IEA INTERNATIONAL ENERGY AGENCY

# COUNTRY REPORTS ON PV SYSTEM PERFORMANCE

PVPS

PHOTOVOLTAIC
POWER SYSTEMS
PROGRAMME

**Report IEA-PVPS T2-05:2004**

INTERNATIONAL ENERGY AGENCY
PHOTOVOLTAIC POWER SYSTEMS PROGRAMME

# COUNTRY REPORTS ON PV SYSTEM PERFORMANCE

IEA PVPS Task 2, Activity 2.6

Report IEA-PVPS T2-05:2004

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## Foreword

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

The IEA Photovoltaic Power Systems Programme (PVPS) is one of the collaborative R & D Agreements established within the IEA. Since 1993, the PVPS participants have been conducting a variety of joint projects in the application of photovoltaic conversion of solar energy into electricity.

The mission of the Photovoltaic Power Systems Programme is "to enhance the international collaboration efforts which accelerate the development and deployment of photovoltaic solar energy as a significant and sustainable renewable energy option". The underlying assumption is that the market for PV systems is gradually expanding from the present niche markets of remote applications and consumer products, to the rapidly growing markets for building-integrated and other diffused and centralised PV generation systems.

The overall programme is headed by an Executive Committee composed of one representative from each participating country, while the management of individual research projects (Tasks) is the responsibility of Operating Agents. By the end of 2004, ten Tasks were established within the PVPS programme.

The overall objective of Task 2 is to improve the operation and sizing of photovoltaic power systems and subsystems by collecting, analysing and dissemination information on their technical performance and reliability, providing a basis for their assessment, and developing practical recommendations for sizing purposes.

This report contains an analysis of the monitoring annual performance data in the IEA PVPS Performance Database grouped by countries and type of plant.

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The report expresses, as nearly as possible, the international consensus of opinion of the Task 2 experts on the subjects dealt with.

Further information on the activities and results of the Task can be found at:
http://www.iea-pvps-task2.org and http://www.iea-pvps.org.

## Introduction

Over the past phases of the Task 2 activities the IEA PVPS Performance Database has been setup and contains monthly operational performance data of PV systems from all the member countries and also from non-members. Part of the ongoing work of Task 2 is to provide information on system performance to the target groups. The scope of this report is to give an overview of the operational performance of PV systems in the database to those target groups which are also interested in a summarised overview rather than in a detailed analysis of single systems. The systems analysed range from small stand-alone domestic or professional PV systems to large grid-connected power stations and include freestanding, roof top and facade integrated systems. The PV plants investigated were built between 1983 and early 2002. The monitoring period for these plants ranges from 1 to 13 years. The report gives an overview of all the systems, grouped by country and type of system.

## Executive Summary

For this report all the 1 202 annual datasets of the 370 PV systems in the IEA PVPS Performance Database were analysed as a whole and grouped in grid-connected PV systems for each member country, integrated facade PV systems, stand-alone and stand-alone-hybrid PV systems. In addition 25 stand-alone PV systems and 28 annual datasets from France are also included in this report. The presented results in graphic form should give an overview of all the plant data and the operational performance of all the PV systems in the Performance Database (Version: 2003-04). The plant data and the monitoring data was supplied by the Task 2 member of the respective country. Data from the past Task 2 members, Israel and the Netherlands, is also available in the database. Some non-members also supplied operational data.

The operational data of the 395 systems is represented in a normalised graphical form and includes:

- Nominal power
- Outage fraction
- Irradiation
- Final yield
- Module temperature
- Performance ratio
- Annual final yield
- Array efficiency
- Inverter efficiency

With overview reports for:

Grid-connected PV systems:

| | |
|---|---|
| • All grid-connected PV systems, | 339 |
| • Austrian grid-connected PV systems, | 22 |
| • German grid-connected PV systems, | 108 |
| • Italian grid-connected PV systems, | 29 |
| • Japanese grid-connected PV systems, | 82 |
| • Dutch grid-connected PV systems, | 20 |
| • Swiss grid-connected PV systems, | 62 |
| • Other grid-connected PV systems, | 16 |
| • Facade mounted grid-connected PV systems, | 20 |

Stand-alone PV systems:

| | |
|---|---|
| • Stand-alone PV systems, | 43 |
| • Stand-alone hybrid PV systems, | 13 |
| • French stand-alone PV systems, | 34 |

The results of the PV system analysis of all 339 grid-connected PV systems shows that there is a clear trend towards a better performance ratio for the newer PV systems (built since 1996) compared to the early PV systems.

The stand-alone PV systems are more diverse in their size, location and application. The graphical representation in this report gives an overview of all the 56 stand-alone PV systems in the IEA PVPS Performance Database.

## 1. PV Systems in the IEA PVPS Performance Database

Of the 395 PV systems built between 1983 to early 2002 represented in this report 339 systems or 92 % of the total nominal power are grid-connected, of these 20 are facade PV systems. Of the 56 stand-alone PV systems 13 are stand-alone hybrid PV systems. There are also four grid-connected hybrid PV systems from Japan. The performance of these Japanese plants was not separately investigated as a group. In 1992 grid-connected PV systems in all the IEA PVPS member countries accounted for about 30% of the total PV power installed and at the end of 2001 have reached almost 70% [1]. This shift is mainly due to high growth rate of grid-connected PV systems in the industrialised countries. The grid-connected PV systems analysed in this report are representative in numbers and size for some countries and for others they are a good selection in terms of location and type of system. The stand-alone PV systems tend to be small and decentralised and are rarely monitored for evaluation purposes. The stand-alone PV systems in the database are mainly professional systems or systems monitored as part of a national programme. They represent a small sample of stand-alone PV plants in some of the IEA PVPS member countries.

