commercial modules (1982-1994)
(Average market growth rate has been 15% year)

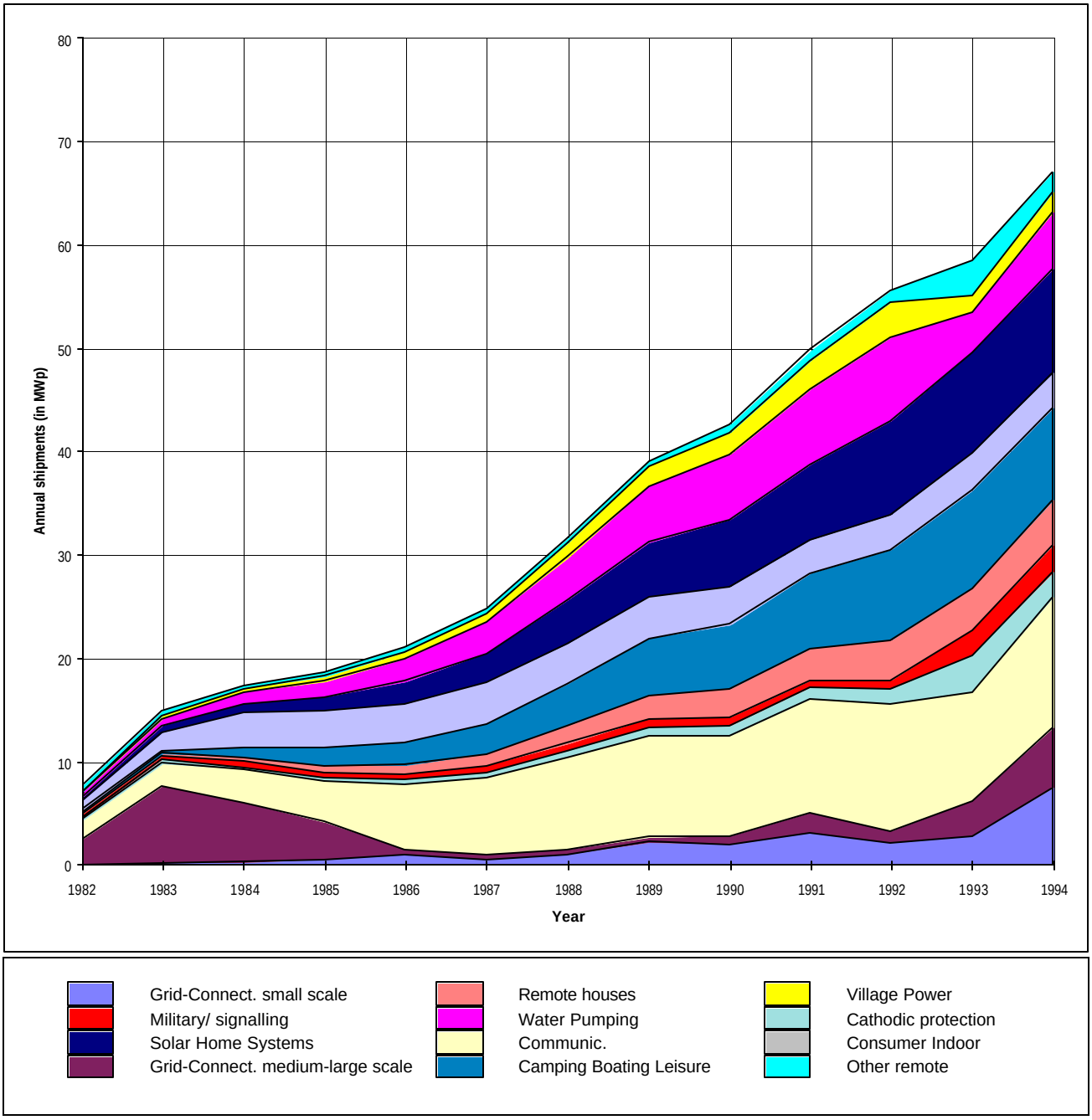
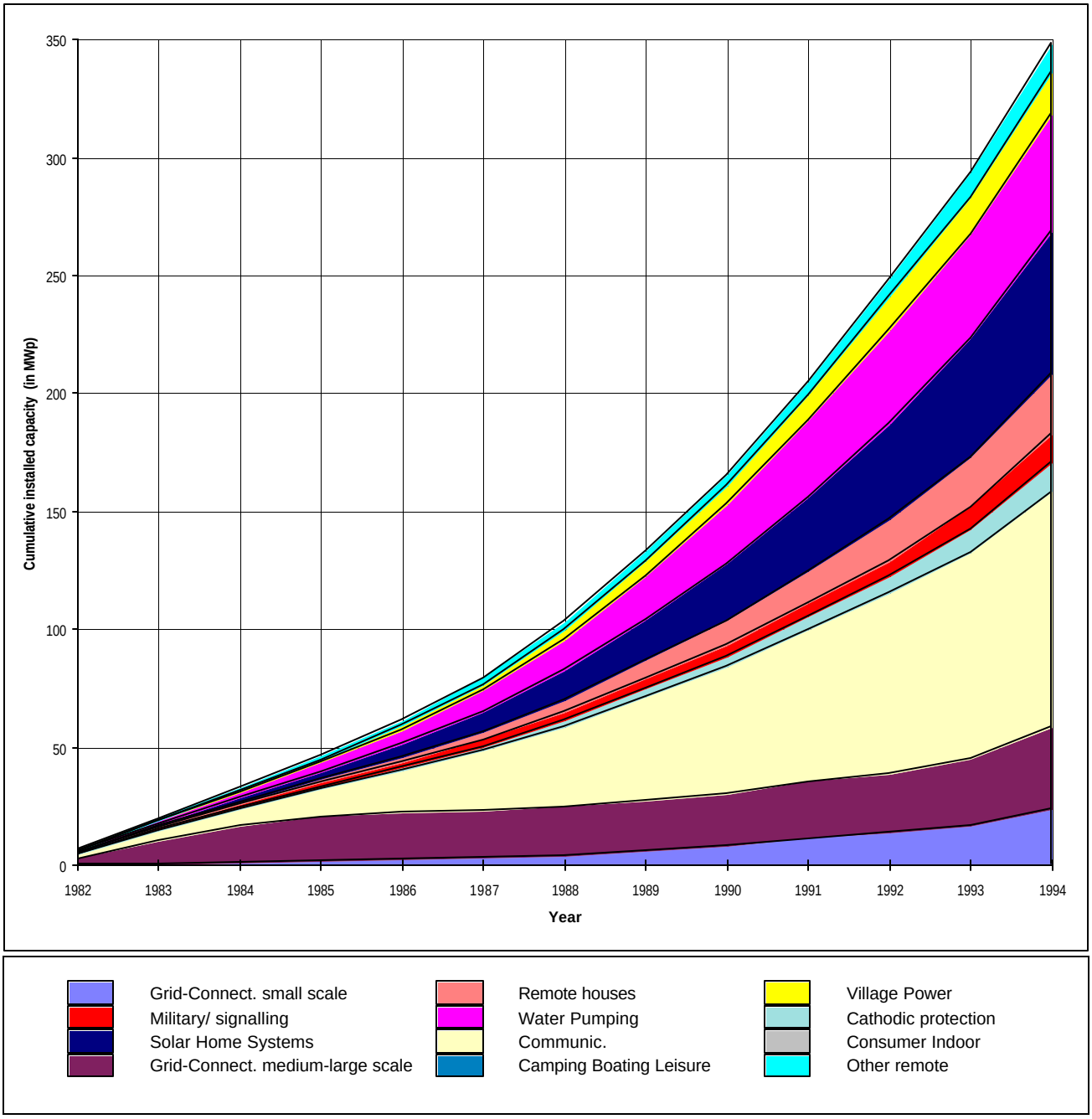


Figure 1.9 - Cumulative whole world installed PV capacity (commercial modules 1982-1994) for main application segments



1.4.3 Business as usual scenario until year 2010

1.4.3.1 Shipments and resulting installed PV capacities

As illustrated by the tables and figures presented in the previous paragraph, the world PV market has developed during the last decade (from 1984 to 1994) at an average annual growth rate of 15 %. There is presently no reason "at the horizon" making us doubt that the PV market will continue to grow at the same (or even higher) pace also for the next decade. Other technologies, such as PC personal computers and mobile (cellular) telephony have in the last years shown that even extremely high market growth rates between 25% and up to even 50% per year are possible under given favourable circumstances.

Accordingly, to remain "on the safe side", the here presented "business as usual" development scenario has been calculated by extrapolating to year 2010 the same 15% annual market growth of the period 1984-1994, by means of the previously presented computer based integrated PV market model.

This approach assumes, obviously, that there will be no marked changes in policies and general conditions external to the PV market, which means that also subsidies and public financial support will continue to flow "as usual".

The 1982-1994 market figures presented in the previous paragraph make evident, that the PV sector tends slowly to outgrow its dependency from public support, since PV shipments (and sales) have grown significantly faster than public financing support. On the other hand, Europe, in order to maintain or to strengthen its market position, needs to outweigh effectively targeted public support actions launched recently by USA and Japan to favour their own PV industries (see relevant paragraphs), since otherwise the European PV industry will not be able to keep pace.

The here presented figures illustrate the outcomes of the "business as usual" scenario extrapolated to year 2010, which may be summarised as follows:

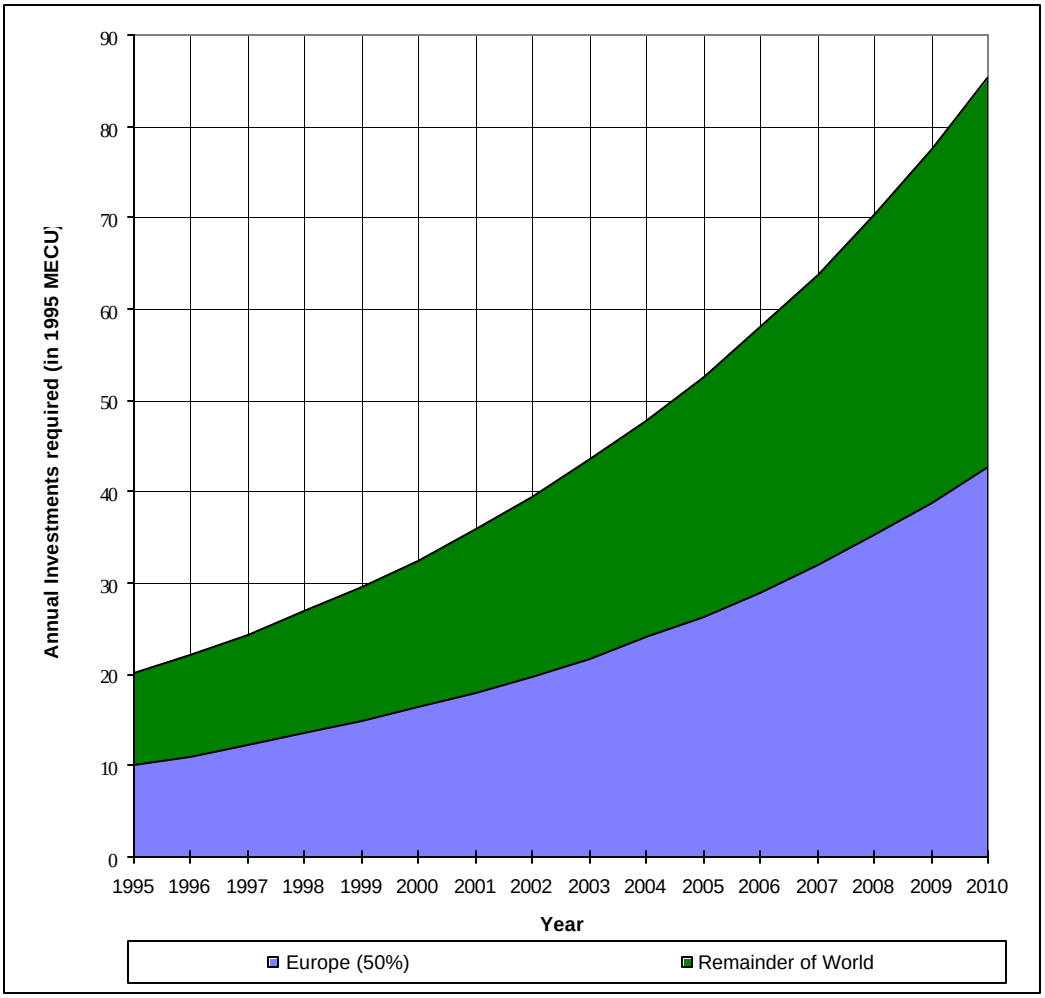
- **Annual world PV shipments** will reach 630 MWp in year 2010. The today market dominating applications such as communications, leisure, camping, boating and indoor will diminish their importance in time. In year 2010 the four largest PV market segments are expected to become (in decreasing order of importance):
  - **Solar home systems** (major part in developing world);
  - **Grid-connected small-scale** (mainly in industrialised countries);
  - **Grid-connected large-medium** PV (in industrialised countries);
  - **Communications** (both in developing and in industrialised world);
- The **installed whole world PV capacity** (i.e. PV generation systems, not manufacturing plants) is reasonably to be expected to reach nearly 4.000 MWp for year 2010. This figure does not include the leisure, boating, caravaning and the indoor applications, as well as all capacities exceeding 20 years age (considered dismantled). If PV capacities installed in Europe in year 2010 are assumed to account for roughly 30% of the world total (as mentioned previously, in 1994 the European PV system capacity share was 20%), according

to this "business as usual" scenario, the European installed PV capacity in year 2010 will most probably reach roughly 1.200 MWp

1.4.3.2 Investment forecast for required PV manufacturing capacities

The following figure illustrates the estimated forecast of the annual investments required world-wide from PV industries to increase PV manufacturing capacities according to the here presented "business as usual" scenario.

Figure 1.10 - Annual investments required for PV manufacturing capacity increases
Business as usual scenario (15% annual market growth)



Specific investment requirements for year 1994 have been assumed to amount to roughly 2 ECU per Wp of annual PV manufacturing capacity. During the time till year 2010, this figure has been assumed to drop to 1 ECU/Wp (assuming an ECU value equal to that of year 1995).

For the "business as usual" scenario, **annual investment requirements have resulted to equal roughly 7-8% of overall PV module sales**.

Certainty of market demand will be the crucial factor allowing decision makers in PV industries to provide for the required very consistent investments and to implement the capacity increases required for the next decade until year 2010.

1.4.3.3 PV employment

The following table presents the methodology and parameters adopted to estimate the employment generated by the PV sector world-wide. Basically, the manpower needs of the PV sector have been subdivided into two main groups as follows:

- Employment arising in **areas of origin** of PV equipment, including:
  - PV manufacturing and BOS production activities,
  - PV manufacturing plant construction,
  - PV services such as research, engineering and wholesales activities
- Employment generated in the **areas of destination**:
  - Local services, sales and retailer activities
  - Installation on site
  - Maintenance

TYPICAL SPECIFIC MANPOWER REQUIREMENTS IN 1994

PV system size class	Number of systems	Employment in area of origin of PV equipment					Employment in areas of destination					OVERALL TOTAL
		New manufacturing plant construction	PV module production	BOS production	Services, engineering, wholesales	Total in area of origin	Retailers, local services	On site installation	Maintenance of all existing (cumulative) PV systems		Total in area of destination	
	units/MWp	my/MWp	my/ MWp	my/ MWp	my/ MWp	my/ MWp	my/ MWp	my/ MWp	mdays/ unit	my/ MWp	my/ MWp	my/MWp
Medium-large	1	5	15	11	3	28	-	5	200	1	6	**34**
1-5 kWp	350	5	15	14	6	34	5	7	3	5	18	**52**
0.3-1 kWp	5.000	5	15	18	7	40	25	25	1	25	75	**115**
< 0.3 kWp	10.000	5	15	23	8	45	50	50	1	50	150	**195**
Leisure/indoor	1.000.000	5	15	26	4	45	100	-	-	-	100	**145**

my = manyears mdays = mandays

WHOLE WORLD PV EMPLOYMENT IN 1994

PV system size class	Employment in area of origin of PV equipment							Employment in areas of destination					OVERALL TOTAL
	New manufacturing plant construction		PV module production		BOS production	Services, engineering, wholesales	Total in area of origin	Retailers, local services	On site installation	Maintenance of all existing (cumulative) PV systems		Total in area of destination	
	MWp/year	Employed	MWp/ year	Employed	Employed	Employed	Employed	Employed	Employed	MWp	Employed	Employed	Employed
Medium-large	0,9	4	5,9	88	62	15	169	-	30	35	35	64	**233**
1-5 kWp	1,1	5	7,5	112	101	43	261	39	53	24	124	216	**477**
0.3-1 kWp	3,8	17	25,2	377	453	166	1.013	629	629	192	4.804	6.062	**7.075**
< 0.3 kWp	2,4	11	16,2	242	363	121	738	808	808	98	2.450	4.065	**4.802**
Leisure/indoor	1,9	8	12,4	186	316	50	561	1.240	-	-	-	1.240	**1.801**
TOTAL	**10,1**	**45**	**67,1**	**1.006**	**1.295**	**395**	**2.741**	**2.715**	**1.519**	**348**	**7.412**	**11.647**	**14.388**

Productivity improvements assumed for extrapolation to year 2010

		100%		100%	50%	20%		20%	20%		0%	

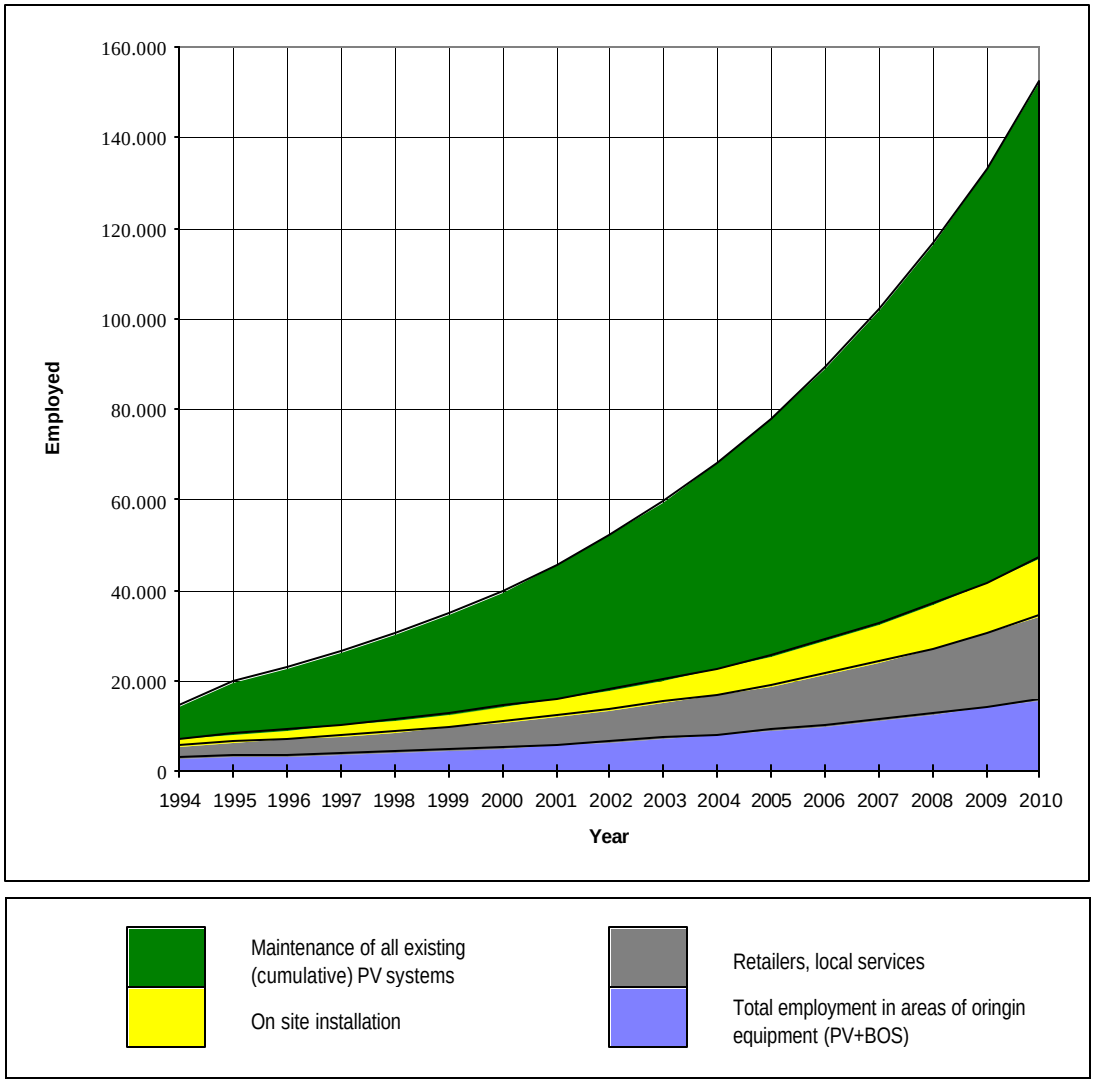
Note : 100% improvement means doubled productivity (expressed in MWp/employed)

The first part of the table presents the specific manpower requirements of the above segments of the PV sector. The second part presents the results of the adopted model for year 1994, whereas the last part gives the assumptions made to extrapolate the model to year 2010 (expected productivity improvements). The application of this model to the previously presented "business as usual" scenario is illustrated by Figure 1.11 and makes evident, how **PV**

technology will produce in time a marked multiplicator effect on employment. According to this model, in year 2010 the large majority of employment (more than 85%) will be generated in the areas of destination of PV equipment, and mostly by the demand for maintenance and servicing activities arising from the accumulation in time of long-lasting small-scale PV installations (of typically 20 years and more lifetime). Furthermore, from the point of view of economic development, the employment generated by PV technology presents some particularly convenient characteristics as follows:

- It is entirely additional, i.e. it will not substitute employment in other sectors (PV technology does not replace other conventional technologies, but provides for completely new applications and needs);
- It is distributed over the territory, since linked to the diffusion of PV systems, and not to some concentrated power generation facility;
- It ensures continuity in time and presents no seasonality;
- It will develop precisely in those areas, which mostly need economic development stimulation, i.e. the remote rural areas in the developing world as well as in less developed areas of the industrialised world.

Figure 1.11 - Employment forecast for world PV sector - Business as usual scenario (15% annual market growth)



1.4.3.4 Different world PV market development scenarios until year 2010

The TERES study states for year 2010 a probable European installed PV systems capacity of 1250 MWp and an objective of 7400 MWp, whereas the Madrid plan calls for an objective only for Europe of 16.000 MWp.

These goals may be viewed by comparison with the following table, which presents the relationship resulting from the here presented world market model between the annual PV market growth rates and the PV industry investments (for manufacturing capacity increases) required from 1995 till 2010 to achieve certain year 2010 **whole world** PV market scenarios:

Table 1.11 - Annual market growth rate and investments required during period until year 2010 to reach certain world market goals

What is required		**to reach in year 2010 a whole world PV market scenario of:**				**Europe (assuming 32% of capacity installed in EU)**	
World PV market growth rate	Investment for manufacturing capacity increase	Annual shipments	Cumulative installed capacity	PV sector Employment	Remarks	Cumulative installed capacity	PV sector Employment
% year	% of sales	MWp/year	MWp	Employed		MWp	Employed
15%	7,2%	630	3.900	152.000	Business as usual, will develop spontaneously	1.200	32.000
20%	9,3%	1.240	6.300	261.000	Achievable by eliminating market barriers	2.000	56.000
25%	11,1%	2.380	10.200	453.000	Requires consistent market stimulation	3.300	98.000
30%	12,8%	4.460	16.700	783.000	Requires breakthrough in technology and costs	5.300	170.000
35%	14,4%	8.160	27.300	1.345.000	Extreme scenario	8.700	294.000

Figure 1.12 - Year 2010 World PV market forecast per application

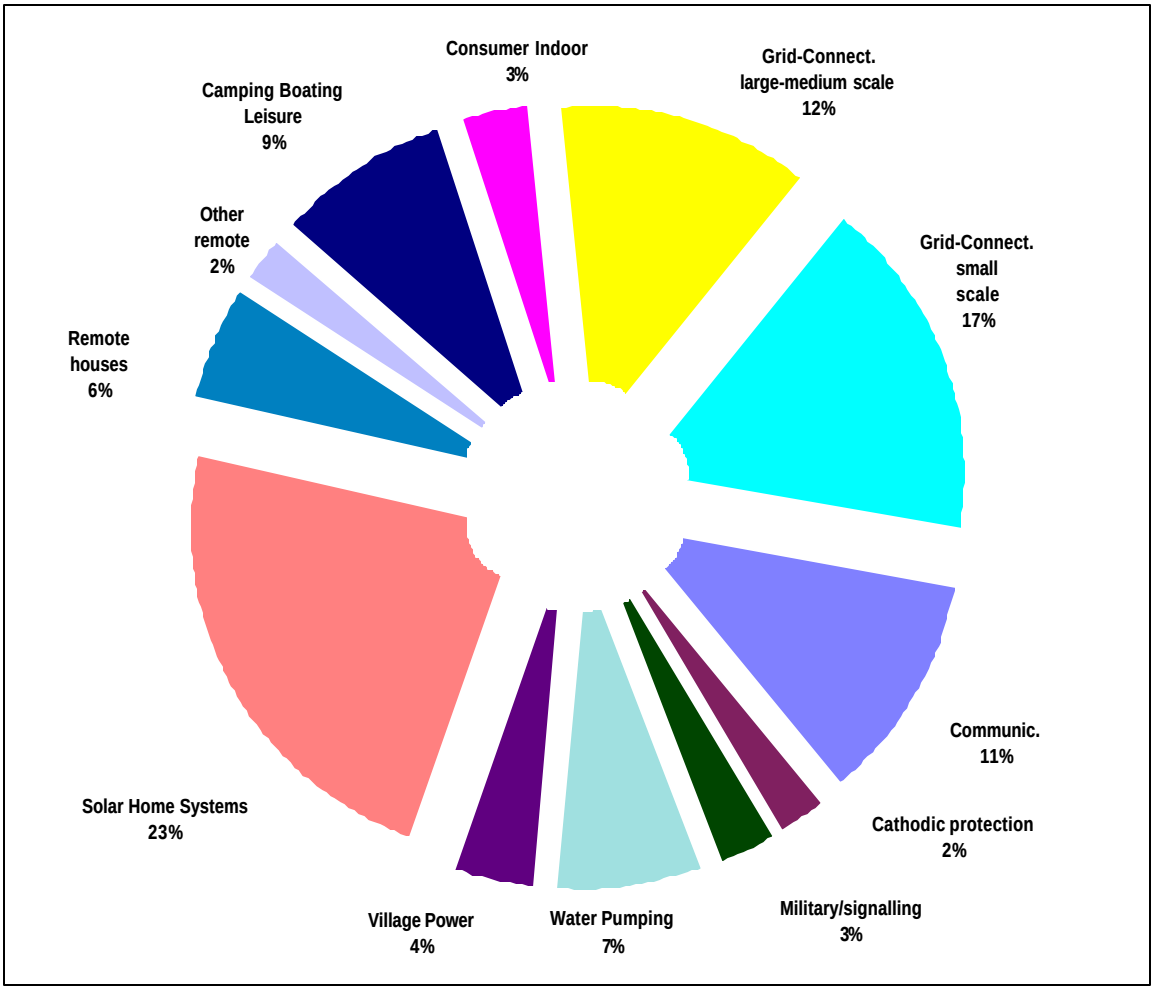


Figure 1.13 - World PV market forecast up to year 2010
(Figures beyond 1994 extrapolated by assuming overall market growth rate = 15% year)

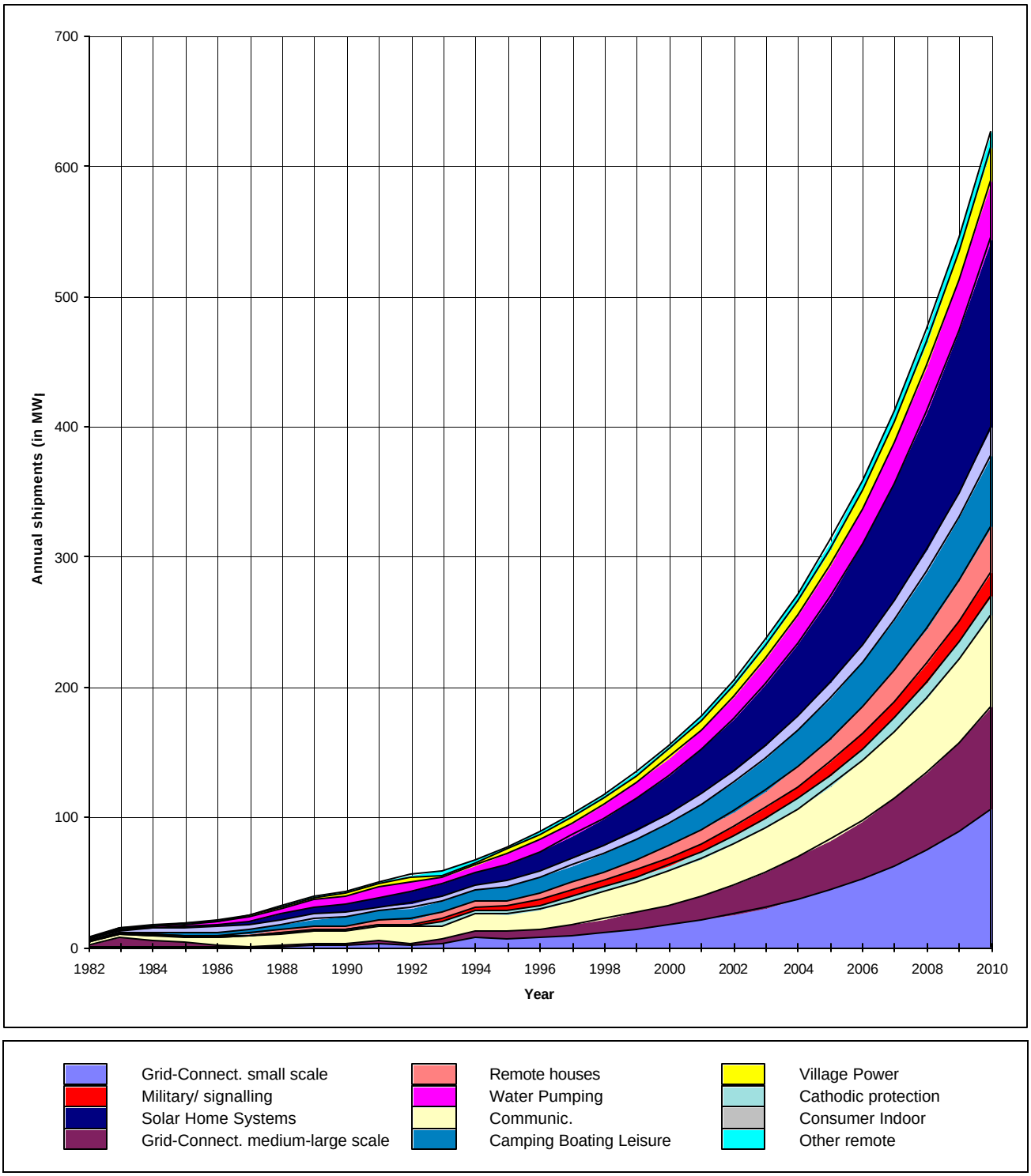
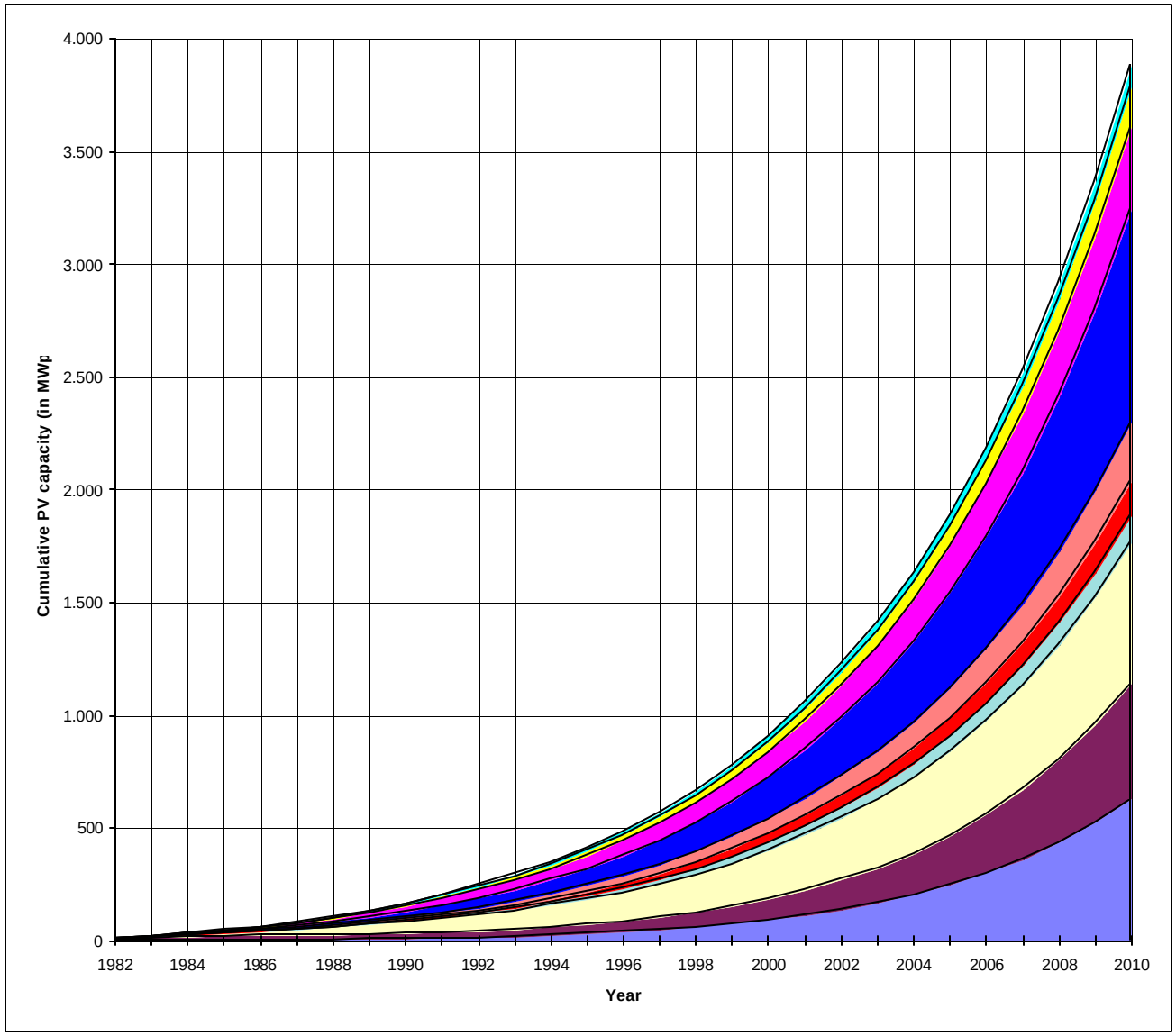


Figure 1.14 - Installed world PV capacity forecast until year 2010
Figures beyond 1994 extrapolated by assuming overall shipment growth rate of 15% year
(more than 20 years old PV capacities subtracted since assumed dismantled)



1.4.4 Large and medium size PV power plants

1.4.4.1 Present status

As to be seen from the following table 1.12, since 1983 more than 34 MWp (≈10%) of world shipments went into medium and large PV plant installations. Since 1991 roughly 6 MWp went into grid-connected rooftops (see relevant paragraph), while the remaining majority of shipments went into small-scale stand-alone applications (down to the mini- and micro-scale including the amorphous gadget and consumer product market).

Table 1.12 - Cumulative world capacity of medium to large scale PV systems (1994)

Plant size	*Capacity*
capacity >=100 kWp grid connected	32.696
capacity < 100 kWp grid connected	756
capacity >=100 kWp autonomous	500
capacity < 100 kWp autonomous	555
TOTAL	**34.507**

The share of shipments, which went into large-medium PV plants was very different depending on geographical region:

- Japan: 5 %
- USA: 59 %
- EC: 35 %
- Rest of the World 2 %

Also within EC, distribution among countries has been uneven, favouring primarily such larger scale installations in Italy (6,9 MWp of installed capacity in 1994), in Germany (1,8 MWp of installed capacity in 1994) and in Spain (1,4 MWp of installed capacity in 1994).

1.4.4.2 Large scale PV capacities installed between 1980-1994

Since 1980 the market segment analysed here (see tables 1.13, 1.14, 1.15 and figures 1.15, 1.16), i.e. all larger grid-connected PV systems including medium to large-scale hybrid and stand-alone systems, has shown the following trends:

- Annual installations of larger stand alone plants show, in absolute terms, a basically constant trend, which means that their relative share (percentage of total) is has heavily decreased during the envisaged time period (initial experimentation during early 1980's appear to have shown that large stand-alone systems are economically less convenient that large grid-connected systems);
- Grid connected large scale capacities world-wide presented a sharp increase in 1985 due to the Carissa plains plant (USA). As for the known failure of this project (due to rapid degradation through UV browning of PV modules) no new large US installations followed until 1991, when the new PV-USA programme started. Accordingly, from 1985 till 1992,

world growth in installed large-scale capacity has been governed basically by the European growth, while the last two years show again a strong growth in the USA.

Table 1.13 - Large-medium PV power plants: installed capacity per year in the World (1982-1994)

	INSTALLED PEAK POWER (in kWp) PER YEAR													
	1982	*1983*	*1984*	*1985*	*1986*	*1987*	*1988*	*1989*	*1990*	*1991*	*1992*	*1993*	*1994*	***Total***
Europe	50	762	289	23	300	-	911	268	395	570	1.359	1.215	5.860	**12.001**
USA	1.200	-	-	8.390	600	-	15	-	2.000	-	3.000	1.000	4.000	**20.205**
Japan	-	-	-	1.250	-	-	-	-	-	-	-	-	500	**1.750**
ROW	550	-	-	-	-	200	-	-	-	-	-	-	-	**750**
TOTAL	**1.800**	**762**	**289**	**9.663**	**900**	**200**	**926**	**268**	**2.395**	**570**	**4.359**	**2.215**	**10.360**	**34.706**

Figure 1.15 - Large-Medium size PV power plant capacity started-up per year in the World (1982-1994)

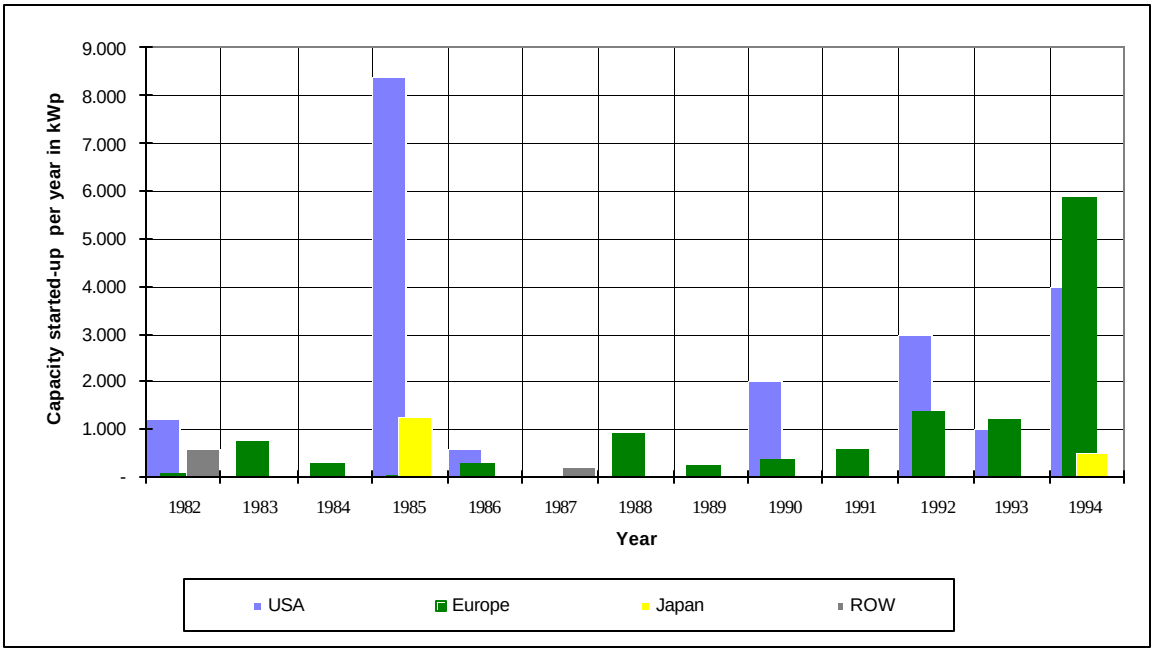


Table 1.14 - Large-medium PV power plants: cumulative installed capacity in the World (1982-1994)

	CUMULATIVE INSTALLED PEAK POWER (in kWp)												
	1982	*1983*	*1984*	*1985*	*1986*	*1987*	*1988*	*1989*	*1990*	*1991*	*1992*	*1993*	*1994*
Europe	50	812	1.101	1.124	1.424	1.424	2.335	2.603	2.998	3.568	4.926	6.141	12.001
USA	1.200	1.200	1.200	9.590	10.190	10.190	10.205	10.205	12.205	12.205	15.205	16.205	20.205
Japan	0	0	0	1.250	1.250	1.250	1.250	1.250	1.250	1.250	1.250	1.250	1.750
ROW	550	550	550	550	550	750	750	750	750	750	750	750	750
TOTAL	**1.800**	**2.562**	**2.851**	**12.514**	**13.414**	**13.614**	**14.540**	**14.808**	**17.203**	**17.773**	**22.131**	**24.346**	**34.706**

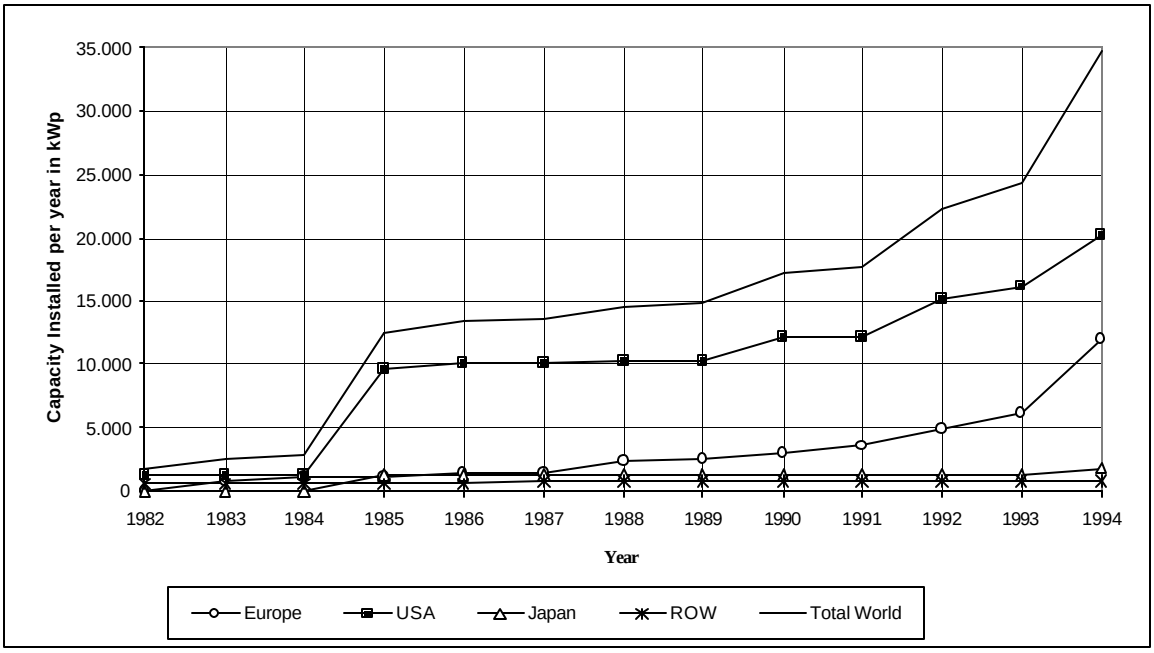
Table 1.15 - Share of installed peak power of large-medium size PV plants per geographical areas and year in the world (1982-1994)

Year	*Distribution of Installed Peak Power per year and geographical areas [1]*				***% total per year [2]***
	Europe	*USA*	*Japan*	*ROW*	
1982	3%	67%	…	31%	**5%**
1983	100%	...	…	…	**2%**
1984	100%	...	…	…	**1%**
1985	0,2%	87%	13%	…	**28%**
1986	33%	67%	…	…	**3%**
1987	...	...	…	100%	**1%**
1988	98%	2%	…	…	**3%**
1989	100%	...	…	…	**1%**
1990	16%	84%	…	…	**7%**
1991	100%	...	…	…	**2%**
1992	31%	69%	…	…	**13%**
1993	55%	45%	…	…	**6%**
1994	57%	39%	5%	…	**30%**
% total per areas	**35%**	**58%**	**5%**	**2%**	**100%**

[1] percentage refers to total value per areas

[2] percentage refers to total value per areas and cumulative per year

Figure 1.16 - Large-Medium size PV power plant cumulative capacity installed in the World (1982-1994)



1.4.4.3 Market forecast for medium and large-size PV power

The here discussed market segment is expected to evolve (see figure 1.17) entirely towards grid connected utility applications for bulk power purposes, since larger stand alone PV plants have shown to be, although technically feasible, economically less convenient (both in the industrialised and in the developing world).