Table 1 Comparison of the total nominal power of the PV systems installed (2001-12-31) in the Task 2 member countries [1] to the nominal power of the PV systems represented in this report.

| Status 2001 | Grid-connected installed $P_0$ [kW] | in database $P_0$ [kW] | | Stand-alone installed $P_0$ [kW] | in database $P_0$ [kW] | |
|---|---|---|---|---|---|---|
| Austria | 4 681 | 70 | 1.5% | 1 857 | 5 | 0.27% |
| France | 972 | | — | 12 884 | 29 | 0.22% |
| Germany | 178 000 | 1 286 | 0.7% | 16 700 | 5 | 0.03% |
| Italy | 8 350 | 4 933 | 59.1% | 11 650 | 71 | 0.61% |
| Japan | 385 986 | 1 803 | 0.5% | 66 827 | 868 | 1.30% |
| Netherlands | 16 179 | 536 | 3.3% | 4 330 | 1 | 0.02% |
| Switzerland | 14 900 | 1 964 | 13.2% | 2 700 | | — |
| Total | 609 068 | 10 592 | 1.7% | 116 948 | 979 | 0.8% |
| installed | 84% | | | 16% | | |
| in database | | 92% | | | 8% | |

Table 2 Overview of all the PV systems represented in this report. Grouped by country and type of plant.

| in Database | Plants | $P_0$ [kW] | Grid-connected Plants | $P_0$ [kW] | Datasets | Stand-alone Plants | $P_0$ [kW] | Datasets |
|---|---|---|---|---|---|---|---|---|
| Austria | 23 | 75 | 22 | 70 | 45 | 1 | 5 | 3 |
| France | 34 | 29 | | | | 34 | 29 | 45 |
| Germany | 109 | 1 291 | 108 | 1 286 | 416 | 1 | 5 | 2 |
| Italy | 30 | 5 004 | 29 | 4 933 | 81 | 1 | 71 | 3 |
| Japan | 94 | 2 671 | 82 | 1 803 | 218 | 12 | 868 | 14 |
| Netherlands | 24 | 537 | 20 | 536 | 52 | 4 | 1 | 6 |
| Switzerland | 62 | 1 964 | 62 | 1 964 | 301 | | | |
| Others | 19 | 247 | 16 | 246 | 38 | 3 | 1 | 6 |
| total | 395 | 11 819 | 339 | 10 838 | 1 151 | 56 | 980 | 79 |
| Facade | | | 20 | 322 | 78 | | | |
| Stand-alone | | | | | | 43 | 182 | 55 |
| Stand-alone hybrid | | | | | | 13 | 798 | 24 |

## 2. Monitoring data

The monitoring data for the 395 PV systems are monthly datasets from 1986 to the end of 2002 ranging from 1 to 13 years of monitoring per plant, totalling in more than 1 200 operational years or on average 3 years per plant. Depending on the type of monitoring implemented not all the defined data values are available for some plants. In the case of global monitoring only irradiation and production data has been supplied.

In general the monthly data in the database is consistent and of good quality. In some cases analytical monitoring was carried out during daytime hours only, resulting in daytime mean values for the ambient temperature and not over a 24 hour period as defined. It appears that for some datasets the mean module temperature was calculated as a linear average and not weighted with the array power, resulting in a lower than realistic value for the effective mean module temperature (see **Annex A**).

For the purpose of comparison the monitoring monthly data available was summed and averaged to give the mean annual values for the whole monitoring period for each plant. This means 395 datasets of the annual mean were used for all the histograms showing the performance ratio (Graph type f) , the annual yield (Graph type g) and the annual irradiation (Graph type h).

In addition, some of the annual datasets show an outage factor (O) of zero and it is not clear, if the outage was not recorded or the plant had no failure. In order to have a realistic comparison all the values for the annual yield (Graph type g) were adjusted to 100% operation of the plant.

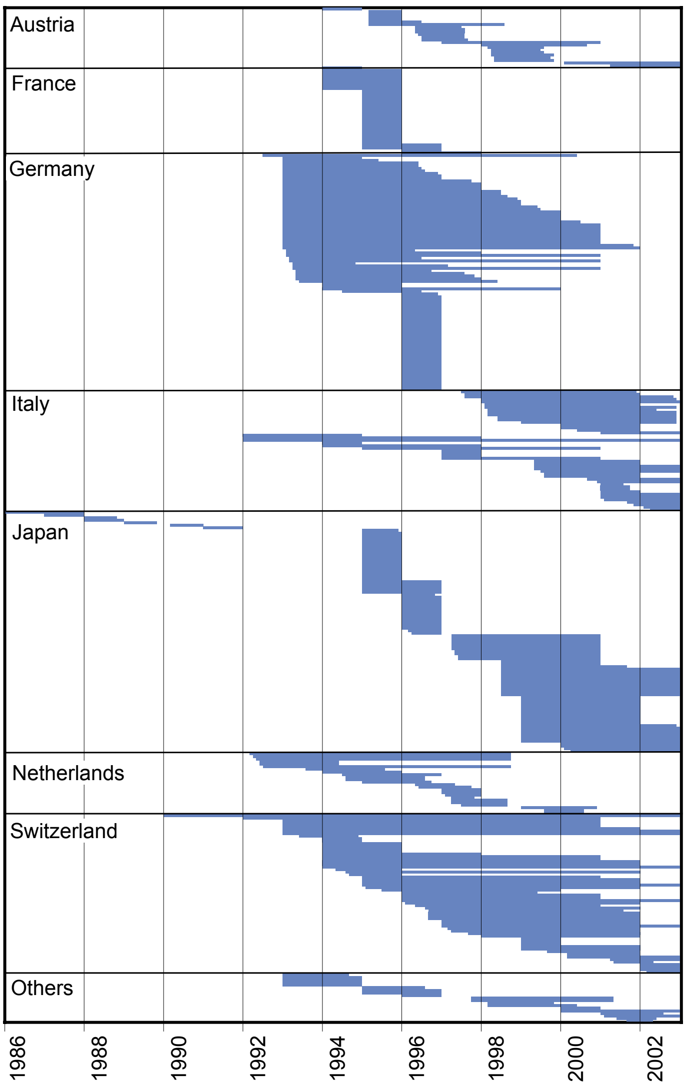



*Figure 1, Overview of all the monitoring data from 1986 to 2002 used in this report, of the PV systems built up to 2001, grouped by country.*

# 3. Graphical presentation of results

For all the graphic presentations in the following pages the same type of diagrams (Graphs type a to i) were used for all the groups. Table 3 shows the main parameters used in the graphical presentations for grid-connected (GCS) and for stand-alone systems (SAS) (for full list of parameters see Annex A).

Table 3 List of parameters used for the graphic presentations

| Typ of graph | Main parameter | Symbol | Graphical presentation | Application |
|---|---|---|---|---|
| a) | Nominal power | $P_0$ | Distribution of $P_0$ | GCS & SAS |
| b) | Outage fraction | O | Distribution of O | GCS |
| c) | Final yield | $Y_f$ | $Y_f$ as a function of $Y_r$ ; $PR=Y_f / Y_r$ | GCS & SAS |
| d) | Mean module temperature | $T_{m,mean}$ | $(T_{m,mean}-T_{am,mean})$ as a function of $H_I$ | GCS |
| e) | Matching factor | MF | Distribution of annual MF | GCS & SAS |
| f) | Performance ratio | PR | Distribution of annual PR | GCS & SAS |
| g) | Annual final yield | $Y_{f,y}$ | Distribution of annual final yield $Y_{f,y}$ | GCS & SAS |
| h) | Annual irradiation | $H_{I,y}$ | Distribution of annual $H_{I,y}$ | GCS & SAS |
| i) | Production factor | PF | PR as a function of PF ; PR/PF | SAS |
| *) | Array efficiency | $\eta_{A,mean}$ | $\eta_{A,mean}$ as a function of $\eta_{A0}$ | GCS |
| *) | Efficiency of the inverter | $\eta_I$ | Distribution of annual $\eta_I$ | GCS |

*) only applied in the overview of GCS

In instances where no data was available the relevant diagram was left out. The scale is always adjusted to the data values available.

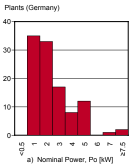
Figures 3.1 to 7.2 show the data for the 339 grid-connected PV systems in the database. Earlier evaluations have shown a trend of improved system performance over time. Histograms showing the performance ratio are presented for three time periods (Figures 4.1 to 4.3). Because not all the plant data show the year of the construction of the plant, the year where the monitoring activity started was assumed to be the year the plant went into operation. Therefore the label "Plants from ..to.." in figures 4.2 and 4.1 and graph type f) refer to the first year of monitoring data available and not in all cases to the year of the construction of the plant.

All the grid-connected PV systems of the present Task 2 member countries plus data from the former member the Netherlands are separately grouped (Figures 8.1 to 13.10). Grid-connected PV systems from non-members plus the data from the former member Israel are represented in one group (Figures 14.1 to 14.9).

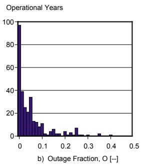
A special group shows the data of the 20 grid-connected facade integrated PV plants (Figures 15.1 to 15.7).

The types of standardised graphics used for this report are more explicit commented under the heading "**3.1 Remarks to graphs**" (Figures 2.a to 2.i).

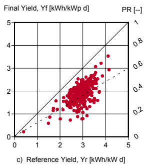
## 3.1. Remarks to graphs



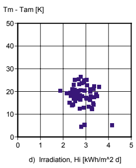

a) Histogram of nominal power, $P_0$ [kW]. If necessary more than one figure shows the distribution of the nominal power of the plants for each group.



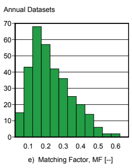

b) Histogram of outage fraction, O [--]. The outage fraction is an indication of the continuous operation of the plant. The value O is $T_{NAV} / \tau$ . Normaly the value $T_{NAV}$ is recorded as zero, when irradiance Gi is > 0.08 kW/m$^2$ and array power $P_A < 0.05\ P_0$, otherwise 1.



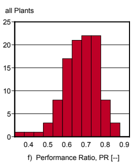

c) Plot of final yield Yf [kWh / kW] as function of reference yield Yr [kWh / kW]. The scale to the right shows the performance. The numerical value of the reference yield Yr, is identical to the irradiation value Hi [kWh / m$^2$] in the plane of the PV array.