Within the utility frame, the main application for large PV bulk power plants has been identified in Transmission and Distribution (T&D) grid support, which may be subdivided into the following two specific types of grid support applications:

- **Area grid support** means that typically 100-500 kWp (or larger) PV capacities are installed near a substation. This application produces advantages to the utility in all those cases, where peak power demand presents a similar behaviour in time as the availability of Solar PV power. Typically, this is the case in all those areas, where a consistent share of power is consumed for air conditioning purposes.
- **Radial line support** is provided by siting typically 50-200 kWp (or more) PV unit capacities along single feeder distribution circuits, allowing thereby to alleviate various problems such as, for example, load growth beyond feeder capacity, voltage drops along the feeder, or simply bad power quality. The economic advantages for the utility arising from this kind of application stem from the consideration that otherwise, without PV support, the utility would have to provide for an increase in capacity of the entire feeder line which, in many cases, may represent a very consistent investment. For most OECD countries, the costs of overhead distribution line extensions range typically between 8.000 - 40.000 ECU/km.

Furthermore, unless a dramatic breakthrough occurs in PV cost reduction, the following considerations may be made concerning grid connected applications of PV technology:

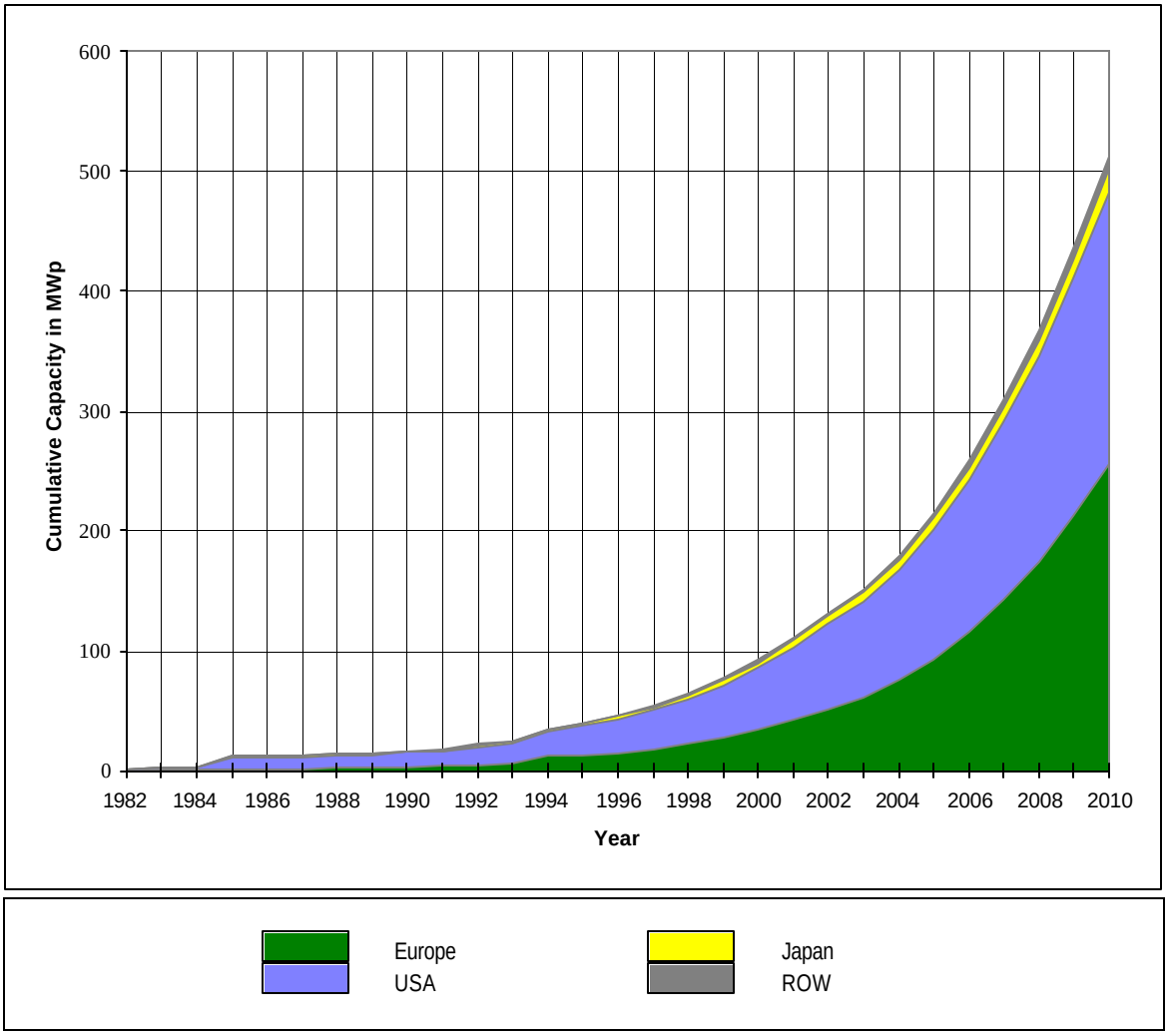
- Unlike conventional energy technologies, **PV technology presents no significant scale-economy effect**, i.e. specific costs of smaller PV systems (typically expressed in ECU/Wp installed capacity or in ECU/kWh of produced PV energy) are not much higher than those of larger PV systems. Since conventional energy technologies present, instead, a marked scale-economy effect, the result is that competing conventional power is usually more convenient for large-scale applications, whereas PV power becomes more convenient in smaller applications
- Consequently, for grid-connected applications, there is no marked economic advantage in the implementation of few large-scale PV plants, in comparison to the realisation of many small-scale systems of equivalent total capacity. Actually the distributed generation concept offers several advantages in comparison to large scale concentration of PV generation capacities such as:

Investments and manpower requirements (employment) for installation and maintenance are not concentrated, but may be distributed over larger territories and diluted in time (over several years), producing durable effects on development of local economy (employment) as well as steady development of the PV sector

- Nevertheless **large-scale grid-connected PV power plants** are definitely to be considered an important strategic instrument to involve **utilities as the most important energy key-players** in the PV Scenario, allowing thereby to reduce PV costs through relevant market demand stimulation provoking scale-up of optimised (automated) manufacturing facilities. The relevant US programme PV-USA defines important concepts necessary to achieve the production levels and cost reductions for the accelerated commercialisation of PV for utility applications (presented in the chapter on "strategies"):

In any case, if utilities are to make the most of distributed generation, ***PV generators are to be sited as close as possible to customer loads, since thereby more utility-side upstream operations are saved, and benefits may be captured more fully***.

Figure 1.17 - Large-medium PV plants capacity forecast Figures beyond 1994 extrapolated by assuming overall shipment growth rate of 15% year (more than 20 years old PV capacities subtracted since assumed dismantled)



1.4.5 Grid-connected small-scale applications: PV rooftops

The market category of grid-connected small-scale PV systems embraces such typical applications as PV rooftops, PV building facades and building integrated PV facilities in general. Grass-root installations of grid-connected small-scale type are also included in this category, but at least in Europe their market share is not significant.

These systems are expected to become the backbone of the **distributed generation utility concept**, where the utility network is expected to provide no more exclusively for the distribution to consumers of power produced by few concentrated generation facilities, but to collect, at the same time, power from a large number of self-producers distributed over the territory.

Although economics of grid-connected small-scale PV systems are similar to those of the larger scale grid-connected facilities, they have been considered separate from the larger grid connected systems, since they address primarily the interests of private investors (such as house owners, small enterprises, etc.), which is a purchaser target very different from the mostly institutional larger scale PV (bulk) power market, such as utilities and public authorities.

It is also understood, that the here investigated market segment **addresses primarily the industrialised world** presenting electrification levels of national population approaching saturation. As for their lower electrification level, developing and third world countries present primarily a dramatic demand for rural electrification, and priorities and financing resources are therefore oriented towards stand-alone PV applications.

1.4.5.1 Capacities installed since 1991

In Europe, grid-connected small-scale PV systems, namely PV rooftops, have started to be installed since 1991, primarily in German language countries including Germany, Austria and Switzerland (see tables 1.16, 1.17, 1.18 and figures 1.18, 1.19).

Important work has been done in these countries to overcome institutional barriers such as safety and grid interfacing regulations limiting the possibility to adopt this technology.

If relevant financing support from public sources is provided, allowing to alleviate the economic losses suffered by investors, there appears to be a significant demand for such applications among private house owner and smaller enterprises.

Facade cladding and large building integration projects are just now (1993/1994) starting in Europe and they are expected to be very promising especially since they bring PV technology into the cities and allow to produce a significant impact onto public opinion;

Table 1.16 - Grid-connected small-scale PV capacity (rooftops) installed in the World (1989-1994)

	INSTALLED PEAK POWER (in kWp) PER YEAR						
	before 1989	*1990*	*1991*	*1992*	*1993*	*1994*	***TOTAL***
Europe	3		25	204	2.057	4.186	**6.474**
USA	6.000	2.000	2.000	2.000		3.000	**15.000**
Japan						2.100	**2.100**
ROW							
TOTAL	**6.003**	**2.000**	**2.025**	**2.204**	**2.057**	**9.286**	**23.574**

Note: The 1989 figure presents the capacity accumulated during all previous years

Figure 1.18 - Grid-connected small-scale PV (rooftops and other): capacity started-up per year in the geographical areas, where this market segment presents significant developments (1989-1994)

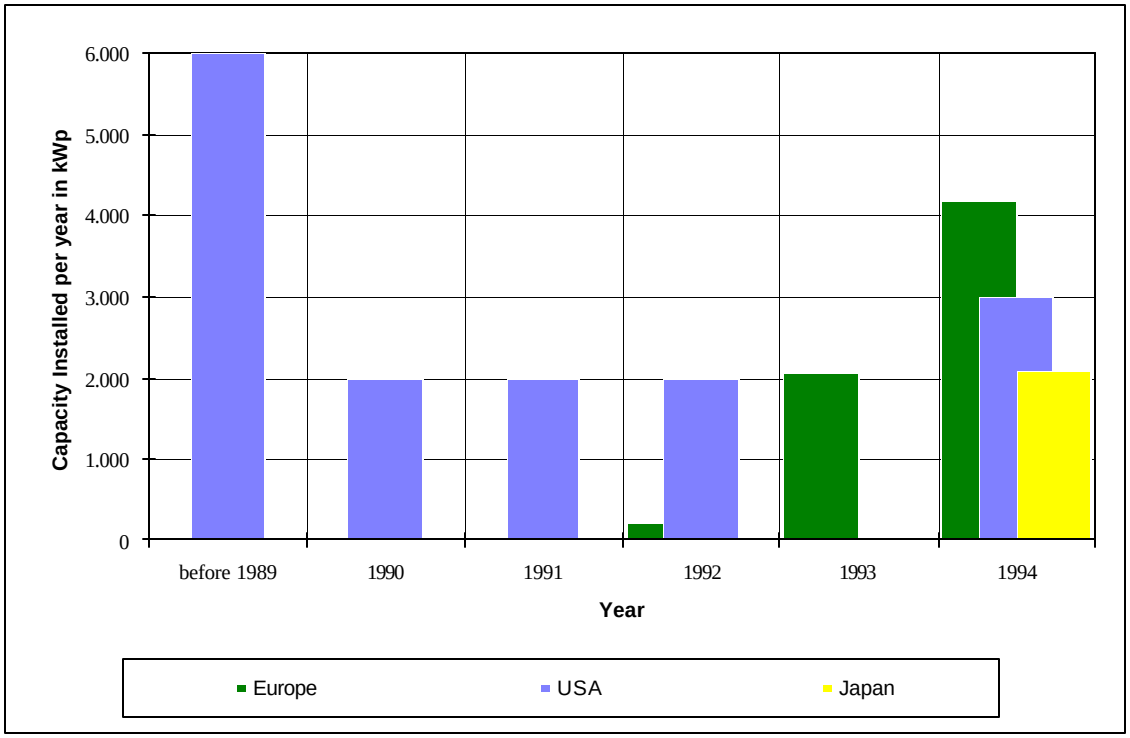


Table 1.17 - Cumulative capacity of grid-connected small-scale PV applications (rooftops) installed in the World (1989-1994)

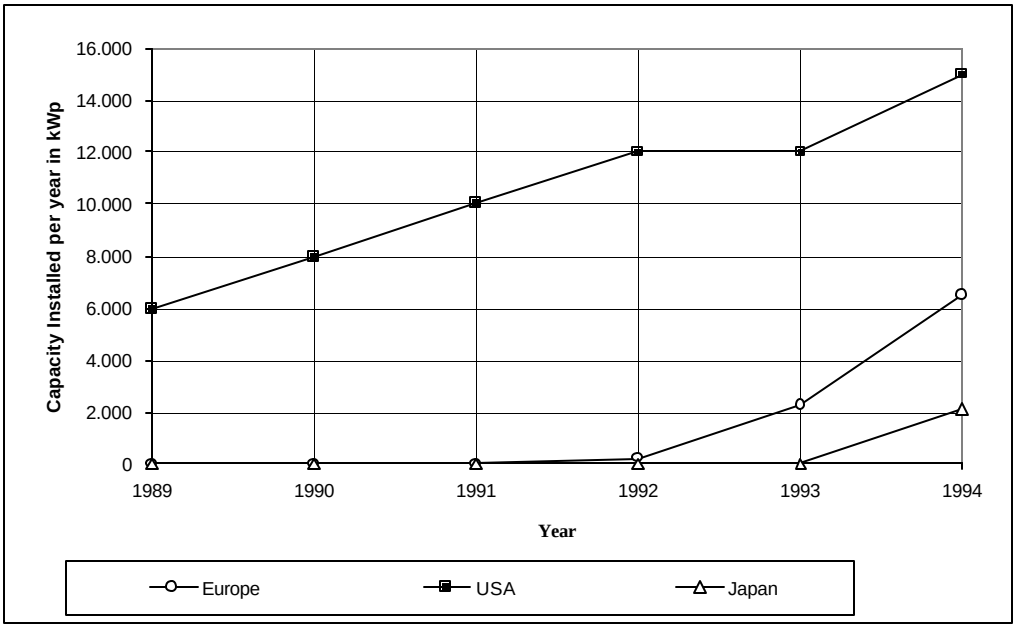
	INSTALLED PEAK POWER (in kWp)					
	1989	*1990*	*1991*	*1992*	*1993*	*1994*
Europe	3	3	28	231	2.288	6.474
USA	6.000	8.000	10.000	12.000	12.000	15.000
Japan						2.100
ROW						
TOTAL	**6.003**	**8.003**	**10.028**	**12.231**	**14.288**	**23.574**

Table 1.18 - Share of annually installed grid-connected small-scale PV capacity per geographical area and year (1982-1994)

Year	*Distribution of Installed Peak Power per year and geographical areas [1]*				***% total per year [2]***
	Europe	*USA*	*Japan*	*ROW*	
1989	...	100%	...	...	**25%**
1990	...	100%	...	...	**8%**
1991	1%	99%	...	...	**9%**
1992	9%	91%	...	...	**9%**
1993	100%	...	...	...	**9%**
1994	45%	32%	23%	...	**39%**
% total per areas	**27%**	**64%**	**9%**		**100%**

[1] percentage of whole world equalling 100% for given year
[2] percentage referred to present total world capacity, cumulative for year
[3] 1989 figure (USA) presents the cumulative capacity of all previous years

Figure 1.19 - Cumulative capacity of grid-connected small-scale PV applications (rooftops) installed in geographical areas, where this market segment presents significant developments (1982-1994)



1.4.5.2 The potential demand for grid-connected PV rooftop applications

To evaluate and quantify the potential market demand for diffused small-scale grid-connected PV systems, it is becoming common practice to adopt for the purpose estimates of the rooftop surfaces available in the investigated geographical regions. This approach is based on the following considerations:

As regards building integration of PV technology, considering both retrofits to existing buildings as well as new building integration, the application of PV generators to rooftop surfaces presents minor technical, architectural and aesthetic problems that those arising from building facade integration, since facades have to comply with a large variety of different technical requirements, such as structural characteristics, daylight illumination, thermal isolation, weather protection, etc.

Accordingly, to provide for an acceptable estimate of the market demand potential for small-scale and diffused grid-connected PV applications, is was deemed sufficiently accurate to take into consideration only rooftops of buildings and to exclude from computations the in any cases limited contribution of potential facade surfaces.

Estimates of the net rooftop surfaces available for solar installations have been taken from relevant investigations[2- 3- 4] covering the solar rooftop potential estimate for all OECD countries, specifically as regards buildings for civil uses (residential, offices, services) and for industrial uses.

The considered studies have been limited to OECD countries since, as mentioned before, the market segment for grid-connected PV systems addresses the industrialised world presenting high electrification levels of national populations. As for their lower electrification level (and lower purchase power), **developing and third world countries** may be expected to **present a very limited demand for grid connected PV applications**.

The available net solar rooftop surface has been determined by the mentioned authors on the basis of typical statistical and urbanistic parameters for each investigated country, and by applying appropriate surface area utilisation factors, which quantify the specific losses of available surface areas by taking into account misorientation, obstacles, row spacing, access areas, etc. Typical values for such utilisation factors determined and used by the mentioned authors have been as follows:

- roofs of residential buildings — -20% ÷ -25% for inclined roofs, due to orientation and obstacles
  -40% ÷ -44% for flat roofs due to row spacing and obstacles.
- Roofs of offices and service buildings — -40% ÷ -44% due to row spacing and obstacles
- Roofs of industrial buildings — -40% ÷ -44% due to array distances and obstacles

The following table 1.19 gives a summary of results (for each OECD country) in terms of available net surface in km^2 of rooftops as subdivided into the investigated main building utilisation categories.

Table 1.19 - Estimate of available net solar rooftop surfaces in OECD Countries (1992)

Countries	*Irradiation*	*Net Available Solar Surface*			
		houses	*offices & services*	*industrial buildings*	*TOTAL 1992*
	kWh/ m2 year	*km2*	*km2*	*km2*	*km2*
Austria	1.200	50	15,0	13	78
Belgium	1.000	43	20,0	14	77
Denmark	1.000	34	11,0	6	51
Finland	900	45	11,0	8	64
France	1.200	362	122,0	85	569
Germany	1.000	532	214,0	242	988
Greece	1.500	64	11,0	6	81
Iceland	800	2	1,0	0	3
Ireland	1.000	16	5,0	4	25
Italy	1.300	336	120,0	86	542
Luxembourg	1.000	2	1,0	1	4
Netherlands	1.000	63	30,0	21	114
Norway	900	34	10,0	8	52
Portugal	1.700	54	11,0	11	76
Spain	1.600	145	60,0	51	256
Sweden	900	78	20,0	13	111
Switzerland	1.200	42	18,0	12	72
United Kingdom	1.000	248	123,0	96	467
Japan	1.300	486	289,0	264	1039
Australia	2.000	153	36,0	25	214
Canada	1.200	224	76,0	55	355
New Zealand	1.400	34	6,0	4	44
Turkey	1.700	324	37,0	33	394
Alaska	1.000	5	2	1	8
USA - Rest	1.600	1838	599	395	2832
USA - South West	2.100	491	167	110	768

Computations available from literature are referred to the situation in the investigated countries during the period 1992-1993. Nevertheless, the need to extrapolate results towards the year 2010 time horizon required to uniform all data (on demographic developments and electricity consumptions) to the three ten year intervals between 1960, 1970, 1980 and 1990. Accordingly solar rooftop surface figures have been referred to year 1990 for the purpose. This has been made by assuming that the available rooftop surface **per inhabitant** in the investigated countries presents basically a constant behaviour in time, defined by building standards, climate, economic

conditions and cultural characteristics. Accordingly, extrapolation of available solar rooftop surfaces has been calculated in proportion to number of inhabitants (see table 1.20).

Table 1.20 - Estimated available net solar rooftop surfaces per inhabitant in 1992 and 1990

Countries	Available net Solar surface pro capita					
	houses	offices & services	industrial buildings	TOTAL 1992		TOTAL 1990
	m2/ inhabitant	m2/ inhabitant	m2/ inhabitant	km2	m2/ inhabitant	km2
Europe	5,7	2,1	1,8	3.630	9,5	3.596
USA	9,1	3,0	2,0	3.608	14,1	3.531
Japan	3,9	2,3	2,1	1.039	8,3	1.031
Rest of OECD	6,9	1,5	1,1	1.007	9,4	972

The corresponding potential demand for PV capacity, which may be installed on these available solar rooftop surfaces has been calculated according to the following formula:

PV capacity [Wp] = Available net surface [m^2] x Standard Irradiance [W/m^2] x Module Efficiency [%]

where: the available net surface is derived from table 1.19
the standard irradiance is 1.000 W/m^2
module efficiency is evaluated from following figure 1.25

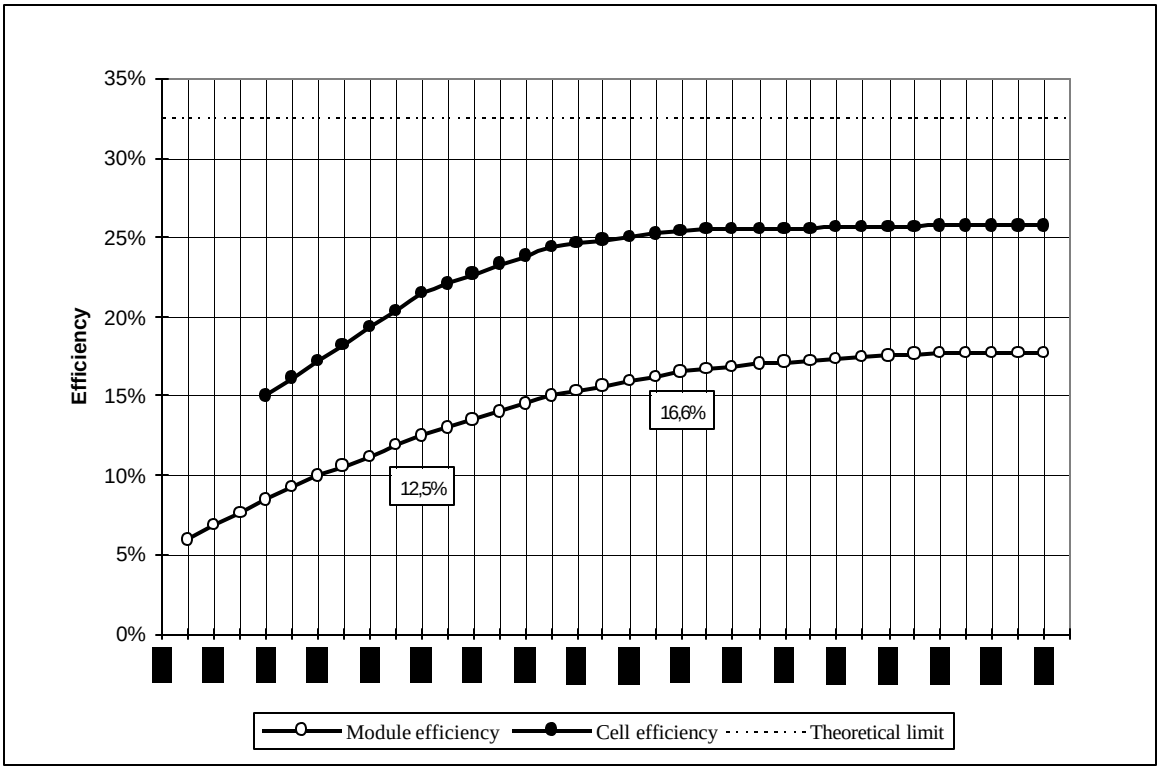
Calculations have been made on the basis of the following considerations concerning future PV module efficiency developments:

- Typical efficiency values for crystalline Si PV modules have been used, since amorphous, ribbon or other thin film PV technologies, at least for the next future, are expected to remain of minor importance for power applications and this specific market segment (their significantly lower efficiency results in higher surface requirement).
- The expected future evolution in time of commercial crystalline Silicon PV module efficiencies was taken from curve[5] as illustrated in the following figure 1.20. Efficiency quoted for years after 1992 are projected; those quoted up to and including 1992 are actual values.

The following table 1.21 presents the results of computations for year 1990, both in absolute terms as well as per inhabitant.

It must be emphasised, that **calculations do not take into consideration** that a consistent part of the available solar rooftop surfaces will be used for **concurrent thermal solar applications**, which obviously will have to be subtracted from the quantified rooftop surface potential.

Figure 1.20 - Trend in the past and forecast of crystalline silicon module and cell efficiency



The amount of produceable electric energy has been calculated by using the following simplified formula.

*Produceable PV Energy [MWh/year]=PV Capacity [MWp]*Solar Irradiation [kWh/m^2 year]*BOS efficiency*

where: installable PV capacity is taken from table 1.25
solar irradiation is taken from table 1.22
BOS (system) efficiency is assumed equal to 70%

The following table 1.21 presents, accordingly, the results of calculations for the investigated geographical areas.

Table 1.21 - Installable PV Rooftop Capacities in 1990 for OECD Countries

Countries	*Installable PV Capacity 1990*		*Producible PV Energy 1990*	
	MWp	*Wp/ inhabitant*	*MWh/year*	*kWh/year inhabitant*
Europe	449.157	1.182	360.563.789	957
USA	441.323	1.728	526.749.945	2.108
Japan	128.874	1.035	117.274.934	949
Rest of OECD	121.794	1.140	134.215.841	1.302

Calculated PV rooftop potentials in terms of produceable electricity have then been compared with the overall final electricity consumption of same OECD countries, to quantify the share of overall consumption, which can be covered by PV rooftop power.

Except for Japan with its high population density (and consequently low rooftop surface availability), all other OECD countries, including Europe, present a ***potential contribution of PV rooftop power of roughly 1000 kWh/year per inhabitant equalling more than 15 % of final electricity consumption.***

The following table 1.22 and related figure 1.21 show in addition a comparison with the present **hydropower contribution** to electricity consumption. The purpose of this comparison was to provide a rough quantification means for the maximum Solar PV power contribution, which the utility network would be able to absorb without need for significant changes in present network management techniques.

Table 1.22 - Today's PV Rooftop energy potential as share of Final Electricity Consumption

Countries	*Final Consuption of Electricity 1990*		*PV Rooftop Potential Energy Share [*] 1990*	*Actual Hydro Energy Share [*] 1990*
	MWh/year	*kWh/year inhabitant*	*%*	*%*
Europe	2.210.396.000	5.870	16,3%	19,9%
USA	3.022.386.000	12.093	17,4%	9,0%
Japan	857.273.000	6.939	13,7%	11,5%
Rest of OECD	704.475.000	6.834	19,1%	49,0%

[*] as compared to total final electricity consumption

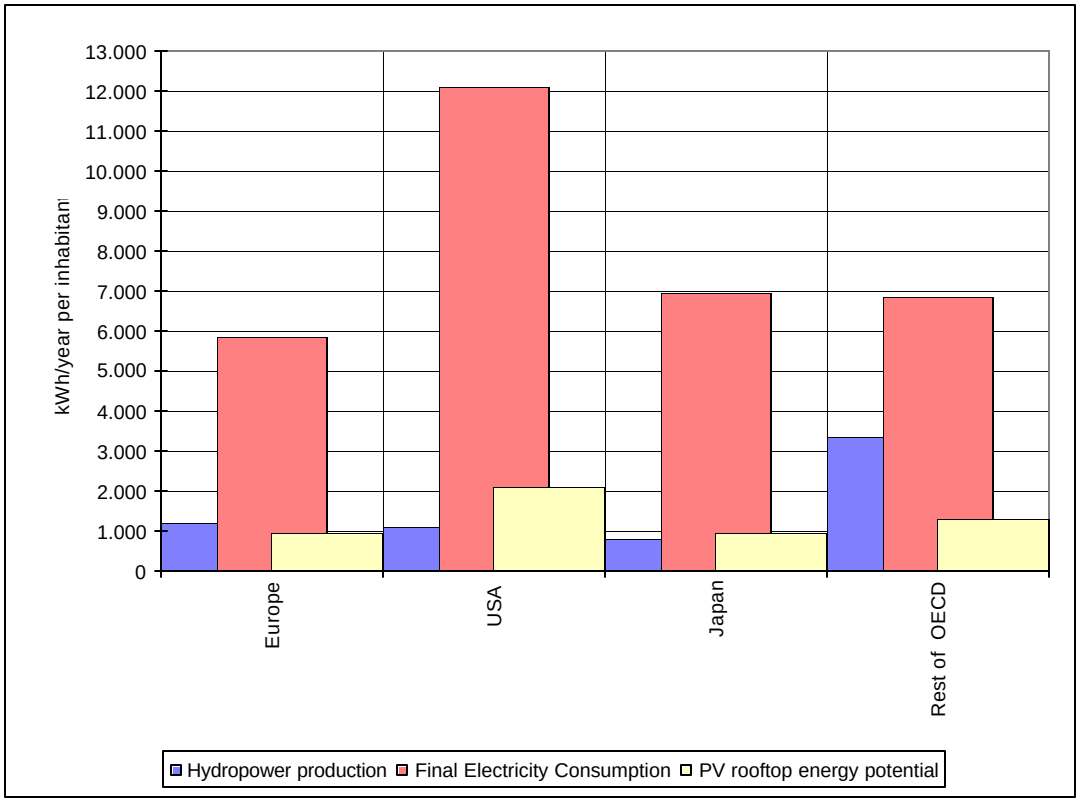
Unfortunately, solar PV installations (but same applies also to wind-power) are not controllable power sources, and their instantaneous power is governed exclusively by the incident solar irradiation (the wind in case of wind-power). This makes it difficult for the electric utility network to manage such kind of power contribution in case that it exceeds a certain threshold share of probably 2-3% of the total instantaneously consumed power. In fact the central dispatcher and

the automatic regulation systems of the electric network have to ensure instantaneously (every second) the exact balance between incoming power (from all generator facilities connected to the network) and outgoing power consumed by all connected consumers.

Hydropower is known to be very useful for the envisaged purpose, since hydropower facilities allow to compensate rapidly (and economically) for unbalance situations in the electric network. Thermal power facilities are either less flexible and allow for only limited load variations (base load steam power plants), or else are very costly (turbogas). Relevant rough estimates state that, as long as the total energy contributions to an electric network from non controllable power sources (like PV power) are below 50% of the energy contribution from hydropower facilities, the network can be managed and maintained in stable operating conditions without need to provide for new power management techniques. If, instead the contribution from non controllable power sources exceeds such 50% hydroenergy threshold share, special provisions must be made to counteract possible excess power situations in the electric network.

Typical known possibilities for such excess power management scenarios are the increased use of thermal peak generation capacities such as turbogas plants (costly, polluting and therefor not desirable) or demand side management (= load management) and electric energy storage (electric accumulator batteries and/or water pumping). On the other hand, in case that distributed PV generation capacities are installed primarily in areas presenting a large share of air conditioning consumption, this will, to a large extent, allow to compensate this kind of problem, since the resulting daily load profile meets the daily solar energy availability curve.

Figure 1.21 - Comparison between PV rooftop energy potential, final electricity consumption and hydropower share in OECD Countries (1990)



1.4.5.3 Year 2010 market forecast for grid-connected small-scale PV (rooftops)

The potential market forecast for year 2010 specifically for grid-connected small-scale PV systems (rooftops and similar) has been extrapolated based on the following assumptions and conditions:

- According to explanations presented in the previous paragraphs, the evolution of the *Net Available Solar Surface* has been extrapolated proportionally to the demographic trend of each single country as given the World-bank population development forecast[6].
- The potentially installable PV rooftop capacity for year 2000 and year 2010 has been calculated by using the expected crystalline silicon PV module efficiency values as presented in the previous figure 1.20 (15 % for year 2000, 16,5% for year 2010).
- To calculate the potential PV rooftop energy share in total final energy consumption, for each country, the trend of final energy consumption has been extrapolated on the basis of the trends experienced during the three ten-year periods between 1970, 1980 and 1990. Accordingly the extrapolations for the time horizons year 2000 and year 2010 have been determined by the minimum square root linear regression method.

All remaining calculations have been performed using same formulas and algorithms presented in the previous paragraph. Tables 1.23, 1.24 and 1.25, as well as figure 1.22 produce a synthetic overview, for each considered geographical macro-area, of results.

Table 1.23 - Forecast for year 2010 of available net solar rooftop surface in OECD Countries

Countries	Available net Solar surface year 2010	
	TOTAL km2	procapita m2/ inhabitant
Europe	3.723	9,5
USA	4.563	14,1
Japan	1.050	8,3
Rest of OECD	1.273	9,4

Table 1.24 - Forecast for year 2010 of Installable PV rooftop capacity in the OECD Countries

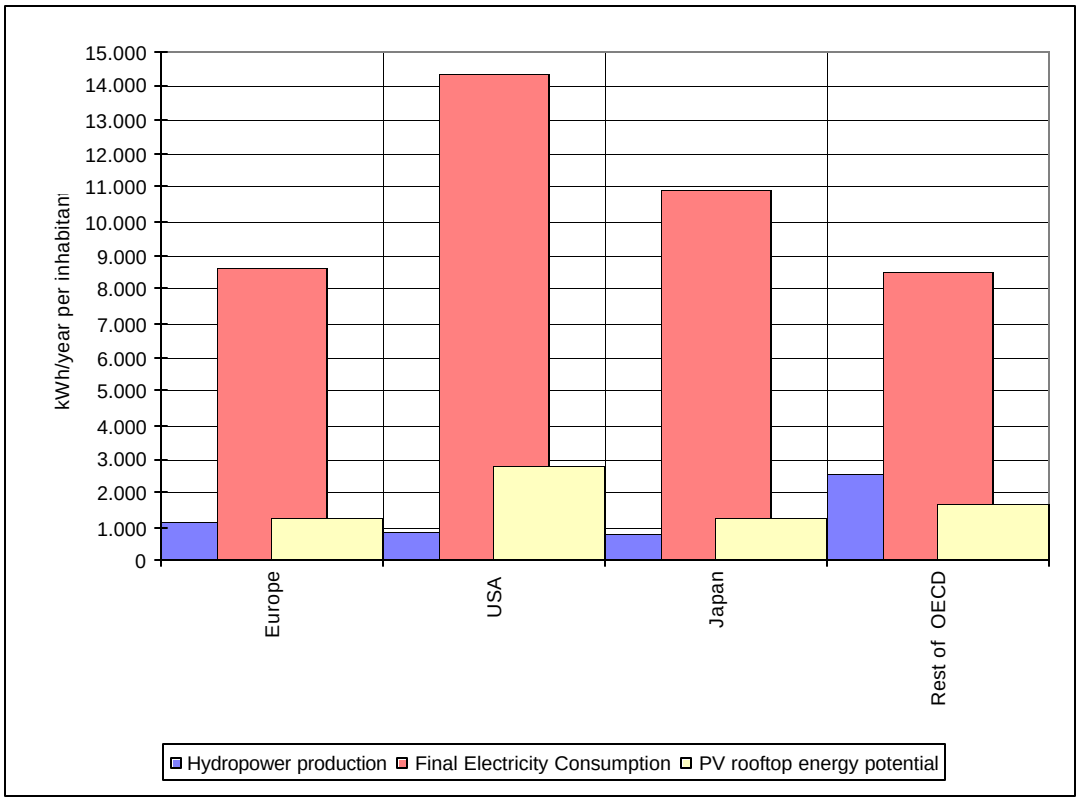
Countries	Installable PV Capacity		Producible PV Energy	
	year 2010		year 2010	
	MWp	Wp/ inhabitant	MWh/year	kWh/year inhabitant
Europe	617.662	1.584	494.194.649	1.268
USA	757.039	2.344	903.579.106	2.797
Japan	174.179	1.385	158.503.338	1.260
Rest of OECD	211.231	1.564	230.435.051	1.707

Table 1.25 - Forecast for year 2010 of potential PV Rooftop share in OECD Countries as compared to Final Electricity Consumption

Countries	Final Consumption of Electricity		PV Rooftop Energy Share [*]	Hydro Energy Share [*][**]
	year 2010		year 2010	year 2010
	MWh/year	kWh/year inhabitant	%	%
Europe	3.376.264.633	8.660	14,6%	13,0%
USA	4.623.186.067	14.313	19,5%	5,9%
Japan	1.373.048.233	10.915	11,5%	7,2%
Rest of OECD	1.146.311.883	8.489	20,1%	30,1%

[*] as compared to total final electricity consumption
[**] hydro energy production (in MWh/year) assumed equal to year 1990

Figure 1.22 - Comparison between PV rooftop potential energy contribution, final electricity consumption and hydropower share in the OECD Countries (year 2010 forecast)



1.4.5.4 Market considerations for grid-connected small-scale PV power

A previously presented general rules stated that, if utilities are to make the most of distributed generation, PV generators are to be sited as close as possible to customer loads, in order to allow for maximum savings in utility-side upstream operations, and consequent full exploitation of economic benefits.

The nearest possible place to customer loads for a PV generator is the roof of the customer himself. Accordingly, the best way to comply with the above general rule on distributed generation, is to favour rooftop installations of PV power.

As also previously mentioned, unlike conventional energy technologies, **PV technology presents no significant scale-economy effect**, i.e. specific costs of smaller PV systems are not much higher than those of larger PV systems.

Consequently, for grid-connected applications, there is no marked economic advantage in the implementation of few large-scale PV plants, in comparison to the realisation of many small-scale systems of equivalent total capacity.

Actually the distributed generation concept offers several advantages in comparison to large scale concentration of PV generation capacities:

Investments and manpower requirements (employment) for installation and maintenance are not concentrated, but may be distributed over larger territories and diluted in time (over several years), producing durable effects on development of local economy (employment) as well as steady development of the PV sector

Small-scale grid-connected PV plants, installed mostly on rooftops or integrated into buildings may be expected to become the backbone of the future distributed generation scenario for the electric utility networks, and accordingly are to be considered of strategic importance for the development of PV technology.

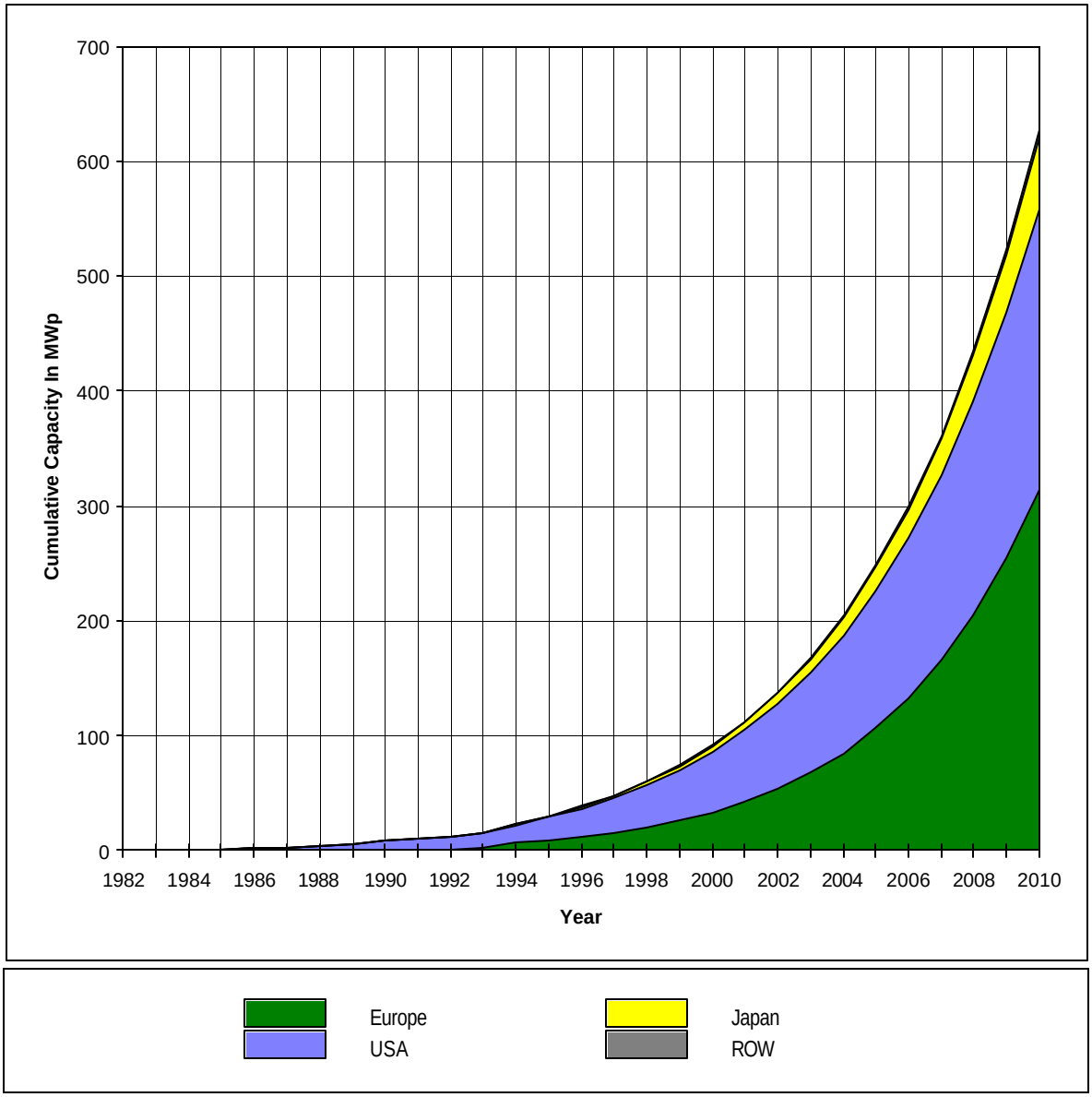
Also, since many middle class house owners in Europe are today interested in environmental issues, they are frequently willing to invest into environmental safeguard without taking profitability considerations too much into account.

Accordingly, lower levels of public financial contributions (like in Switzerland) are likely to trigger off PV rooftop implementations nevertheless, producing on a whole an improved cost/benefit ratio of public financing.

The resulting consistent market demand stimulation effect may be expected to provoke scale-up and optimisation (automation) and manufacturing facilities and, on the long run, consequent reduction of costs.

However, in order to allow for this kind of PV technology applications, all national regulatory limitations resulting from safety standards and particularly from ***not adequate grid interfacing requirements must be eliminated.***

Figure 1.23 - Grid-Connected Small-Scale PV Capacity Forecast
Figures beyond 1994 extrapolated by assuming overall shipment growth rate of 15% year
(more than 20 years old PV capacities subtracted since assumed dismantled)



1.4.6 Stand-Alone Applications

The following tables and figures present the results of the integrated computer based PV market model developed for the purpose of correlating and checking for consistency between interdependent market parameters, such as between annual shipments, market shares, prices, installed PV capacities, required investments, employment, etc. This model has allowed to check for and to detect inconsistencies between available market figures and estimates given by literature. Specifically as regards the stand-alone application market segments, data and information available from PV manufacturers and from literature have resulted to be frequently fragmentary and difficult to correlate.