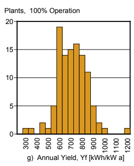

d) Plot of $T_{m,mean}$ - $T_{am,mean}$ ($\Delta$T) [K] as function of irradiation Hi [kWh / m$^2$]. This plot shows the annual mean of the module temperature above the annual mean ambient temperature. In some cases $\Delta$T is low, this is probably because $T_{am}$ is the annual average of the daytime temperature only and not the 24 hr average.



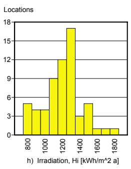

e) Histogram of Matching Factor, MF [--] (see **3.1.1**).




f) Histogram of the annual mean of the performance ratio, PR [--] for the whole monitoring period of the plant: 1 - for all the operational years; 2 - for early and 3 - for more recent construction dates of the plant. The years indicated refer to the construction date of the PV plant. The performance ratio, PR is the result of $Y_f / Y_r$ .

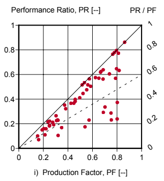



g) Histogram of the mean annual yield, Yf [kWh / kW], for the whole monitoring period of the plant, adjusted to 100% operation (Outage O = 0) for all the systems.




h) Histogram of the mean annual irradiation in the array plane Hi [kWh / m$^2$], for the whole monitoring period of the plant. The irradiation value is equal to the reference yield Yr [kWh / kW].

## 3.1. Remarks to graphs (cont.)




i) Plot of performance ratio PR [--] as function oft the production factor PF [--]. The production factor PF was introduced for the analysis of stand-alone PV systems (see **3.1.2**).

*Figures 2.a to 2.i* *Samples of the graphs used in this report. The letters a) to i) indicate the type of graph.*

### 3.1.1. Matching factor (MF)

The matching factor MF is the product of the performance ratio (PR) and the array fraction FA. This MF indicator was introduced with respect to stand-alone hybrid PV systems for a better illustration of the performance. The matching factor is valuable for all hybrid systems (Solar fraction, FA less than one) and for grid-connected PV systems with a considerable contribution from the grid (FA less than one). The matching factor indicates how the PV generated energy matches the electrical load while using a back-up contribution (SAS) or energy from the grid (GCS) [6].

### 3.1.2. Production factor (PF) and usage factor (UF)

The usage factor UF was introduced in the report on the analysis of PV systems. This factor being the ratio of the energy supplied by the PV array ($E_A$) and the potential PV production ($E_{pot}$), has been used to demonstrate how the system is using the potential energy. $E_{pot}$ is a measured energy quantity, which is equal to EA (UF = 1) for all grid-connected PV systems and differs from $E_A$ for all SAS presenting PV array disconnection due to a fully charged battery. UF values are used to highlight the different operation of SAS having the same PR and allow the detection of system problems [6].

Unfortunately, for most of the installed systems $E_{pot}$ is not monitored, therefore UF can not be determined. Hence a new coefficient is introduced in the following by calculating the array production to the one specified at STC by the manufacturer of the systems :

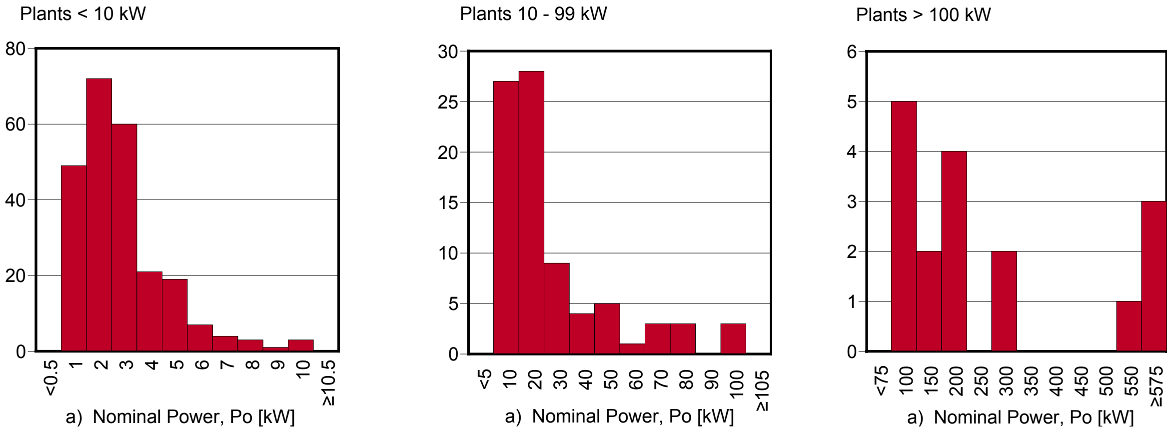
$$PF = E_A / (P_0 \; H_I / G_{STC}) = Y_A / Y_r$$

$$PR / PF = \eta_{SYS} = Y_f / Y_A$$

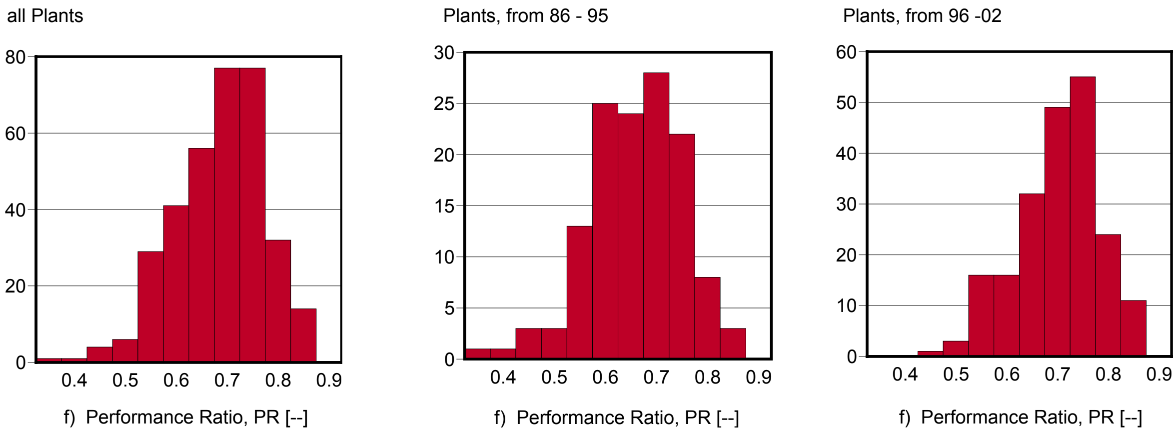
The system efficiency, the relationship between PR and PF, is more or less a linear function like UF. First calculations and system analysis show that strong deviations of the expected combined PR / UF or PR / PF curves may indicate malfunctions of the systems.

Conclusions regarding the two introduced coefficients UF and PF. The IEC - Guidelines [8] and the EU - Guidelines [9] have only been elaborated to measure the systems performance and not to distinguish between bad results due to a poor sizing or to a technical problem. It is difficult or even impossible to find out the technical reasons of e.g. a disappointing performance of a PV system. The two introduced coefficients UF and PF allow to overcome this fact and give indications on the system operation with monitoring data typically gathered on a monthly or even yearly basis within the IEA PVPS Performance Database [3].

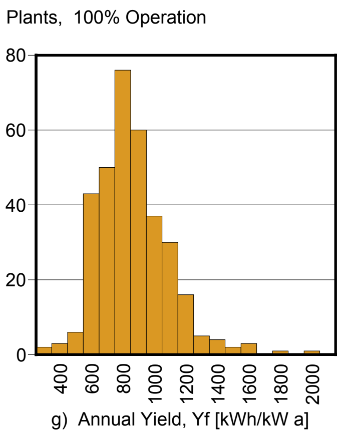
## 4. Overview of grid-connected PV systems

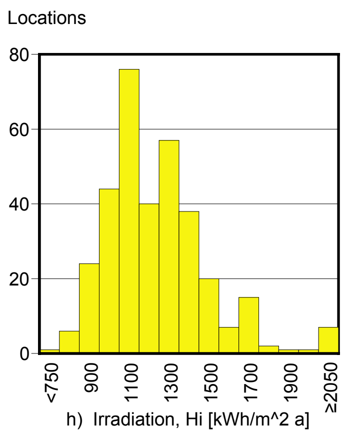



*Figures 3.1, 3.2, 3.3,* *Histograms of the nominal power of all grid-connected PV plants.*



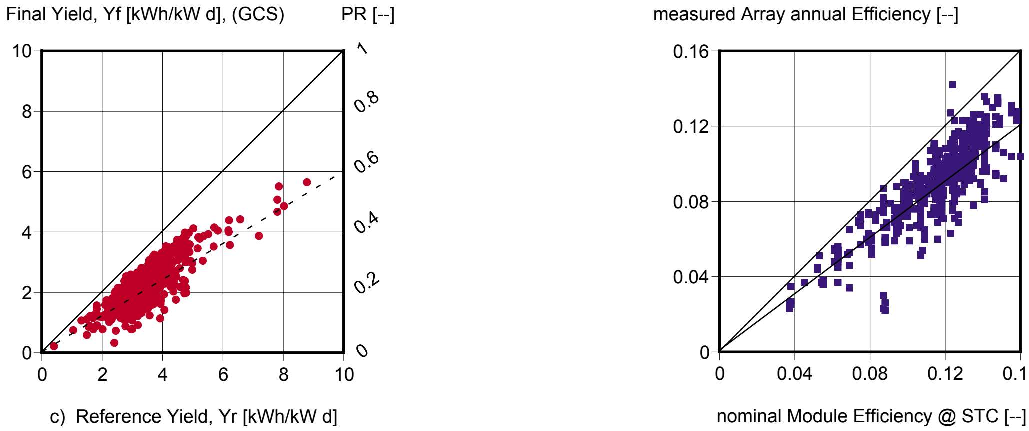

*Figures 4.1, 4.2, 4.3,* *Histograms of the mean annual performance ratio of all grid-connected PV plants. Figure 4.2, PV plants installed from 1986-1995. Figure 4.3, PV plants installed from 1996-2002.*