The outcomes of this stand-alone PV market investigation are presented in the following two paragraphs according to areas (countries) of destination and according to type of application as follows:

1.4.6.1 Total capacities installed 1982-1994

Table 1.26 - Estimated installed capacity of PV stand-alone systems in kWp per year (1982-1994)

Years	*Installed Capacity in kWp per year*		
	Remote Industrial Applications	*Remote Electrification*	*TOTAL*
1982	2.450	1.700	4.150
1983	2.900	2.400	5.300
1984	4.050	3.050	7.100
1985	4.800	4.400	9.200
1986	7.200	6.300	13.500
1987	8.500	8.400	16.900
1988	10.300	12.000	22.300
1989	11.400	15.500	26.900
1990	11.500	18.400	29.900
1991	12.700	21.500	34.200
1992	14.600	25.700	40.300
1993	16.500	22.600	39.100
1994	17.700	23.600	41.300
TOTAL	**124.600**	**165.550**	**290.150**

Table 1.27 - Estimated installed capacity of PV stand-alone systems in kWp per year (1982-1994)

Years	*Installed PV Capacity in kWp per year and application*									
	North America	*Latin America*	*Europe*	*Middle East and North Africa*	*Central and South Africa*	*Oceania*	*Southeast Asia*	*Asia*	*West Asia*	*TOTAL*
1982	470	350	940	450	520	270	420	340	390	4.150
1983	600	450	1.200	570	660	340	540	440	500	5.300
1984	800	600	1.610	760	880	470	720	590	670	7.100
1985	1.040	760	2.090	980	1.140	620	930	770	870	9.200
1986	1.520	1.120	3.070	1.440	1.680	900	1.360	1.130	1.280	13.500
1987	1.900	1.400	3.840	1.800	2.100	1.140	1.700	1.420	1.600	16.900
1988	2.200	2.200	4.600	3.000	3.000	1.100	2.400	1.800	2.000	22.300
1989	2.750	3.100	6.300	3.700	3.800	1.200	2.200	1.850	2.000	26.900
1990	3.350	3.500	6.540	4.300	4.700	1.140	2.000	1.970	2.400	29.900
1991	3.620	4.700	7.680	4.800	5.500	840	2.300	1.570	3.200	34.210
1992	4.190	5.400	8.030	5.600	6.500	1.060	2.800	2.430	4.300	40.310
1993	8.480	3.930	7.020	4.700	5.210	3.130	1.640	1.250	3.740	39.100
1994	8.000	4.700	7.600	5.100	6.100	2.500	1.700	1.400	4.200	41.300
TOTAL	**38.920**	**32.210**	**60.520**	**37.200**	**41.790**	**14.710**	**20.710**	**16.960**	**27.150**	**290.170**

Figure 1.24- Trend of installed PV stand alone systems per year and geographical areas

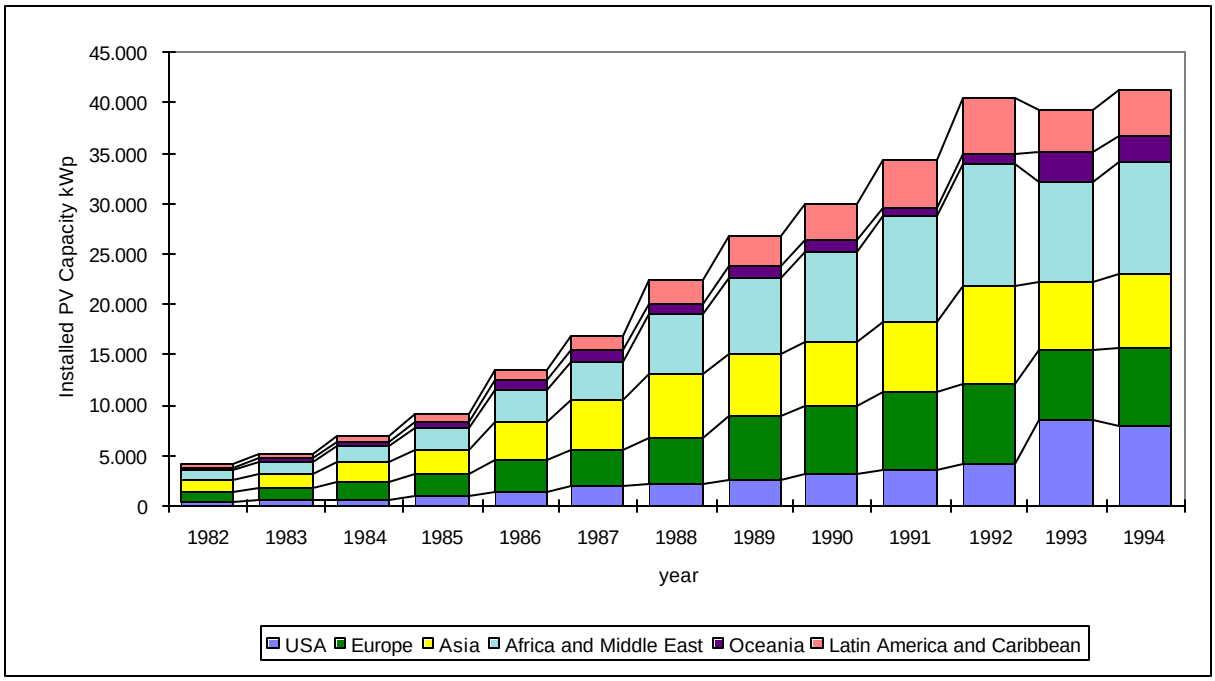


Table 1.28 - Estimate cumulative installed PV stand alone capacity (1982-1994) per geographical areas

Years	*Cumulative installed PV Capacity in kWp per year and application*									
	North America	*Latin America*	*Europe*	*Middle East and North Africa*	*Central and South Africa*	*Oceania*	*Southeast Asia*	*Asia*	*West Asia*	*TOTAL*
1982	470	350	940	450	520	270	420	340	390	4.150
1983	1.070	800	2.140	1.020	1.180	610	960	780	890	9.450
1984	1.870	1.400	3.750	1.780	2.060	1.080	1.680	1.370	1.560	16.550
1985	2.910	2.160	5.840	2.760	3.200	1.700	2.610	2.140	2.430	25.750
1986	4.430	3.280	8.910	4.200	4.880	2.600	3.970	3.270	3.710	39.250
1987	6.330	4.680	12.750	6.000	6.980	3.740	5.670	4.690	5.310	56.150
1988	8.530	6.880	17.350	9.000	9.980	4.840	8.070	6.490	7.310	78.450
1989	11.280	9.980	23.650	12.700	13.780	6.040	10.270	8.340	9.310	105.350
1990	14.630	13.480	30.190	17.000	18.480	7.180	12.270	10.310	11.710	135.250
1991	18.250	18.180	37.870	21.800	23.980	8.020	14.570	11.880	14.910	169.460
1992	22.440	23.580	45.900	27.400	30.480	9.080	17.370	14.310	19.210	209.770
1993	30.920	27.510	52.920	32.100	35.690	12.210	19.010	15.560	22.950	248.870
1994	38.920	32.210	60.520	37.200	41.790	14.710	20.710	16.960	27.150	290.170

Figure 1.25 - Behaviour in time of cumulative installed PV stand alone systems capacity (1982-1994) per geographical area

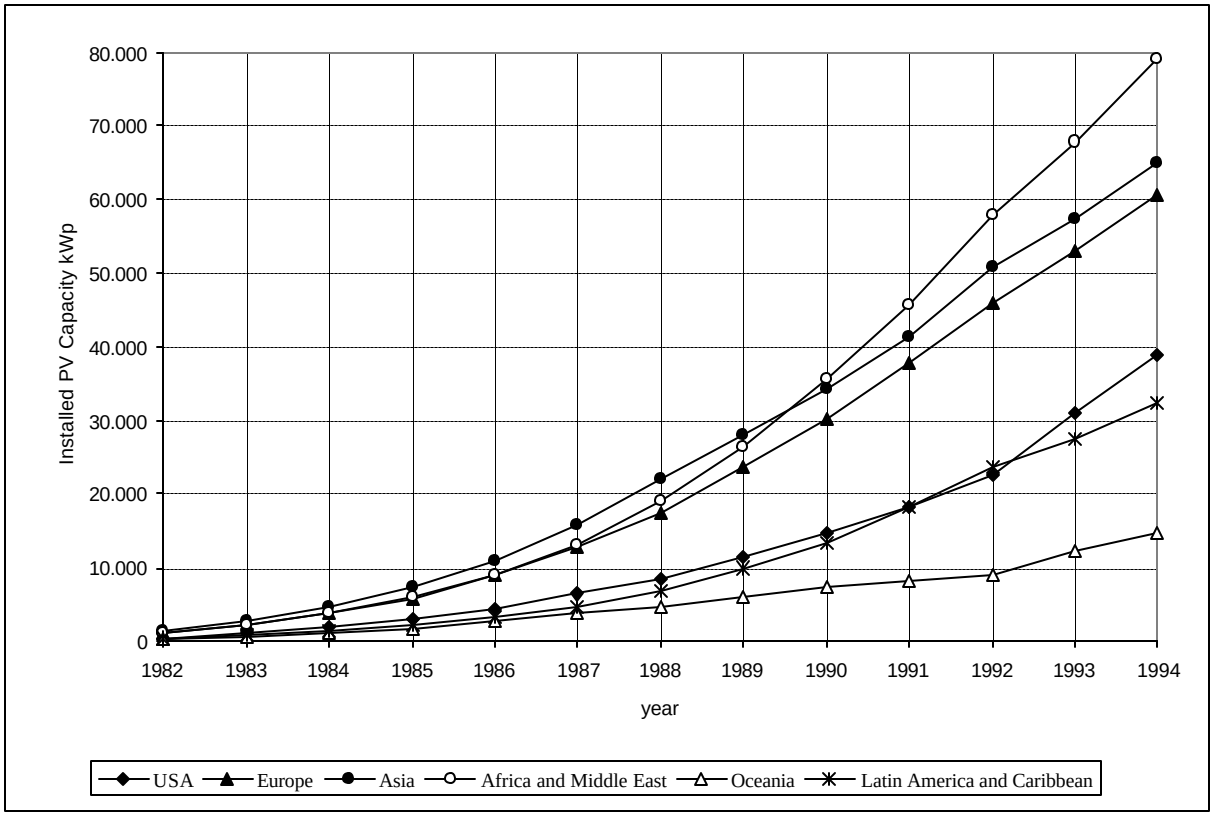
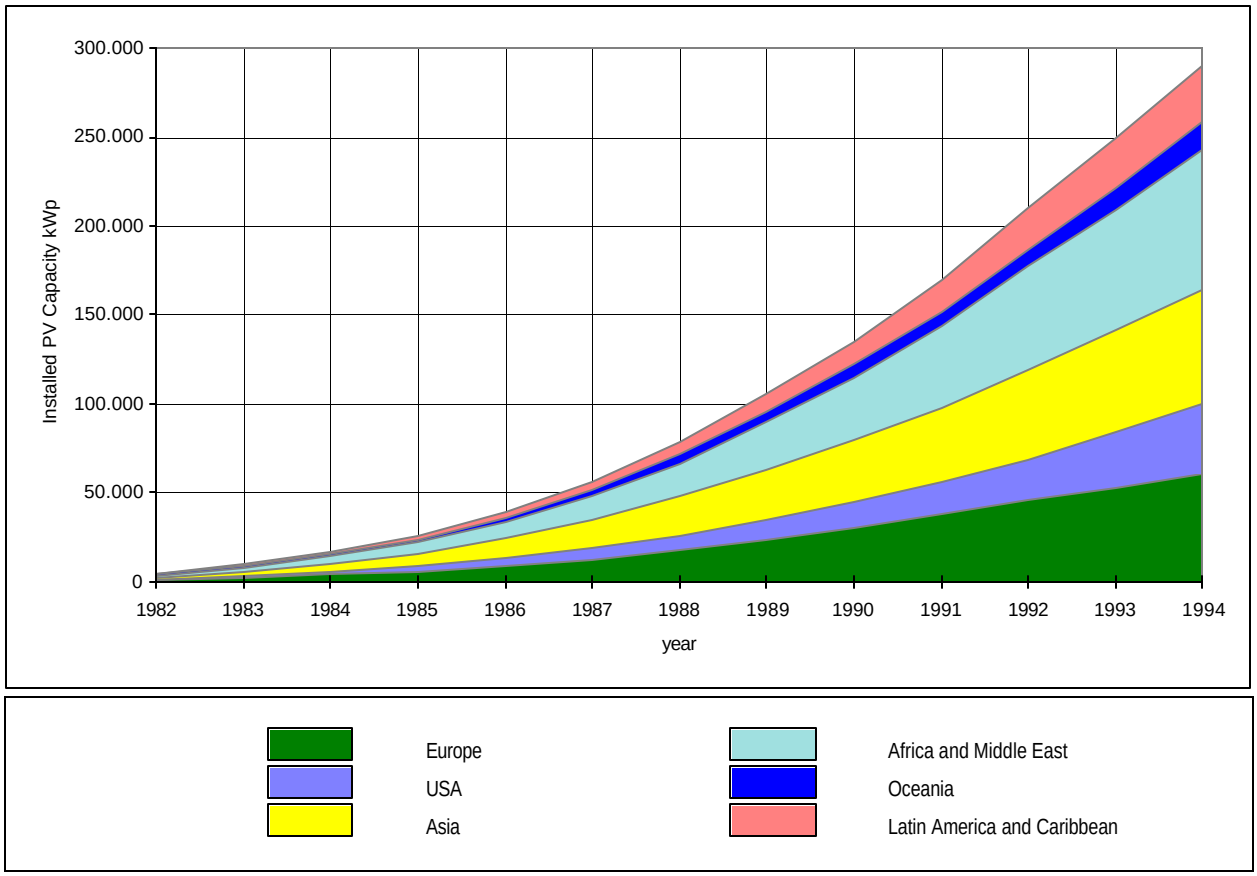


Figure 1.26 - Actual World PV stand alone market development (1982-1994)



1.4.6.2 Capacities installed 1982-1994 per market segment applications

Table 1.29 - Installed PV stand alone systems capacity per year and type of applications

Year	PV Stand-alone systems capacity										TOTAL
	Remote industrial			Remote rural					Consumer/leisure		
	Telecom	Cathodic protection	Military/ signalling	Water Pumping	Village Power	Solar Home Systems	Remote houses	Other remote	Camping Boating Leisure	Consumer Indoor	PV stand-alone applic. module Shipments
1982	1,9	0,3	0,3	0,4	0,1	0,4	0,2	0,6	0,2	0,9	**5,2**
1983	2,2	0,4	0,4	0,7	0,3	0,7	0,3	0,5	0,3	1,7	**7,3**
1984	3,3	0,2	0,6	1,2	0,3	0,8	0,4	0,4	1,0	3,4	**11,4**
1985	4,0	0,3	0,5	1,6	0,5	1,3	0,6	0,4	1,8	3,5	**14,5**
1986	6,3	0,4	0,5	2,1	0,7	2,1	0,9	0,5	2,2	3,8	**19,5**
1987	7,4	0,5	0,6	3,0	0,9	2,8	1,2	0,5	2,8	4,1	**23,8**
1988	8,9	0,7	0,7	4,2	1,3	4,2	1,7	0,6	4,0	3,9	**30,2**
1989	9,8	0,8	0,8	5,4	1,9	5,3	2,3	0,6	5,5	4,0	**36,4**
1990	9,8	0,9	0,8	6,4	2,1	6,4	2,7	0,8	6,3	3,7	**39,9**
1991	10,9	1,1	0,7	7,3	2,8	7,3	3,1	1,0	7,3	3,2	**44,7**
1992	12,4	1,3	0,9	8,0	3,5	9,1	3,9	1,2	8,7	3,4	**52,4**
1993	10,5	3,6	2,4	4,0	1,6	9,6	4,1	3,3	9,5	3,7	**52,3**
1994	12,6	2,5	2,6	5,4	2,0	10,1	4,3	1,8	8,9	3,5	**53,7**
TOTAL	**100,0**	**12,9**	**11,7**	**49,6**	**17,9**	**60,1**	**25,7**	**12,2**	**58,5**	**42,7**	**391,3**

Figure 1.27- Distribution of cumulative PV stand alone installed capacity per type of applications (1982-1994)

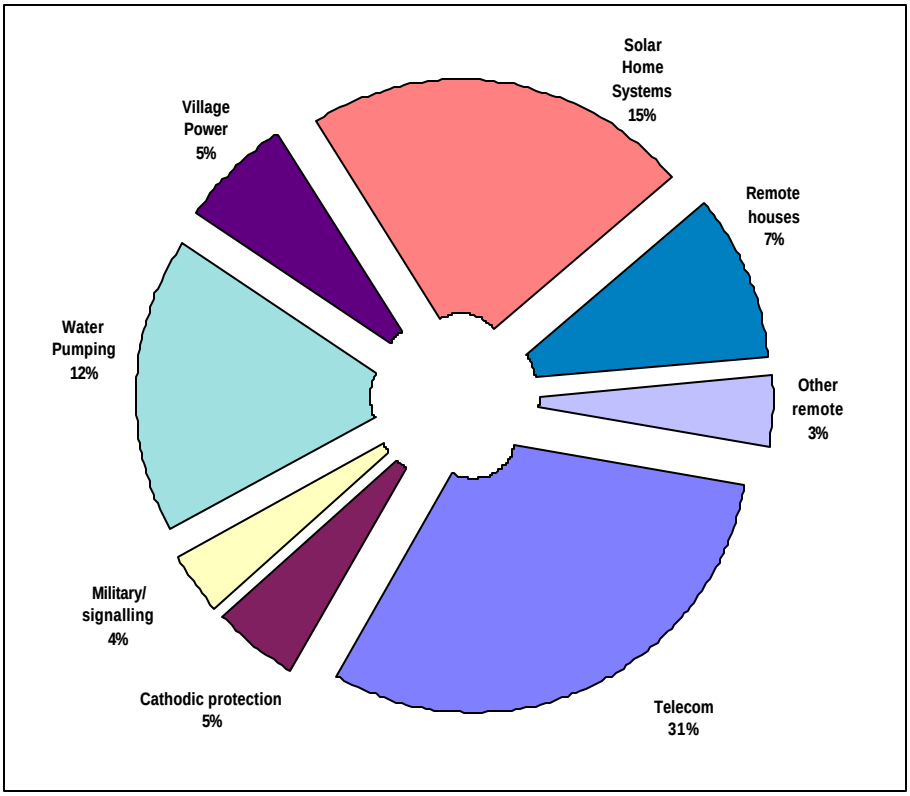
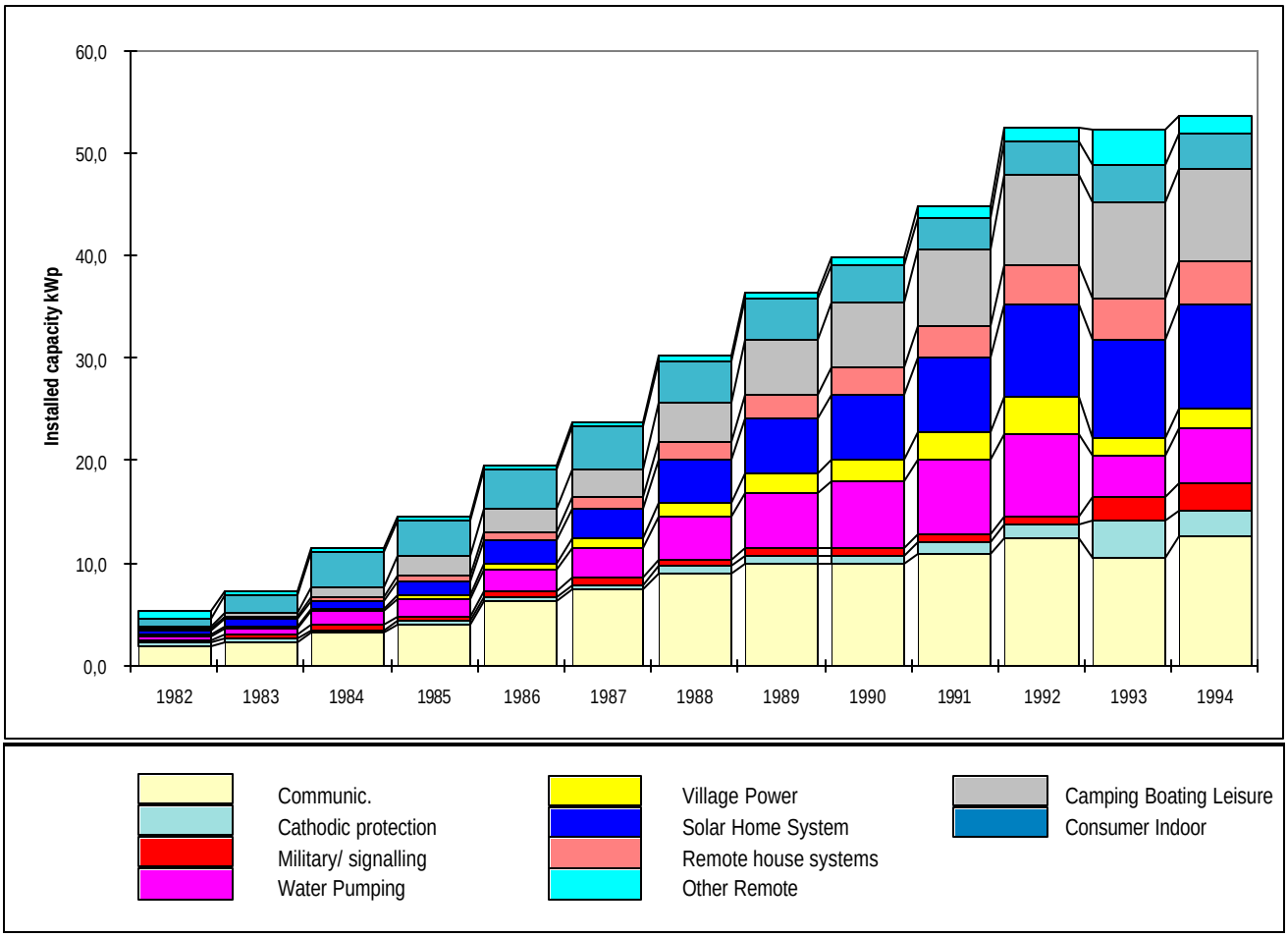


Figure 1.28 - Installed PV stand-alone systems capacity per year and type of applications



1.4.7 Potential demand for stand alone PV applications

The potential demand for stand alone PV applications has been estimated on the basis of the number of non-electrified population living in non-OECD countries and specifically in the third world. The following table 1.30 presents the rural non-electrified population for year 1990 living in the countries belonging to the considered geographical macro-areas.

Initially, the evaluation of the potential world market was intended to be extrapolated to year 2010 by adopting the demographic projection figures given by the UN and the World Bank[7] reflecting present urbanisation and rural migration trends in the considered various countries[8].

However, a preliminary analysis of available data made evident that generally, in all third world countries, and specifically in those belonging to the "low income" category, the urbanisation trend of population is that much pronounced that, in spite of the expected sharp increase in total population, the non-electrified rural population may be expected to remain practically constant. Accordingly the potential demand for stand-alone PV systems has been projected to year 2010 on the basis of the non-electrified rural population levels of year 1990.

The resulting estimate may be considered "on the safe side" (underestimated rather than overestimated) since, especially in the poorest countries, where electrification levels are still very far from satisfying the needs, existing utility networks may be expected to expand their services considerably towards a larger number of consumers living inside and near the urban centres (this takes into account the consistent number of traditional electrification programmes in any case being today implemented world-wide (Cifr. Note 1).

To provide an indication for the level of penetration of conventional network electrification, analysis of countries has been executed by classifying and grouping these countries according to average income per inhabitant, since infrastructural developments are known to be strongly linked to this parameter. Relevant classification has been performed according to the guidelines of the World Bank(cifr. Note 1), which define the following income categories for the purpose:

- low income economies — GNP per capita year — US$ 675 or less in 1992 (ECU 510 or less)
- low-medium income economies — GNP per capita year — US$ 676-2.695 in 1992 (ECU 511-2.034)
- upper-medium income economies — GNP per capita year — US$ 2.696-8.355 in 1992 (ECU 2.035-6.308)
- upper income economies — GNP per capita year — US$ 8.356 or more in 1992 (ECU 6.309 or more)

The results of such subdivision are presented in the following table 1.30.

Table 1.30 - Total population and share of rural population per income category countries for the investigated geographical macro-areas, in year 1990 and expected for year 2010

Geographical Areas	*Population (in millions inhabitants)*		*Rural Population*		*% of Rural Population per Income Category (1990)*		
	1990	*2010*	*1990*	*2010*	*Low Income Countries*	*Low-Middle Income Countries*	*Upper-Middle Income Countries*
Central America and Caribean	136	185	36%	24%	55%	52%	27%
Latin America	297	386	25%	11%	65%	32%	22%
North Africa	115	157	51%	44%	56%	50%	11%
Saharian Africa	49	89	76%	65%	76%	---	---
Sub-Saharian Africa	369	607	73%	63%	74%	60%	55%
South Africa	105	170	64%	55%	74%	58%	51%
Middle East	194	316	44%	26%	74%	41%	31%
South Asia	1.092	1.549	75%	69%	75%	---	---
Central Asia	1.184	1.394	72%	64%	74%	42%	29%
East Asia	435	579	69%	58%	70%	67%	57%
Oceania	4	7	83%	82%	---	99%	---
TOTAL	**3.980**	**5.440**	**66%**	**55%**	**74%**	**49%**	**28%**

The following table 1.31 presents the share (in %) of rural population having access to infrastructural facilities, i.e. to the minimum services required for decent living. Percentage figures are to be interpreted as follows.

- *access to drinking water* means access to safe water by either standpipe or house connections. Safe water is defined here as treated surface waters or untreated but uncontaminated waters such as from protected springs, boreholes and sanitary wells;
- *access to sanitation* refers to that share of rural population, which has the possibility to access medical health services.
- *access to education* refers to that share of rural population, for all age classes, which is enrolled in the education system of the country. This indicator value has been corrected in order to take into account the age classes addressed by primary school education (from 5 to 15 years of age), since thereby also the eventual utilisation of school structures by adult analphabets is considered.
- *electrified population* is given in terms of percentage of total households (rural and urban) having access to electricity sufficient for at least electric lighting. Since the percentage of electrified rural population is not given by World Bank statistics, it has been estimated as follows, by assuming the family size (number of members per family) of rural families to be equal to the country average:
    - If the total electrified population of a country resulted to be larger than the urban population of the country, the electrified population exceeding the urban population was considered to be electrified rural population, and the remainder of rural population was accordingly considered to be not electrified.
    - If the total electrified population of a country resulted to be smaller than the urban population of the country, all rural population was considered to be not electrified.

Accordingly the non-electrified rural population has been estimated as the difference, for each country, between the total rural population and the electrified rural population.

Table 1.31 - Access of rural population to basic infrastructural services

Geographical Area	*1990*			
	% of Rural Population without access to safe drinking water	*% of Rural Population without access to health system*	*% of Rural Population (age 5-15 years) without access to education*	*% of Rural Population without electricity*
Central America and Caribean	40%	23%	34%	45%
Latin America	46%	67%	22%	60%
North Africa	35%	42%	38%	60%
Saharian Africa	76%	93%	74%	79%
Sub-Saharian Africa	70%	72%	56%	55%
South Africa	64%	77%	58%	64%
Middle East	35%	47%	39%	53%
South Asia	32%	95%	54%	40%
Central Asia	32%	19%	41%	27%
East Asia	47%	55%	35%	65%
Oceania	80%	47%	53%	39%
TOTAL	**40%**	**57%**	**45%**	**43%**

On the basis of these data, the potential world market demand for stand-alone PV systems allowing to satisfy the envisaged *minimum basic needs* has been estimated.

The following paragraphs present more in detail the criteria adopted for this estimate.

To avoid to overestimate the potential market demand, the concept of *minimum basic needs* has been quantified at the effectively minimum level, since otherwise results may become misleading for national and international planning and financing authorities.

1.4.7.1 The PV capacity required for safe drinking water supplies

The following table 1.32 presents the outcomes of the estimate of the demand (per GDP/inhabitant class) for safe drinking water of rural populations in the investigated geographical macro-areas.

Table 1.32 - The share of rural population presently having no access to safe drinking water

Geographical Area	*DEMAND FOR SAFE DRINKING WATER % of Rural Population*			
	Low Income Countries	*Low-Middle Income Countries*	*Upper-Middle Income Countries*	*TOTAL*
Central America and Caribean	63%	56%	22%	*40%*
Latin America	29%	48%	44%	*46%*
North Africa	14%	56%	---	*35%*
Saharian Africa	76%	---	---	*76%*
Sub-Saharian Africa	71%	50%	50%	*70%*
South Africa	64%	78%	10%	*64%*
Middle East	75%	31%	19%	*35%*
South Asia	32%	---	---	*32%*
Central Asia	32%	42%	24%	*32%*
East Asia	57%	21%	34%	*47%*
Oceania	---	80%	---	*80%*
TOTAL	**40%**	**38%**	**33%**	***40%***

The minimum daily water requirement of a human being has been assumed equal to the figures given in the following table 1.33, taking into consideration that the predominant climatic conditions affect this parameter.

Dry desert climates have been considered to provoke a higher daily water requirement than humid tropical or other climatic conditions.

Same table presents also the assumptions made as regards the average pumping head required to pump water from boreholes, assuming more severe average conditions (deeper boreholes) in arid and dry desert climates.

The pumping head was assumed to include pressure losses and the aboveground height of the water storage tank.

Table 1.33 - Average assumptions used for estimate calculations of PV peak power capacity required for safe drinking water pumping

Type of Climate	*STANDARDS ADOPTED*	
	litres per capita/ day	*Pumping head m*
Equatorial Climate	15	30
Sub-Equatorial Climate	15	30
Tropical Dry Climate with summer rainfall	20	50
Tropical very Dry Climate with summer rainfall	20	50
Arid Climate	20	50
Continental Arid Climate	20	50
Continental Humid Climate	15	30

The following table 1.34 presents the calculation results for the forecasted requirement for safe drinking water of rural populations presently not having access to this kind of infrastructural service, based on the above presented daily requirement per capita. Results are here presented aggregated for each geographical macro-area, but calculations have been performed separately for each single country.

Table 1.34 - Demand forecast for safe drinking water

Geographical Area	*SAFE DRINKING WATER REQUIREMENT FORECAST* *000 m ^{3} /year*			
	Low Income Countries	*Low-Middle Income Countries*	*Upper-Middle Income Countries*	*TOTAL*
Central America and Caribean	26.200	40.100	69.800	*136.100*
Latin America	800	72.800	192.600	*266.200*
North Africa	132.600	124.300	2.600	*259.500*
Saharian Africa	212.000	---	---	*212.000*
Sub-Saharian Africa	922.200	32.600	1.400	*956.200*
South Africa	167.700	33.600	90.000	*291.300*
Middle East	125.900	172.700	29.900	*328.500*
South Asia	1.887.500	---	---	*1.887.500*
Central Asia	2.473.600	6.000	---	*2.479.600*
East Asia	859.400	190.900	15.600	*1.065.900*
Oceania	---	7.300	---	*7.300*
TOTAL	**6.807.900**	**680.300**	**401.900**	***7.890.100***

The above calculated minimum safe drinking water requirement of rural non-electrified populations has then been used to calculate the energy required to pump this quantity of water.

Taking into account the average expected pumping head as presented in the above table 1.33, the traditional algorithm (given in hydraulic engineering handbooks) was used for the calculation of the required pumping energy as follows:

$$E = \frac{Q * H}{C * h_{ep}}$$

Where: E = Electric energy required for pumping (in MWh/year);
Q = Pumped water volume (in 1000 m^3/year);
H = Pumping head (in metres of water column);
C = Hydraulic energy equivalent = 367,2 m^4/kWh;
η_{ep} = Overall electric pumping efficiency, typical average considered = 20 %;

Whereas the PV peak power capacity required to produce this pumping energy has been calculated according to the following simplified formula:

$$P_{PV} = \frac{E}{I_{equiv.} * h_{sh}} \quad \text{whereby} \quad I_{equiv.} = I_S / I_{STC}$$

Where: PPV = Required PV peak power capacity (in MWp);
E = Electric energy required for pumping (in MWh/year);
Iequiv.= Equivalent annual STC solar irradiation time (in h/year);
IS = Irradiation on horizontal plane (in kWh/m2 year);
ISTC = Irradiance under STC (Standard Test Conditions) = 1 kW/m2
h sh = Solar energy harvesting efficiency, typical average considered = 70 %;

At a first glance, this estimate method may appear astonishing simple since no sizing of adopted PV pumping systems nor a quantification of the required number is performed.

In practice, since it utilises exclusively energy equivalencies, it makes no difference between using for same pumping performance either many small pumps, or few large pumps or, in the extreme, one enormous solar PV pump.

Eventual differences may reflect themselves exclusively in the adopted energy efficiencies.

The following table 1.35 presents the results of the estimate calculations performed (for each country separately) according to the above algorithms, and aggregated under the considered geographical macro-areas.

For better understanding, the presented results have been converted into per capita figures by dividing the results by the number of rural population presently not having access to this kind of infrastructural service. The following table 1.36 gives this kind of representation of results, expressed in required Wp per person of PV peak power capacity.

Table 1.35 - Demand potential for PV capacity required for safe drinking water pumping

Geographical Area	PV CAPACITY DEMAND FORECAST FOR WATER PUMPING							
	Low Income Countries		Low-Middle Income Countries		Upper-Middle Income Countries		TOTAL	
	Energy required MWh/year	Peak Power Required MWp	Energy required MWh/year	Peak Power Required MWp	Energy required MWh/year	Peak Power Required MWp	Energy required MWh/year	Peak Power Required MWp
Central America and Caribean	10,7	6,3	16,4	9,7	47,4	30,9	74,5	46,9
Latin America	0,3	0,2	34,1	20,5	78,7	50,9	113,1	71,6
North Africa	90,3	51,2	84,6	59,1	1,8	1,0	176,7	111,3
Saharian Africa	144,4	83,0	---	---	---	---	144,4	83,0
Sub-Saharian Africa	542,3	317,5	13,9	8,8	0,6	0,4	556,8	326,7
South Africa	104,0	59,6	16,3	10,1	61,2	36,1	181,5	105,8
Middle East	85,7	49,0	117,6	70,6	20,4	11,1	223,7	130,7
South Asia	875,5	530,4	---	---	---	---	875,5	530,4
Central Asia	1.010,5	941,6	4,1	3,8	---	---	1.010,5	941,6
East Asia	351,0	234,4	78,0	55,2	6,4	3,9	435,4	293,5
Oceania	---	---	3,0	1,8	---	---	3,0	1,8
TOTAL	**3.214,7**	**2.273,2**	**368,0**	**239,6**	**216,5**	**134,3**	**3.799,2**	**2.647,1**

Table 1.36 - Per capita demand potential for PV capacity required safe drinking water pumping

Geographical Area	PV PEAK POWER (Wp) PER CAPITA DEMAND FORECAST FOR WATER PUMPING			
	Low Income Countries	Low-Middle Income Countries	Upper-Middle Income Countries	AVERAGE
Central America and Caribea	1,3	1,3	3,2	2,2
Latin America	1,3	1,8	1,5	1,6
North Africa	2,8	3,5	2,8	3,1
Saharian Africa	2,9	---	---	2,9
Sub-Saharian Africa	2,3	1,5	1,6	2,2
South Africa	2,4	1,8	2,9	2,5
Middle East	2,8	3,0	2,7	2,9
South Asia	1,6	---	---	1,6
Central Asia	4,2	4,6	---	4,2
East Asia	1,5	1,6	1,4	1,5
Oceania	---	1,3	---	1,3
TOTAL AVERAGE	**2,4**	**2,2**	**2,2**	**2,4**

It is interesting to note, that PV capacity requirements for safe drinking water pumping do not depend significantly on country income levels, that the order of magnitude of results remains similar all over the world, and that results correspond roughly to one fourth of the "Power for the World" programme target of 10 Wp per capita.

The resulting cost may be expected to range between 20-40 ECU per served inhabitant.

1.4.7.2 PV application potential for rural education

The PV application potential for rural education, that is the installed PV peak power capacity required for a reasonable (minimum level) electrification of educational centres and schools in not electrified rural areas throughout the world has been estimated on the basis of the following:

- presently non-electrified schools in rural areas throughout the world;
- new schools required in rural areas to ensure a minimum level of education for all children in the world belonging to the primary school education age class.

As regards the electrification levels of presently existing rural schools, the following data sources have been adopted:

- UNESCO[9] from where also the data on population having access to school education, on population age classes between 5 to 15 years, and on the number of presently existing schools have been taken for each considered country individually.
- Specific documentation available on individual countries;
- In those cases, where such data were not available, the age class population between 5 to 15 years and the non-electrified rural population have been estimated accordingly.

In any case, to remain "on the safe side" and to avoid overestimates, in case of uncertainties, the presented results reflect the outcomes of lower estimates rather than higher ones.

The need for new schools and education centres for the envisaged primary school age classes of population has been quantified based on the following considerations:

- For each individual country, the present average student number per (existing) school has been determined;
- On the basis of this figure, the number of new schools required to satisfy the need for school education of the envisaged age class population with presently no access to education has been determined;

The presented results may be considered relatively reliable since, for those countries for which relevant detailed data were available, they basically confirmed the outcomes of the above presented estimate procedure, and secondly since the adopted estimate approach utilises averaged data representing the school situation of each country as a whole, so that differences in school density between urban and rural areas are thereby compensated for.

The outcomes of the above presented estimates are presented in the following table 1.37

Table 1.37 - School electrification demand potential, including number of today existing non-electrified schools and number of required new schools (to be also electrified)

Geographical Area	*NEEDS OF EDUCATION*				
	% of Rural Population (age 5-15 years) without access to education	*Estimated number of schools todays unelectrified*			*Estimated number of new schools*
		Low Income Countries	*Low-Middle Income Countries*	*Upper-Middle Income Countries*	*TOTAL*
Central America and Caribean	34%	9.300	13.100	29.200	95.600
Latin America	22%	---	24.300	33.000	122.600
North Africa	38%	6.100	17.600	4.200	42.100
Saharian Africa	74%	10.400	---	---	49.300
Sub-Saharian Africa	56%	82.500	10.900	500	202.900
South Africa	58%	25.200	8.100	600	37.500
Middle East	39%	6.000	39.200	10.000	104.200
South Asia	54%	256.400	---	---	992.200
Central Asia	41%	186.100	600	---	660.800
East Asia	35%	152.100	25.200	2.100	217.900
Oceania	53%	---	900	---	4.000
TOTAL	**45%**	**734.100**	**139.900**	**79.600**	**2.529.100**

The minimum level of electrification to be provided to these schools by means of stand-alone PV systems has been determined on the basis of the installed PV peak power capacity required per school as given by the following table 1.38. The table makes evident, that the minimum required PV electrification level depends on the type of economy of the country (level of income per inhabitant), where the school is located. Low income countries may be expected to adopt minimum levels of PV electrification per school (typically 600 Wp per school), whereas upper-middle income countries may be expected to adopt higher levels of school PV electrification (typically 2000 Wp per school).

Generally, the following minimum services, facilities and equipment have been considered necessary for each school or education centre:

- Lighting (energy saving type such as Neon-tube or PL type);
- Small water pump for water distribution purposes;
- Communication (rural telephony) means;

In upper-middle income countries, some further services and commodities may be expected to be provided such as:

- More lighting;
- Larger household refrigerator (energy saving type);
- TV set + Videorecorder;

Table 1.38 - Average PV peak power capacity per school expected to be adopted, depending on income category of country

Type of Economy	*STANDARDS ADOPTED*
	Peak Power needs for each school Wp
Low Income Countries	600
Low-Middle Income Countries	1200
Middle-Upper Income Countries	2000

Based on the above figures, the potential demand for PV electrification for schooling and educational purposes in non-electrified rural areas world-wide has been calculated for each single country in absolute terms, and as pro-capita value.

The outcomes of such estimate calculations aggregated according to the considered geographical macro-areas are presented in tables 1.39 and 1.40.

Table 1.39 - Demand potential for PV peak power capacity required for schooling and education in non-electrified areas world-wide

Geographical Area	*PV PEAK POWER (MWp) DEMAND FORECAST FOR EDUCATION (existing not electrified and new schools)*			
	Low Income Countries	*Low-Middle Income Countries*	*Upper-Middle Income Countries*	*TOTAL*
Central America and Caribean	12,4	44,2	179,5	236,1
Latin America	0,6	94,2	200,8	295,6
North Africa	14,0	50,1	9,8	73,9
Saharian Africa	35,9	---	---	35,9
Sub-Saharian Africa	162,5	30,3	1,3	194,1
South Africa	36,5	11,5	2,2	50,2
Middle East	10,8	146,3	34,3	191,4
South Asia	749,2	---	---	749,2
Central Asia	502,8	3,4	13,1	519,3
East Asia	175,5	119,3	10,6	305,4
Oceania	---	5,9	---	5,9
TOTAL	**1.700,2**	**505,2**	**451,6**	**2.657,0**

Table 1.40 - Per-capita demand potential for PV peak power capacity required for schooling and education in non-electrified areas world-wide

Geographical Area	*PV PEAK POWER (Wp) PER CAPITA DEMAND FORECAST FOR EDUCATION (existing not electrified and new schools)*			
	Low Income Countries	*Low-Middle Income Countries*	*Upper-Middle Income Countries*	*AVERAGE*
Central America and Caribean	2,6	6,0	18,7	10,9
Latin America	4,0	8,3	6,1	6,7
North Africa	0,8	2,9	27,2	2,1
Saharian Africa	1,2	---	---	1,2
Sub-Saharian Africa	1,2	5,2	5,1	1,3
South Africa	1,5	2,0	0,2	1,2
Middle East	0,6	6,2	8,4	4,3
South Asia	2,3	---	---	2,3
Central Asia	2,2	4,1	---	2,3
East Asia	1,1	3,4	3,7	1,6
Oceania	---	4,4	---	4,4
TOTAL AVERAGE	**1,8**	**4,7**	**7,2**	**2,4**

The presented results show a pronounced dependence on country income levels, and again remain significantly below the “Power for the World” programme target of 10 Wp per capita. Relevant PV electrification costs may be expected to range between 15-100 ECU per inhabitant (not per student).

1.4.7.3 PV application potential for rural minimum health care

The PV application potential for rural health care, that is the installed PV peak power capacity required for a reasonable (minimum level) electrification of rural health care centres in not electrified rural areas throughout the world has been estimated on the basis of the following criteria (for each country separately):

- The number of population without access to health care services has been determined from the difference between total population and the share of population having such access to health care as given by relevant WHO[10] data;
- The average number of population presently served by each physician has been determined by using same WHO data;
- The number of required new rural health care centres has then been determined by dividing the number of population presently having no access to health care by the average number of population presently served by each existing physician.

The outcomes of the above presented calculations are presented in the following table 1.41.

Table 1.41 - Number of required new rural health care centres

Geographical Areas	*HEALTH SYSTEM NEEDS*				
	% of Rural Population without access to health system	*Estimate number of new minimum health care centers per income category countries*			*TOTAL*
		Low Income Countries	*Low-Middle Income Countries*	*Upper-Middle Income Countries*	*TOTAL*
Central America and Caribean	47%	1.800	1.600	15	3.415
Latin America	67%	30	9.300	19.000	28.330
North Africa	74%	2.000	500	14	2.514
Saharian Africa	93%	2.400	---	---	2.400
Sub-Saharian Africa	77%	10.500	300	100	10.900
South Africa	77%	2.200	700	42	2.942
Middle East	47%	1.000	7.800	400	9.200
South Asia	95%	72.600	---	---	72.600
Central Asia	19%	14.300	800	---	15.100
East Asia	55%	7.800	2.100	100	10.000
Oceania	47%	---	100	---	100
TOTAL	**59%**	**114.630**	**23.200**	**19.670**	**157.500**

Generally, the following minimum services, facilities and equipment have been considered necessary for each rural health care centre:

- One vaccine refrigerator;
- Lighting (energy saving type such as Neon-tube or PL type);
- Small water pump for distribution purposes;
- Communication (rural telephony) means;

In upper-middle income countries, some further services and commodities may be expected to be provided such as:

- More lighting including some special lamp for medical purposes;
- Household refrigerator (energy saving type)

Again the typical average PV electrification requirements have been defined according to the following table 1.42 depending on income level per inhabitant of the country.

Table 1.42 - Average PV peak power capacity per rural health centre expected to be adopted, depending on income category of country

Type of Economy	*STANDARDS ADOPTED*
	Peak Power needs for each health centers Wp
Low Income Countries	600
Low-Middle Income Countries	1000
Middle-Upper Income Countries	1000

Based on the above figures, the potential demand for PV electrification for rural health care centres in non-electrified rural areas world-wide has been calculated for each single country in absolute terms, and as per-capita value. The outcomes of such estimate calculations aggregated according to the considered geographical macro-areas are presented in tables 1.43 and 1.44.

Table 1.43 - Demand potential for PV peak power capacity required for rural health care centres in non-electrified areas world-wide

Geographical Areas	*PV PEAK POWER (MWp) DEMAND POTENTIAL FOR HEALTH SYSTEM*			
	Low Income Countries	*Low-Middle Income Countries*	*Upper-Middle Income Countries*	*TOTAL*
Central America and Caribean	1,1	1,6	0,02	2,7
Latin America	0,02	9,3	19,0	28,3
North Africa	1,2	0,5	0,01	1,7
Saharian Africa	1,5	---	---	1,5
Sub-Saharian Africa	6,3	0,3	0,1	6,7
South Africa	1,3	0,7	0,0	2,0
Middle East	0,6	7,8	0,4	8,8
South Asia	43,5	---	---	43,5
Central Asia	8,6	0,8	---	9,4
East Asia	4,7	2,1	0,1	6,9
Oceania	---	0,1	---	0,1
TOTAL	**68,8**	**23,2**	**19,7**	**111,7**

Table 1.44 - Per-capita demand potential for PV peak power capacity required for rural health care centres in non-electrified areas world-wide

Geographical Areas	*PV PEAK POWER (Wp) PER CAPITA DEMAND POTENTIAL FOR HEALTH SYSTEM*			
	Low Income Countries	*Low-Middle Income Countries*	*Upper-Middle Income Countries*	*AVERAGE*
Central America and Caribean	0,2	0,2	0,0	0,1
Latin America	0,1	0,8	0,6	0,6
North Africa	0,1	0,0	0,0	0,0
Saharian Africa	0,1	---	---	0,1
Sub-Saharian Africa	0,0	0,1	0,4	0,0
South Africa	0,1	0,1	0,0	0,0
Middle East	0,0	0,3	0,1	0,2
South Asia	0,1	---	---	0,1
Central Asia	0,0	1,0	---	0,0
East Asia	0,0	0,1	0,0	0,0
Oceania	---	0,1	---	0,1
TOTAL AVERAGE	**0,1**	**0,2**	**0,3**	**0,1**

PV capacity requirements for rural health-care centres present generally a very low value of 0,1 - 0,3 Wp per served inhabitant. If we consider that the corresponding cost for electrification of such rural health care centres is roughly 1-2 ECU per served inhabitant, this application as definitely to be considered of high priority to improve living conditions of rural populations.