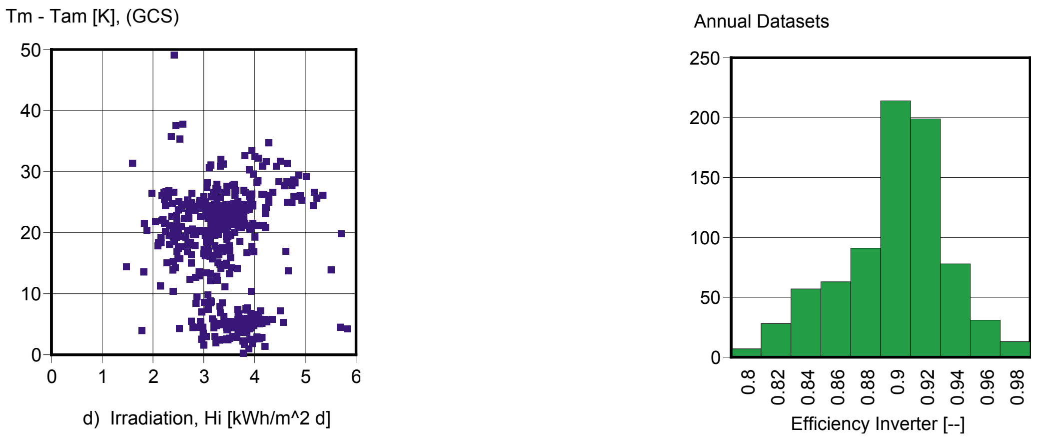




*Figures 5.1 and 5.2,* *Histograms of the mean annual yield and the annual irradiation of all the grid-connected PV plants and locations, adjusted to O = 0 , 100% operation.*

## 4. Overview of grid-connected PV systems (cont.)




*Figures 6.1 and 6.1, Annual values of grid-connected PV systems, reference yield (Yr) vs. final yield (Yf), 6.1) and measured array efficiency vs. nominal module efficiency at STC, 6.2).*




*Figures 7.1 and 7.2, Annual values of grid-connected PV systems, irradiation (Hi) vs. Tm-Tam (ΔT), 7.1) and Histogram of annual inverter efficiency, 7.2).*

The nominal power of the grid-connected PV systems is shown in the figures 3.1 to 3.3. There are 239 plants with a total of 692 kW in the range up to 10 kW, 83 plants with a total of 2.35 MW in the range from 10 to 100 kW and 17 plants with a total of 7.8 MW in the range > 100 kW.

The average performance ratio of all the 339 grid connected plants with a total of 1 200 operational years is 0.684 (Figure 4.1). The average PR for the 132 plants built up to 1995, with a total nominal power of 5.7 MW, is 0.657 (Figure 4.2) and for the 207 newer plants from 1996, with a total nominal power of 5.0 MW, the PR is 0.702 (Figure 4.3). This is a trend towards a better performance ratio for the newer PV systems. Figure 4.3 shows a clear peak of the performance ratio at around 0.75 for 55 of 207 systems. This improvement in the PR can also be observed for most of the grid-connected systems in the reports for the individual countries (Section **5.1** to **5.7**).

## 5. Country reports of grid-connected PV systems

Detailed standardised presentations and the performance data of the grid-connected PV systems for each Task 2 member country, other countries and integrated facade PV systems are shown in section **5.1** to **5.8**.

## 5.1. Austria

Until the end of 1996 the stand-alone sector dominated the Austrian PV market. From 1997 the majority of new systems are grid-connected. Most Austrian monitoring data within the IEA PVPS Performance Database were and are monitored within the framework of the “200kWp Rooftop Programme” and of EC funded demonstration projects. The implemented PV systems and monitoring results can only be categorized as representative within the context of this programme and in comparison with other projects.

**200kWp Rooftop Programme** – The PV plants installed in the 200kWp Photovoltaic Rooftop programme were tested and analysed scientifically and technically by a field test over a period of 5 years (1/1994 to 12/1999). Within the Programme 110 small residential grid-connected PV systems were installed up to 1994. The average capacity of the plants is 2.28 kW. Those grid-connected PV systems represent typical technologies for that period. Two technical programmes accompanied the 200kWp Rooftop Programme:

**Analytical monitoring** - An intensive measuring programme where operational data was collected from 18 selected PV systems according to the EU-Guidelines for one year. The data collected from these plants is included in the IEA PVPS Performance Database.

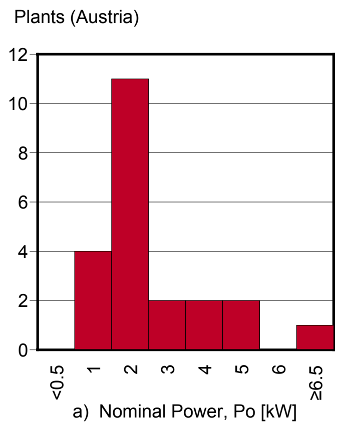
**EC funded demonstration projects** –The main goal of those projects were to foster the market penetration of PV systems in Europe by removing technical and non-technical barriers as well as developing new PV products for reducing costs through innovative design and/or optimised sizing. The grid-connected and building-integrated photovoltaic (GC-BIPV) system in Villach represents a suitable solution to integrate PV in the building facade and on the roof. EC funded demonstration projects include: EURALP, MULTIBAT and HIP-HIP.