1.4.7.4 PV applications for minimum Communications

The PV application potential for communications, that is the installed PV peak power capacity required for a minimum level of radio-communications in not electrified rural areas throughout the world has been estimated on the basis of the following criteria (for each country separately):

- Rural telephony radiotransceivers are assumed to be installed at the above discussed rural schools and health care centres.
- Relays and repeater stations required to ensure sufficient coverage of territory have been calculated on the basis of the territorial extension of investigated countries;

Results of estimate calculations are given by the following table 1.45.

Table 1.45 - Required communication facilities

Geographical Areas	*NEEDS FOR COMMUNICATIONS [*]*		
	Estimated number of new units of relay stations and radiotransceivers per income category countries		*TOTAL*
	Radio transceivers	*Relay Stations*	*TOTAL*
Central America and Caribean	150.700	1.000	151.700
Latin America	208.300	7.100	215.400
North Africa	72.500	2.300	74.800
Saharian Africa	62.200	2.900	65.100
Sub-Saharian Africa	307.700	4.100	311.800
South Africa	74.400	2.600	77.000
Middle East	172.900	2.700	175.600
South Asia	1.321.200	1.800	1.323.000
Central Asia	862.600	4.500	867.100
East Asia	407.300	1.800	409.100
Oceania	6.000	200	6.200
TOTAL	**3.645.800**	**31.000**	**3.676.800**

[*] estimated number of units intended to support schools and health care centers in non electrified areas

The PV peak power capacity required to power these communication facilities has been calculated on the basis of the typical PV peak power capacity required for each single unit as given by the following table 1.46:

Table 1.46 - Typical PV peak power capacity required to power:

Type of Equipment	*STANDARDS ADOPTED*
	Peak Power needs for each communication unit Wp
Radiotranceivers	80
Relay stations	750

Based on the above figures, the potential demand for PV electrification for communications in non-electrified rural areas world-wide has been calculated for each single country in absolute terms, and as pro-capita value. The outcomes of such estimate calculations aggregated according to the considered geographical macro-areas are presented in tables 1.47 and 1.48.

Table 1.47 - Demand potential for PV peak power capacity required for communications in rural non-electrified areas world-wide

Geographical Areas	*PV PEAK POWER (MWp) DEMAND POTENTIAL FOR COMMUNICATIONS*			
	Low Income Countries	*Low-Middle Income Countries*	*Upper-Middle Income Countries*	*TOTAL*
Central America and Caribean	2	3	8	13
Latin America	0	9	13	22
North Africa	2	4	1	8
Saharian Africa	7	---	---	7
Sub-Saharian Africa	25	2	0	28
South Africa	6	1	1	8
Middle East	2	11	2	15
South Asia	107	---	---	107
Central Asia	71	1	1	73
East Asia	25	8	1	34
Oceania	---	1	---	1
TOTAL	**247**	**41**	**26**	**314**

Table 1.48 - Per capita demand potential for PV peak power capacity required for communications in rural non-electrified areas world-wide

Geographical Areas	*PV PEAK POWER (Wp) PER CAPITA DEMAND POTENTIAL FOR COMMUNICATIONS*			
	Low Income Countries	*Low-Middle Income Countries*	*Upper-Middle Income Countries*	*AVERAGE*
Central America and Caribean	0,4	0,4	0,8	0,6
Latin America	1,0	0,8	0,4	0,5
North Africa	0,1	0,3	2,6	0,2
Saharian Africa	0,2	---	---	0,2
Sub-Saharian Africa	0,2	0,4	0,4	0,2
South Africa	0,2	0,2	0,1	0,2
Middle East	0,1	0,5	0,5	0,3
South Asia	0,3	---	---	0,3
Central Asia	0,3	1,0	---	0,3
East Asia	0,2	0,2	0,2	0,2
Oceania	---	0,4	---	0,4
TOTAL AVERAGE	**0,3**	**0,4**	**0,4**	**0,3**

The presented results show that the pro-capita PV peak power capacity required for rural communications does not depend on the income level per inhabitant of countries. The relevant cost may be expected to range between 3-6 ECU per served inhabitant.

1.4.7.5 PV application potential for remote house electrification

The following tables present the results of the estimated demand potential for PV electrification of individual family households in rural non-electrified areas. The basic data used for calculations are presented in the following table 1.48.

Table 1.49 - Not electrified rural population

Geographical Area	*Rural Population not electrified (in million inhabitants)*			
	Low Income Countries	*Low-Middle Income Countries*	*Upper-Middle Income Countries*	*TOTAL*
Central America and Caribean	8.549	15.180	24.932	48.662
Latin America	523	29.232	44.356	74.112
North Africa	29.602	28.944	515	59.061
Saharian Africa	36.896	---	---	36.896
Sub-Saharian Africa	248.615	19.935	642	269.193
South Africa	40.012	7.342	19.306	66.660
Middle East	20.235	59.709	4.971	84.915
South Asia	819.726	---	---	819.726
Central Asia	840.863	930	---	841.793
East Asia	210.266	78.735	10.059	299.059
Oceania	---	3.666	---	3.666
TOTAL	**2.255.287**	**243.674**	**104.782**	**2.603.742**

The minimum solar PV system configuration considered for the electrification of such family households in non-electrified rural areas is the so-called "Single PV-module Solar Home System (SHS)" and includes the following

- PV module of 50 Wp peak power rating;
- charge regulator;
- storage battery (12V - 35 Ah);

A system of this kind, if installed in an area presenting a typical favourable solar irradiation level of 1800 kWh/m^2 year will produce on average roughly 200 Wh/day of electric energy, which is more than sufficient to power 2-3 fluorescent (Neon-tube) lamps of 10 W rating each for 3-5 hours a day.

Considering a typical average family size of 5 members per family, this minimum household electrification PV system corresponds to a pro-capita installed PV peak power capacity of 10 Wp/inhabitant (the "Power for the World" target figure).

The potential demand for this kind of PV application in not electrified rural areas has been calculated for each country according to average income level per inhabitant and presented according to geographical macro-area (see table 1.50).

Table 1.50 - Demand potential for PV electrification (SHS) of individual households in non-electrified rural areas.

Geographical Area	PV PEAK POWER (MWp) DEMAND FORECAST FOR RURAL HOUSEHOLD ELECTRIFICATION				
	% of Rural Population without electricity	Low Income Countries	Low-Middle Income Countries	Upper-Middle Income Countries	TOTAL
Central America and Caribean	45%	48	73	96	217
Latin America	60%	2	113	329	443
North Africa	60%	182	170	4	356
Saharian Africa	79%	290	---	---	290
Sub-Saharian Africa	55%	1.407	58	3	1.468
South Africa	64%	247	57	123	427
Middle East	53%	172	237	41	450
South Asia	40%	3.272	---	---	3.272
Central Asia	27%	2.259	8	---	2.267
East Asia	65%	1.570	349	28	1.947
Oceania	39%	---	13	---	13
TOTAL	**43%**	**9.448**	**1.079**	**624**	**11.151**

The following table 1.51 presents the summarised results of all previously discussed single PV application potentials, including safe drinking water pumping, educational/school electrification, Health centre electrification, rural communications and individual household electrification by means of small-scale stand-alone PV systems. For better understanding of values, all figures are presented in terms of totally required Wp per inhabitant.

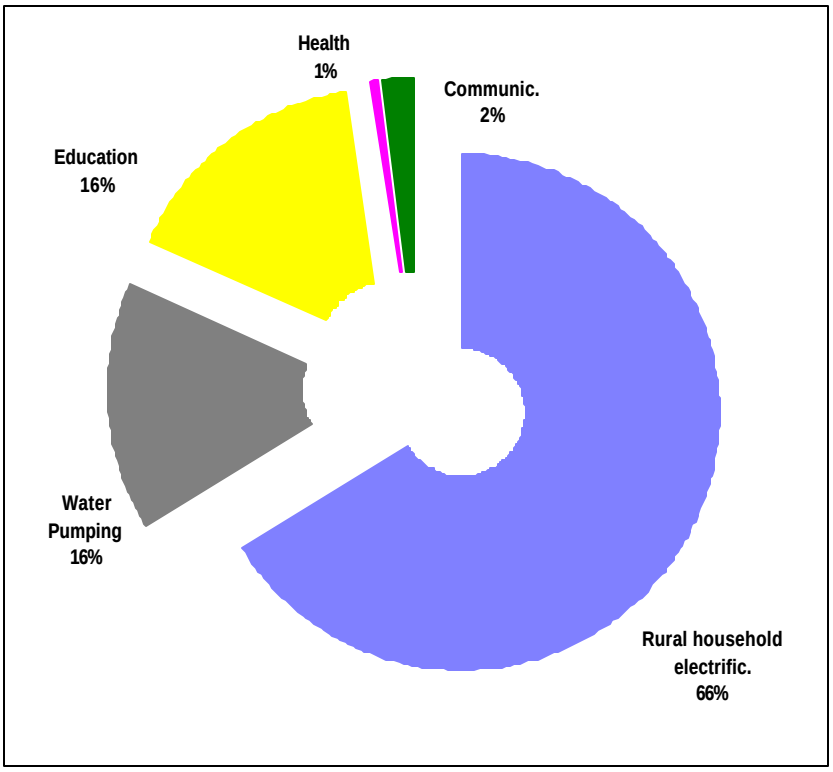
Table 1.51 - Per capita summarised demand potential for all rural PV applications in non-electrified rural areas world-wide

Geographical Area	PV PEAK POWER (Wp) PROCAPITA DEMAND FORECAST FOR ALL RURAL PV APPLICATIONS			
	Low Income Countries	Low-Middle Income Countries	Upper-Middle Income Countries	TOTAL
Central America and Caribean	15	18	33	24
Latin America	16	22	19	19
North Africa	14	17	43	15
Saharian Africa	14	10	10	14
Sub-Saharian Africa	14	17	17	14
South Africa	14	14	13	14
Middle East	14	20	22	18
South Asia	14	10	10	14
Central Asia	17	21	10	17
East Asia	13	15	15	13
Oceania	10	16	10	16
TOTAL	**15**	**17**	**20**	**15**

Table 1.52 - Potential PV Peak Power required in the World (stand-alone applications)

Geographical Area	*Potential PV Peak Power required in MWp*					
	Rural household electrific.	*Water Pumping*	*Education*	*Health*	*Communic.*	*TOTAL*
Central America and Caribean	217	47	236	3	13	516
Latin America	443	72	296	28	22	861
North Africa	356	111	74	2	8	550
Saharian Africa	290	83	36	2	7	418
Sub-Saharian Africa	1.468	327	194	7	28	2.023
South Africa	427	106	50	2	8	593
Middle East	450	131	191	9	15	796
South Asia	3.272	530	749	44	107	4.702
Central Asia	2.267	942	519	9	73	3.810
East Asia	1.947	294	305	7	34	2.586
Oceania	13	2	6	0	1	22
TOTAL	**11.151**	**2.643**	**2.657**	**112**	**314**	**16.877**

Figure 1.29 - PV stand-alone applications market potential in the World



The percentages refer to a potential PV market of 16.900 MWp in the developing world covering the minimum electrification needs of a rural population of 2.600 million people

1.5 PV MARKET BARRIERS

1.5.1 General

The most obvious ingredients to any successful market application are appropriate technology matched to user needs, cost effectiveness, simple access (purchase and installation), effective and simple exploitation (operation and maintenance). The PV industry is rightly focused on reducing costs and developing user-friendly designs, but developing a simple, reliable and low cost PV system is only part of the equation.

World-wide PV market penetration will depend on incorporating consumer feedback on product quality and service, removal of import barriers and encouragement of joint foreign/domestic manufacture and assembly of equipment. Information programmes and other supporting infrastructure that is usually lacking in the developing world are also needed to counter misconceptions about alternative energy performance, applications and cost competitiveness.

Generally speaking the barriers hindering the market development of PV technology may be of technical, economic, financial, social, cultural, institutional and regulatory nature, but definitely one of the most important barriers faced today by the PV sector is simply **lack of public awareness and information** about potentials and specific advantages of PV technology:

1.5.2 Technological Barriers

Unlike the situation just 10 years ago, today the principle barriers hindering market development of PV technology appear to be only to a minor extent of technological nature. During the last 15 years (from 1980 on, and thanks to the substantial support provided also from the EC) terrestrial PV application technology has made giant steps towards user needs and, at least for experts who know where to find it, the technology capable of satisfying the needs of users is mostly available. It may not be very commercial and easy to find, but it has mostly been developed and it is there.

The experiences gathered during 15 years of terrestrial PV applications allow us to summarise the following technological **lessons learned**:

- **PV modules have reached a considerable reliability** and **lifetime** expectations today exceed **30 years and** more. Accordingly, there is a general consensus among PV experts that research is not so much required to further improve quality and reliability, but to reduce costs and to improve efficiencies. Actually, in many applications, such as typically **for gadgets and leisure applications, the quality and reliability of** commercially offered (crystalline) **PV modules go** frequently even **beyond the need**.
- In stand-alone systems, **the battery is** known to be **the weakest link of the chain.** Today batteries in PV installations present a typical lifetime between 1 to 5 years (although exceptional 10 years lifetime are also being reported). No doubt can there be that further research has to focus on the electrical energy storage subject, whereby two sub-areas of possible research are to be distinguished aiming to improve:
    - performance of electrical storage (accumulator battery) systems themselves;
    - battery management systems;

- **Electronics** such as inverters, charge regulators or other have, during first years, revealed many teething troubles, frequently little adequate designs and low reliability, but today performances of more recent makes are rapidly improving. Here the problem is not so much the lack of adequate technology, but the lack of appropriate quality and reference standards, obliging suppliers to adopt adequate technology instead of using low cost components.
- **Adequate application and system design** is in many cases also a reason for poor performance, and also in this case, the reason is to be found in lack of appropriate quality and reference standards.
- **Standardisation** is itself an extremely important issue for diffused market penetration of any technological product. After many years of costly development, computer technology became a consumer product only following standardisation. The Personal Computer and the DOS operating system represent an internationally recognised de-facto standard.
- **Building integration** is an important item still requiring consistent technological development, and again standardisation, but this time in close co-operation with the building sector, is a crucial issue.
- **User friendliness** is also still a deficient area, as well as appropriate designs oriented not so much towards technical issues, but to **match social, cultural, administrative and organisational needs** of users and of rural co-operatives, local utilities or other community organisations and/or institutions providing electrification services to users.

Generally speaking, world-wide PV market penetration will strongly depend on incorporating consumer and key-player **feedback on product quality and service**, and on encouragement of joint foreign/domestic manufacture and assembly of equipment.

1.5.3 Economical barriers

The most significant economic barrier hindering the development of PV technology is without doubt high cost in comparison to conventional bulk energy sources such as coal, oil, nuclear as well as large hydropower. This is the reason why many decision makers in national and international energy planning authorities, utilities and other energy institutions still today assign little importance to PV power developments.

The following table 1.53 provides an overall comparison between average Renewable Energy and conventional energy costs to be found in most countries in the world:

Table 1.53 - Comparison between average Renewable Energy and conventional energy costs

POWER SOURCE	*TYPICAL COST RANGE (in US$/MWh)*
Conventional bulk power sources:	
Average conventional bulk power cost	30-40
large diesel power cost	60 - 100
turbogas peak power	100 - 150
Larger gen-set (diesel) stand-alone power	150 - 250
Medium gen-set (<100kW) stand-alone power	200 - 300
Small gen-sets (gasoline)	300 - 800
PV power sources:	
Mini/micro hydropower	100 - 200
Wind-power grid-connected	100 - 200
Wind-power stand-alone	150 - 300
PV solar power grid-connected	500 - 600
PV-solar power stand-alone	600 - 800

The above table presents comparable cost figures in terms of US$ per MWh of generated electricity. It does not at all take into consideration or reflect other cost items important for comparison as the following:

- Actual **costs of services** provided by the consumed electricity: practical experiences collected with PV electrified residential households (in Europe) have demonstrated, that energy efficient domestic appliances (available off-the-shelf from specialised dealers) allow to reduce, while ensuring same comfort levels, the energy consumption of a typical European household by 3-5 times in comparison to the typically used commercial appliances. This means that **an energy efficient household** providing common comfort levels **requires a 3-5 times smaller PV power source** than a traditionally equipped household. Accordingly the required PV energy power plant will generally result to be same way **3-5 times less expensive**.
- **Energy transportation** costs including transmission and distribution costs: throughout the world, in many electrified areas of low subscriber density transmission and distribution costs may exceed even 85% of the overall costs of the electricity fed to consumers.

In remote areas not covered by the electric grid, power must be generated by means of stand-alone generator sets feeding single users or small distribution grids, which are isolated from the national electric network. Also in such cases, the transportation costs for fuels, lubricants, spares and related qualified manpower contribute significant to increase the cost of conventional energy.

- **Externality costs** take into consideration social costs such as those arising from pollution, health hazard, decommissioning costs and other externalities, usually not considered. Only when it will become **common practice** among utilities and energy decision makers to take into consideration all costs **including externalities** reflecting thereby all costs arising from the entire life-cycle of all factors involved and contributing to a specific production facility, this will allow to avoid distorted cost-effectiveness evaluation of PV energy sources;

In case that also such additional cost parameters are taken into consideration, in many circumstances cost comparison reveals PV technology to be competitive or even more convenient as compared to conventional energy sources.

This is particularly applicable to areas far away from existing bulk power generation facilities, where the cost of energy transportation becomes significant as for the long distances to be covered to feed consumers.

1.5.4 Financial Barriers

Specifically solar PV technology suffers the lack of adequate financing and loan/credit schemes allowing potential user categories, such as rural families and small communities living in non-electrified areas of usually low level of economic development, to overcome the consistent investment initially required for the installation of a PV Energy system.

Although, in many countries, such potential user categories do face today much higher energy expenses (e.g. for the fuelling of kerosene lamps, for throwaway batteries, etc.) than what would be required to improve their living conditions significantly by purchasing a small-scale solar PV system, they are unable to face the required initial investment since no appropriate loan/credit schemes are offered by the local banks and/or the national financing system.

Generally a daunting array of financial barriers hinder PV development. They include:

- macroeconomic pricing
- policy distortions
- donor and power utility preferences for large, centrally-managed energy projects
- emphasis on capital rather life cycle costs
- limited accessibility to affordable credit

For example, subsidised kerosene and electricity prices, especially for the rural and agricultural sectors are the rule, rather than exception, largely because of political considerations. And this situation does little to enhance the attractiveness of solar PV options. Real costs for electricity supplied through rural electrification projects are very high. They frequently exceed even 0.20 ECU/kWh, if low load factors of diesel- generators, large distribution losses and outage costs are common during peak demand periods. Government commitment to energy pricing reforms in rural areas, and in particular, tariff reforms in the power sector, would open the arena to increased use of solar PV, particularly in electric power applications.

Another financial barrier is solar PV's greater up-front capital investment as compared to conventional power technologies. Rural families have barely enough money for subsistence living. Paying cash for relatively expensive home systems is simply out of the question. Yet, solar PV offers very low or no fuel costs, and low operational and maintenance cost, as compared with kerosene or grid-supplied energy. As numerous studies have shown, these factors enhance the commercial viability of solar PV applications in life cycle cost calculations. The commercial viability of PV is further strengthened when environmental costs are considered in the equation. But financing mechanisms and traditional accounting practices discourage appropriate attention to life cycle costs.

Affordable long-term credit is vitally needed for rural households to invest in solar PV systems. Families have little or no collated to secure a loan, and traditional private sector sources of finance have high interest rates and short payback periods. Public sector financing schemes for a range of consumer applications have long been plagued by poor, if not absent, cost recovery along with a host of other administrative and management problems. The need for bold and innovative financing and leasing schemes is therefor absolutely fundamental to greater market share for solar PV applications.

1.5.5 Institutional barriers

The public sector is the main provider of energy services in most developing countries. However the generally poor financial and institutional performance of power utilities limits their willingness to adopt innovative approaches to energy service delivery.

Historically, public utilities have opted for large-scale investments in incremental power generation, transmission and distribution, supported by government financing and the multilateral and bilateral development agencies.

Private sector participation in solar PV or Renewable energy development has been constrained by the absence of appropriate incentives and financial intermediaries for small-scale decentralised energy services.

Decentralised solar PV applications depend on responsive service capability. Encouragement of private sector participation in PV marketing, after-sales service and cost recovery is fundamental for sustainable PV market development.

In fact, the failure of many pilot PV programs rests as much on poor public sector implementation and lack of beneficiary and private sector involvement as it does on costly, over-ambitious or faulty technology.

1.5.6 Regulatory barriers

The development and dissemination of PV technology is hindered by the lack of adequate regulations, designed through their historic evolution to meet primarily the requirements of conventional energy systems:

1.5.6.1 Utility grid interface regulations

To protect their contractual interests as well as own technical facilities (the electric grid) from risks of harmful interactions between the grid and connected consumers and self-producers, utilities throughout the world commonly adopt precise standards and regulations, which define how and under what circumstances consumers and self-producer facilities are to be connected to the utility grid.

The grid interface represents the contractual battery limit between the facilities of the utility and those of any consumer and/or self-producer connected to the grid. The technical requirements defined by the utility for the purpose have different aims and purposes as follows:

- **Contractual**: They define the conditions and technical devices to be installed at the interface, allowing both parties (the utility and the connected consumer/self-producer) to measure exactly the active and reactive energy flows going in and out from the consumer/self-producers facility.
- **Protection of consumer's/self-producer's facilities** from disturbances, damages and/or danger to human beings originated by the electricity grid. A typical example may be a lightning strike entering a transmission line of the electric grid, which may affect the equipment and facilities connected to the relevant electric grid section.
- **Protection of electric utility grid** from disturbances, damages and/or danger to human beings originated by the **facilities of the consumer/self-producer**. A typical example may be again a lightning strike, but entering the facility of a consumer, the propagation of which to the electric grid as well as to other consumers must be avoided.

Particular care is paid by utilities to this second aspect, since relevant non adequate performance of protection devices may not only cause damage to the facilities of the utility but, what is more, be harmful (lethal) to maintenance staff of the utility working on grid sections apparently isolated from any power source of the utility but, if connected to a self-producer, unexpectedly may become energised.

Since the relevant requirement specifications and standards developed by utilities for the purpose have followed the historic evolution of usually larger scale generating facilities, they are generally designed taking into consideration the technical peculiarities of larger size rotating generators such as turbogenerators, diesel-, hydropower turbine driven generators.

The **critical areas**, where common practice and grid interfacing regulations may be considered somehow **in conflict with the requirements of PV technology** may be summarised as follows:

- Grid interface regulations allow mostly only for **large size rotating generators:** Since grid interfacing requirements and standards developed by utilities have followed the historic

evolution of usually large scale generating facilities, they are generally designed taking into consideration the technical peculiarities of larger size rotating generators such as turbogenerators, diesel-, hydropower turbine driven generators.

- **Islanding prevention / safety**: To protect the maintenance staff of the utility working on grid sections isolated from any utility power source of the utility, self-producer facilities are allowed to be connected in parallel to the grid only if intrinsically unable to operate as an island grid.
- **Harmonics injection**: Harmonics being injected into the grid by many types of user appliances such as fluorescent lamps, dimmers, controlled rectifiers, etc. may be harmful to the appliances of other consumers connected to the grid. Same applies also to inverters connected to the grid.
- **Connection to 380Vac/220Vac low-voltage grid not accepted**: Common grid interface requirements do not foresee the possibility to connect a small-scale self-producer facility to the low voltage grid, but foresee **only connection to the medium voltage grid** (typically above 10.000 Vac). Furthermore, **three-phase connection is usually required.** As a result small-scale self-producer facilities of only few kW generation capacity (e.g. typical grid-connected PV rooftops) are either simply not allowed to be connected, or else discouraged by such stringent (and costly) technical requirements, since economically not reasonable.

The result is that, in many countries, the lack of adequate grid interfacing regulations becomes an **insurmountable barrier** for a private customer of a utility, who wishes to install a small grid connected PV system on his roof.

1.5.6.2 Technical quality standards for PV energy systems and component

Unfortunately, Since Photovoltaics is still a young technology branch, and most commonly used conventional (non-PV) norms and standards have been developed prior to the development of this new technology, they usually do not take into account the specific requirements of PV applications and particularly those addressing appropriate system design, configuration and BOS (Balance of System) components.

The result is that, since reference standards are missing, in may cases, it is difficult for non-PV-experts to evaluate the technical appropriateness of solutions being proposed for a PV application. Specifically, the evaluation of alternative bids offered by different competing suppliers requires the evaluator to examine also, whether the technical quality of the offered system configuration, and specifically of BOS components, satisfies the envisaged needs.

Actually, in the large majority of cases, **poor performance of PV systems is not caused by non mature PV module technology, but due to cheaper and apparently equivalent low quality BOS components**. Once installed, such **lower quality BOS components become, during operation, the weakest link of the chain,** but their failure induces people to believe that PV technology is not yet mature. Since non-expert purchasers are frequently unaware of the implications deriving from the selection of low quality BOS components, they do not define sufficiently severe requirement specification for these, but focus only on the PV modules. The result is that, during competitions, suppliers often tend to offer BOS components of cheapest and

lowest possible quality, just sufficient to satisfy the purchasers' requirements, since otherwise their competitor will be able to make a better price and have the contract awarded. Once the relatively short guarantee period for the BOS components has expired (typically 1 year or even less - PV modules are instead guaranteed for several years), in case of a BOS component failure the purchaser is frequently left without assistance with his broken down PV system, although his high cost PV modules are perfectly operating. Norms and reference standards facing this specific problem of PV technology **are presently still missing.**

1.5.6.3 Electrical safety standards applicable to PV technology

Electrical safety standards govern the erection of electric installations in buildings with respect to electric safety. They define requirements for procedures to be followed as well as for components and equipment covered also by other standards. Most related national standards comply and are harmonised with the international standard IEC 364, the most important issues of which are the following:

- protection of human beings against electric shock;
- protection of equipment and immediate surroundings from fire hazard due to overload and short-circuit conditions;
- protection from overvoltage;
- requirements for equipment and components;

The conflict areas between common electrical safety standards and PV technology derive from some specific peculiarities and differences between a PV generator and common practices resulting from the power supply characteristics of the public utility grid (mains):

- A PV generator acts like a *current source*, while the public grid mains provides a *voltage source*. As a result, a **PV generator is intrinsically short-circuit-proof** and cannot overload its connection wires. Furthermore, since its nominal short-circuit current (I_{sc}) is only 1.2 time higher than its nominal operating current (I_{mpp}), **it cannot trip common overcurrent protection devices like fuses or circuit breakers.**
- During daylight conditions, **a PV generator cannot be switched off**. If a PV generator is disconnected from its load (apparently switched off), full open circuit voltage will be present during daylight. For this same reason, leakage currents due to insulation failure are very difficult to be disrupted.
- **A PV generator is a DC source**. There is no zero crossing of current (like in AC-systems), which supports all interrupting actions and helps to extinguish electric arcs. In combination with the aforementioned *current source* characteristics PV systems present a specific risk of stable arc development (which usually causes fire), if an insulation fault develops.
- According to interpretations adopted in some countries **PV modules cannot comply with the double or reinforced insulation requirements of protection class II** since the front glass layer is considered a single and not reinforced insulation means.

Accordingly, latest standard developments in Germany, and specifically as related to VDE 0100 Part 7xx, address these issues specifically as follows.

1.5.7 Lack of access to PV Energy technologies

Again, since PV Energy technology is still a young branch, service structures required for the promotion, distribution, sales, technical assistance and maintenance are still very poorly developed.

For this reason, interested purchasers are obliged to undertake troublesome investigations to find out where to obtain what they need. And what is more, frequently not even the contacted dealers know really about the technology and are unable to develop the required application engineering.

Actually technical proposal development and **application engineering** by local dealers is to be considered a primary bottle-neck in this respect. Many experiences throughout the world have made us learn that, especially for stand-alone small-scale applications, bad performance of PV Energy systems is mostly caused not by the PV Energy power generator itself, but instead due to poor application engineering, system design and selection of little appropriate Balance of System (BOS) components[11].

And what is more, since the overall value of such small-scale applications is relatively low, unless standardised solutions are developed and replicated many times, this small plant value generally does not allow for the required remuneration of an expert engineer to provide for the necessary application engineering and design according to validated sound engineering practices.

1.5.8 The appropriate approach towards rural PV electrification

Many national governments, as well as regional, provincial and municipal authorities in countries presenting significant shares of non-electrified population, are presently taking into consideration the electrification of dispersed rural populations by means of PV technology, but they frequently do not know which is the correct approach.

A typical approach towards rural electrification is the award of concessions to private enterprises and/or rural co-operatives, which provide for all necessary investments, management, operation and maintenance required for the electrification of (as well as the water supply to) the addressed rural population. The monthly tariffs paid by consumers served by the electrification infrastructure may either cover all costs related to the required implementations, or else, in case that governmental subsidies are provided, cover only a certain share, while the remainder is covered by a governmental compensation fund.

Up to this point, the presented procedural approach appears promising and in many cases appropriate to solve electrification problems in rural areas. But it does not face a crucial issue able to condition and to determine the outcomes of a rural electrification programme.

This crucial issue is how objectives of an electrification programme are defined, and how, i.e. by means of which indicator parameters the fulfilment of envisaged services and goals is being measured, and what is more, on the basis of which parameter relevant payments to the concessionaire (both tariffs paid by consumers and subsidies paid by the government) are quantified.

Actually, the choice of such result measurement indicators determines the convenience of PV energy applications as compared to conventional power (national power network extension or stand-alone diesel generation facility with relevant island distribution network)

1.5.8.1 Conventional approach

According to the conventional and most commonly used approach, the basic parameter used for any quantification of an energy service is the **quantity of energy (expressed in kWh** in case of an electric power network) consumed by, i.e. sold to served customers. The result of such approach is generally the following:

- **The concessionaire will** not try to serve as much rural population as possible, but he will **generally tend to favour**, i.e. to anticipate in time the electrification of those potential users, which present more profitable i.e. more promising characteristics in terms of **expected higher individual energy consumption** (e.g. rural enterprises, larger farms, richer residential households, etc.).

  this tendency will in turn produce the effect that the concessionaire will **concentrate first on the implementation of larger facilities**, rather than to create a diffused service for larger numbers of dispersed populations;
- As for the above presented general rule concerning the link between the quantity of demanded energy and the economic convenience of PV Energy systems against conventional power system, **the result will be that** generally **conventional energy systems will apparently result to be more convenient,** rather than PV energy systems.

- Last not least, since the more energy is consumed, the more profit is made by the concessionaire, **he will assign low priority to energy savings and rational use of energy**, and have little interest to promote such issues among his customers.

1.5.8.2 The non-conventional approach towards rural electrification

If instead priorities are not put on the quantity of sold energy, and not the consumed kWh are used to quantify payments of tariffs and subsidies, but other parameter, and namely **the number of days (per month) electrification is made available to a consumer,** things (profitability consideration of the utility) change dramatically as for the following reasons:

- The concessionaire will change his objectives and tend to increase as much as possible the number of served consumers, and specifically he will tend to create and to distribute as many as possible small and smallest electrification units throughout his territory, and accordingly a larger number of population will gain benefit from his services.
- This tendency in turn will produce the effect that the concessionaire will focus his efforts onto the creation of optimised management systems (for consumer servicing, installation, operation and maintenance of all his facilities)
- Furthermore, the concessionaire will also prefer rather the installation of many small facilities (making extensive use of energy saving techniques), rather than few large facilities requiring expensive network extensions.
- As for scale economy considerations which, at the small-scale favour PV technology, the effect will be that generally **PV energy systems will result to be more convenient for the purpose,** rather than conventional energy systems

To summarise: ***It is this second non-conventional approach, based not on sold kWh of energy, but on the number of service points, people served and days the electrification service is provided, which is more appropriate for dispersed rural electrification, and at the same time, which favours the adoption of PV energy systems.***

1.5.9 Lack of awareness and confidence in PV technology

Lack of awareness and confidence among the general public and specifically decision makers is to be considered one of the most important barriers hindering the diffusion of PV technology.

This lack of awareness produces the result that interested people (decision makers, potential purchasers, end-users) do not know:

- Which are the peculiar **specific advantages of PV technology** (apart from obvious fuel-savings and environmental considerations), such as **modularity and economic convenience in small- and micro-scale applications** (the solar calculator represents a typical example for this issue);
- Which are the **specific disadvantages of PV technology**: most people believe that solar PV power systems are "too expensive, do not work and are unreliable", since the sun cannot be considered a reliable energy source. The opposite is actually true: Solar PV systems have first been developed for space applications where reliability requirements are known to be extremely high.
- **Solar PV power systems present little scale-economy** effect, i.e. the larger the facility, the cheaper the specific unit cost of production. This well-known scale-economy effect has for many years dominated the thinking of most energy planners and decision makers throughout the world, resulting in the construction of enormous power generation facilities creating today many operational and organisational problems for their fuelling, waste disposal and the locally concentrated impact of pollutants on the surrounding environment. With solar PV power, there is simply no significant scale-economy effect, which means that **there is no such marked economic advantage to build a few large concentrated PV Energy plants rather than to build a larger number of smaller ones**.
- But what is most, their use **in non-electrified and remote rural areas** represents today the biggest and most **cost-effective application potential** for PV technology, since they allow to avoid the typical disadvantages of conventional stand-alone power generation systems (gen-sets) characterised by high complexity, lower reliability, continuous fuel, lubricant and spare-part needs, frequent maintenance and qualified manpower for the purpose.

To summarise:

For larger and more concentrated energy applications, conventional power technologies (network extensions, diesel generation facilities etc.) are generally more cost-effective;

For smaller and more distributed energy applications, especially in remote areas, PV energy systems are generally more cost-effective than conventional technologies.

1.6 AN EXAMPLE STRATEGIC ACTIONS TO INCREASE MARKET DEMAND IN DEVELOPING COUNTRIES FOR SOLAR HOME SYSTEMS (SHS)

The following describes the human, technical and financial aspects required to bring together appropriate conditions for international programmes on PV rural electrification. Today, it is possible to bring together ideal conditions allowing large-scale PV electrification programmes to be implemented in remote areas of developing countries. The main part of financing would come from money saved by replacing all former solutions such as:

- (individual consumer needs): petrol (kerosene) lamps. chemical batteries for cassette players, etc;
- (collective consumer needs): diesel engines, grid extensions.

However, this competitiveness can only be reached through a series of choices resulting from 15 years of experience accumulated world-wide, and specifically:

- reducing consumption by using specific high efficiency appliances,
- reducing marketing costs by launching international tenders,
- suppressing maintenance and management costs. Users should own, install and take care of their solar PV systems, which are to be delivered in simplified kits.
- public funding and international aid aimed originally for conventional electrification, should be transferred towards technical assistance, follow-up and the use as seed-money for the creation of revolving funds;
- low-rate loans for financing private purchases
- duty free PV appliances,
- subsidies for PV modules, withdrawn little by little with the decreasing prices of PV modules.

Today it is time to launch large scale international programmes for PV electrification in developing countries since:

- Appropriate technology exists and is reliable,
- Funds do also exist, at least for certain areas;
- Human and social (non-technical) aspects exist too;

The technology and funding still need to be adapted to human aspects, since two particular difficulties remain:

- National energy planners and utilities are still very little aware of the potentials and the conditions when (and where) PV Technology becomes cost-effective;
- Lack of access to technology, that is a lack of commercial availability of equipment and appliances for solar PV systems, as well as related technical assistance;

1.6.1 Fully responsible owners

The following presents the preconditions and the choices to be made to ensure the success of a rural electrification programme using Solar Home Systems (SHS). All these start from one main idea resulting from 15 years of experience accumulated all around the world: the beneficiary must be the fully responsible owner of the PV system.

Solar systems must not appear to have fallen from the sky, although in some way they do. They must not be imposed from the top, they must have been chosen by the beneficiaries, paid for, installed and maintained by these users, which own their installation.

The technical and financial approach used for such a programme will have to follow consequently this choice.

1.6.2 Technical aspects

The following presents concepts for the electrification of a house in remote rural areas offering all commodities, even if the market for developing countries addresses mainly small lighting kits.

But what is true for a comfortable house is still more true for small installations. In developing countries, the near term development in rural areas will be probably lighting kits for each house as well as a larger community house, similar to a house with all commodities, for each village, with a refrigerator, a freezer, a TV set and telecommunication (rural telephony) means.

As regards technical aspects, 3 criteria have to be kept in mind:

1) **The house must be individually PV powered** (not powered through a local network): this is the best solution for isolated houses in a rural area, which in any case have to be autonomous anyway.

   Experiences (for example in the Philippines) have demonstrated, that even for non-electrified villages, individual PV powering is a better solution than a central PV generator feeding users through a grid. In case of lack of sun, it is much more difficult to manage and to co-ordinate the required reduction of consumption at the community level.

   With individually PV powered houses, each family feels responsible for their own mistakes, and takes care to avoid them on their own, without delegating the problem to the management of centralised village power supply.

2) **Highly efficient DC appliances must be adopted:** Two alternative ways exist of supplying an individually powered PV house:

   * **AC solution**: PV modules + inverter + standard 220V AC appliances;
   * **DC solution**: PV modules + highly efficient DC appliances for illumination, TV, fridge + small inverter for all other 220V AC appliances;

Table 1.54 - The way to supply home appliances

APPLIANCE	*SUPPLY*	*Characteristic*
Neon tube lamps	DC converter 8-13-18W	50 lumen/W
PL energy saving lamps	DC converter 5 to 18W	70 lumen/W
Refrigerator (3001)	2,5cm^3 compressor DC unit	360 Wh/day
Freezer (3001)	2,5cm^3 compressor DC unit	760 Wh/day
Mixed freezer/fridge	2,5cm^3 compressor DC unit	580 Wh/day
TV 20' to 26'	DC 12 or 24 V	P=45 W
HiFi Radiotape	12 V DC	car-radio
Ceiling Fan	12 V or 24 V DC	P= 28 W
Tools	Cordless 6 V to 12V	
Washing machine	AC semiautomatic+300 W inverter	300 Wh/cycl
Kitchen appliances	commercial 220Vac via 300W inverter	
Coffee grinder. Knife,	commercial 220Vac via 300W inverter	
Iron	AC but 1000 W inverter required	

After having achieved and compared hundreds of installations, experiences have made us learn that the second solution performs much better for the following reasons, in addition to simplicity, global efficiency, cost and reliability.

* The choice for the most important critical appliances (used most of the time like lamps), has to be restricted to DC appliances with high efficiency. Otherwise in the future users will buy by adopting other criteria than efficiency such as: price, brand, size, marketing gadgets, fashion, and jeopardise thereby the entire performance of the system.
* Future PV market appliances designed specifically for PV applications (when a large PV market will come into existence) will be very much different from those we are today used to in our western consumer societies, which are designed and tailored to meet primarily marketing concepts.

The following table 1.55 compares the consumption of a solar DC house with the average consumption of a traditional house with 220V AC appliances.

Table 1.55 - Consumption of a solar DC house with the average consumption of a traditional house with 220V AC appliances

	Daily consumption	
	Solar DC	*Average 220V.*
Lights (6 lights-3h/day)	220Wh/day	1100Wh/day
Refrigerator (300 litre)	360Wh/day	1200Wh/day
Freezer (300 litre)	760Wh/day	1900Wh/day'
colour TV set (8 h/day)	360Wh/day	800Wh/day
TOTAL	1700Wh/day	5000Wh/day

3) Simplified kits and wiring

As a new technology, PV generators were often installed and maintained in remote areas by foreign or local organisations. Carrying out installation and maintenance in remote areas, often by collecting related payments, is very expensive and sometimes impossible.

A PV system has to be like any other system or appliance existing in a house, and just bought, then installed and maintained by the user. For that, the PV system has to be simplified and delivered in kit form.

Wiring is most important in a PV generator. Modules, connecting box, controller, are often made for technicians trained to install highly complex plants. Some simple modifications have to be studied to reduce by a factor of 2 to 5 the number of connections and to have simple strong current connections. The goal is simple: most people in developing countries living in remote areas build their houses themselves. They have to install their own PV system.

1.6.2.1 Cost-effectiveness of PV powered houses as compared to grid extensions

Competitiveness of PV electrification bas already been reached in remote areas. But what is a remote area ? - To define a "remote area", we have to calculate at what distance the cost of a PV system is lower than alternative solutions, namely grid extension or a diesel generator. Typical costs of grid extensions range, more or less in all countries over the world, between 10.000 to 35.000 ECU/km. As compared to such grid extension cost:

- The cost of a PV lighting kit (40Wp module + 3 lights + controler + 50Ah battery) is around 450 ECU.
- The cost of a PV power supply for a house with all comfort (TV, freezer, lights, water pump etc.) is 7 000 to 10 000 ECU.

As a result, the investment for a PV power supply for a house is lower than the grid extension if:

- Houses which need only lighting are farther away from the grid than 30 metres (the line density would result to be less than 33 houses per km of total line length, including feeder line).

- Comfortable houses (or community centres) are farther away from the grid than 300 to 500 metres (the line density would result to be less than 2 to 3 such houses per km of total line length, including feeder line)

1.6.2.2 Reducing costs

Although, at a first glance, some earlier presented recommendations apparently contribute to increase costs (e.g. energy efficient DC appliances cost more than commercial 220Vac appliances), on a whole, they contribute to a substantial reduction in the costs of PV electrification. The following table 1.56 compares the cost of DC and conventional AC appliances in terms of additional cost on specific high efficiency DC appliances as compared to the cost of PV generator oversizing required to compensate for the unnecessarily increased consumption of standard AC appliances. In fact this additional cost for high efficiency is recovered by a factor of 12 to 20.

Table 1.56 - Additional cost of high efficiency DC appliances as compared to the cost of PV generator oversizing otherwise required to compensate for the unnecessarily increased consumption of standard AC appliances

	Additional cost	*Oversizing*
	D C. appliances	*PV generator*
Lights	$ 240	$ 5.280
Refrigerator	$ 450	$5.040
Freezer	$ 450	$ 6.840
Colour TV	$ 150	$ 2.640
Size of PV array	17 modules	50modules

(with 100 Wh/day/modules at $300 each module or $600 for full system: mod+batt.+fr)

1.6.2.3 Suppressing installation, maintenance and management costs.

Whenever possible, users should own, install and take care of their own PV generators, which have to be delivered in simplified kits. Users have to pay for PV installation. The investment should be financed, as much as possible, through loans and transformed into monthly payments to a bank, or in the case of remote areas in developing countries, to a co-operative acting as intermediary. The temptation is often to imitate utilities that have to collect bills depending on variable electric consumption which is not an appropriate approach to PV electrification. Also maintenance should be carried out by users. Some experiences in the past in French Polynesia have shown that very efficient maintenance of a system where, however, users are not the owners, end up like Public Health systems in most countries of the world. The system doesn't really work. At the same time, and in same areas, owners of PV generators were doing well with their PV systems while doing their own maintenance.

1.6.2.4 Reducing marketing costs

In a lot of countries, PV market expansion is slowed down by high prices of PV components. At least for the next few years, some measures have to be taken at the government level:

- Duty free PV equipment and appliances: the autonomy in the field of energy justifies this measure.
- Low profit organisation (or low margin policies) to distribute the main PV equipment.
- International tenders to be launched to supply this equipment.

Solutions depend on local conditions: in the USA for example, PV equipment is available trough the private sector at very low prices. In French Polynesia, it was a low profit organisation: the GIE Soler.

1.6.2.5 Transferring public funding and international aid, existing for conventional electrification.

Public funding is usually oriented towards financing of public electrification. The way of financing private purchases to reach the same purpose is more unusual and may consist only in the following two very cost-effective support actions:

a) Low rate loans financing private purchases;
b) Subsidies on PV modules. Disappearing with the decreasing prices of PV modules.

1.6.3 Conclusion

Large financial resources (from World Bank, from The Global Environment Fund (GEF) are presently used to finance mainly large plants and grid extension around major urban centres.

PV electrification is probably the only solution to bring, at an acceptable cost, electricity to 2000 million non-electrified inhabitants on our world. This solution is ready now to receive part of such funds proportional to this problem. The International Energy Agency (IEA) has started to work on PV, including electrification of remote areas.

CHAPTER 1 - NOTES

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11 BOS = Balance of System components are all other components of a system excluding the PV Energy power generator itself. Typical examples are: the battery, the battery charge regulator, an eventual DC/AC inverter, support structures, cables switches etc.