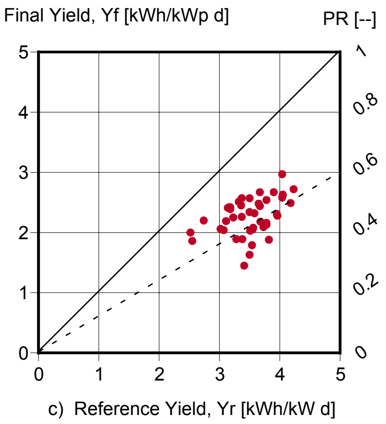
**Monitoring Data**

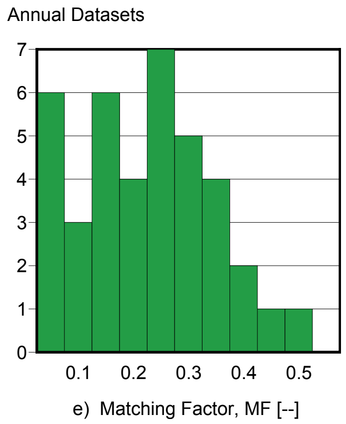
**200kWp Rooftop Programme** – Comparisons of performance ratio and the annual yield of all the PV systems in the standard monitoring programme and the 18 analytically monitored plants of the intensive measuring programme included in the IEA PVPS Performance Database show similar statistical values and characteristics for the annual performance ratio and annual yield. The annual mean values of performance ratio for those grid-connected PV systems is between 0.5 - 0.8. Malfunctions of the PV system and resulting poor PR are mostly related to the inverters of the older generation. For some newer grid-connected PV power plants with excellent inverter efficiencies and high reliability the mean annual performance ratio achieved is as high as PR = 0.8. It can be summarised that the monitoring results of the IEA PVPS Performance Database are representative for the grid-connected PV systems within the Austrian 200kWp Rooftop Programme for that period.

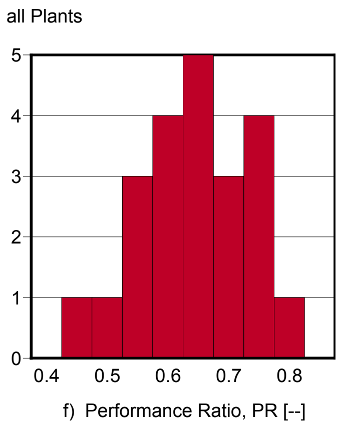
**EC funded demo projects** – Over time the grid-connected PV systems have generally improved in efficiency due to further improvements in component efficiency and optimised system design.

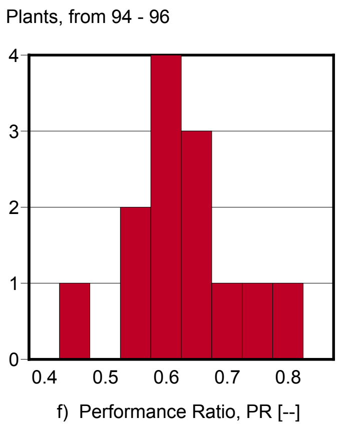
## 5.1. Austria (cont.)

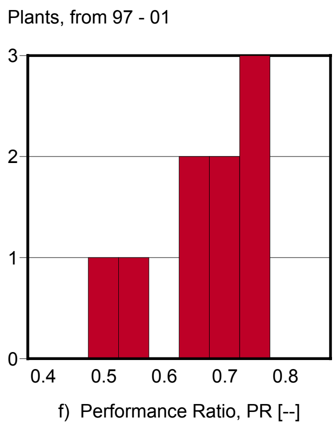


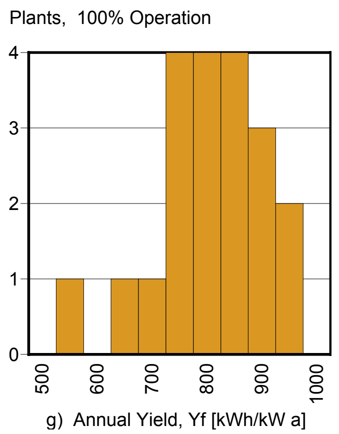



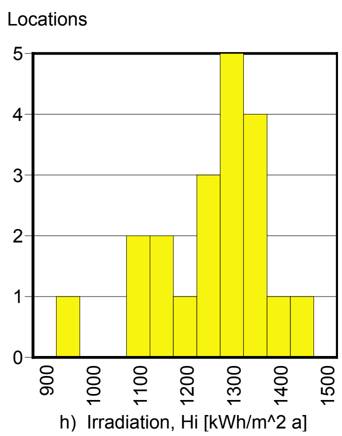




*Figures 8.1 to 8.8*
*Graphical representations of the Austrian grid-connected PV systems.*



## 5.2. Germany

At the end of 2002 the cumulative installed PV power in Germany was 277.3 MW, which corresponds to 3.4 Watt per capita. The high annual growth rate of PV installed between 1999 and 2003 is certainly due to the two main market initiatives:

- the 100 000-Roofs-PV-Power-Programme (HTRP) since January 1999 and
- the Renewable Energy Law (REL) since April 2000, providing buy back rates for every kWh fed into the grid (e.g. 0.481 EUR for PV systems installed in 2002).

Using the low interest loans of 1.19%, about 45 000 PV systems with a total of 205 MW were installed between 1999 and 2002 within the HTRP. Thus, distributed and centralized grid-connected PV systems are dominating the PV market in Germany with 94% of the total installed PV power at the end of 2002.

**The Photovoltaic Systems**

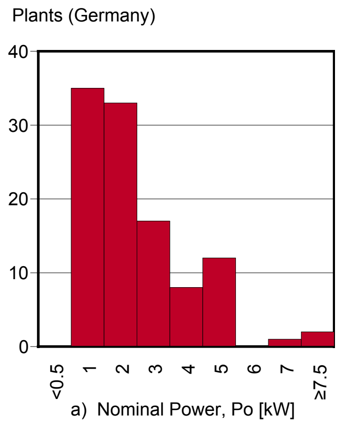
The data of the 108 German plants with a total power of 1287 kW in the PVPS Task 2 Performance Database mainly come from market introduction programmes such as the “1000-Roofs-PV-Programme” (1991-1994), “Sun-at-school” and from Federal State programmes such as the “Solaroffensive Niedersachsen” (- 2003). The PV plants vary between small distributed grid-connected roof-top PV systems of 1-5 kW to large centralized power stations up to 1 MW and include BIPV as well as PV facades.

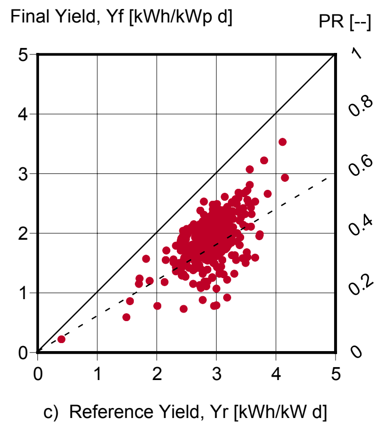
**Monitoring Data**

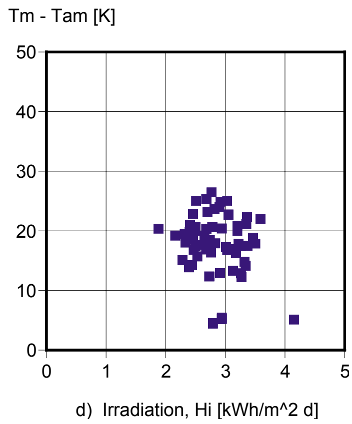
Reliable data of 108 grid-connected PV systems are available for monitoring periods between 1992 and 2002 providing 416 annual datasets. Because of different programmes and installation periods (1991-2000), the kind and quality of data acquisition systems differ considerably from monthly meter readings to high resolution analytical monitoring data. Due to a lack of available monitoring data of the significant HTRP, the PV plants in the Performance Database are not representative for the PV systems in Germany, but they allow important historical trends of long-term operational performance between 1992 and 2002.

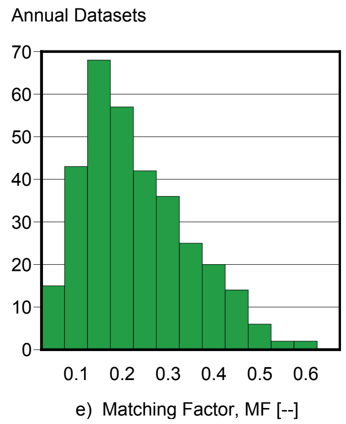
From the histograms of performance ratio (Figure 9, type f) early installed systems from the roof-top-programmes (1991-1994) and new installations built between 1996 and 2002 can be compared. The three figures for the performance ratio show the distribution of mean annual performance ratio calculated from the 416 annual datasets of the 108 grid-connected PV systems constructed between 1992 and 2001, which are grouped into two installation periods. The 53 early installed PV systems (1992-1994) have their maximum in the PR range of around 0.6 and an average mean PR of 0.63. The 55 newer installations (1996-2001) have their maximum in the range around 0.75 with an average value of PR= 0.71. This is a significant rise in PV system performance and reliability, which new systems have gained in Germany during the past years of installation. Better inverter efficiencies, higher system availabilities and realistic PV module ratings are identified as reasons for it.

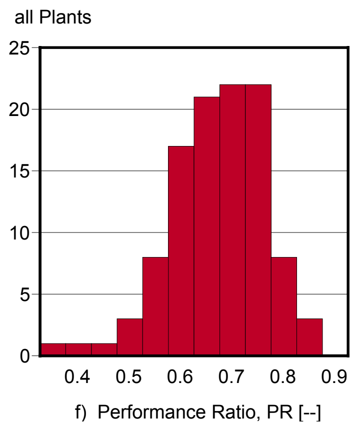
## 5.2. Germany (cont.)

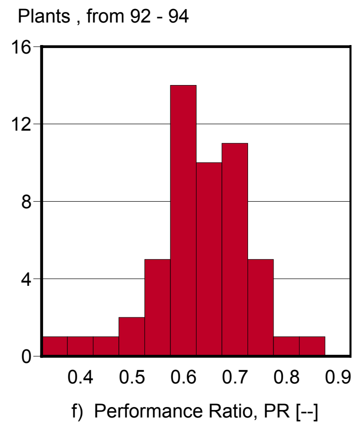


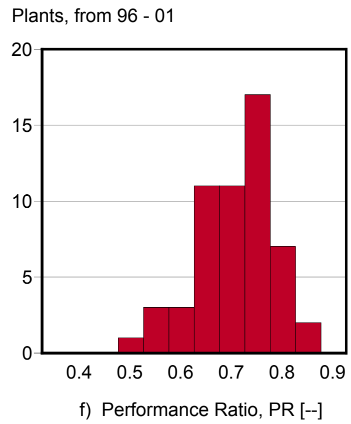



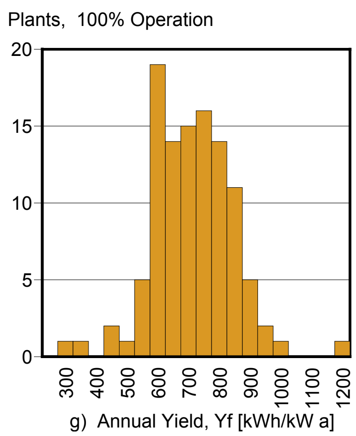



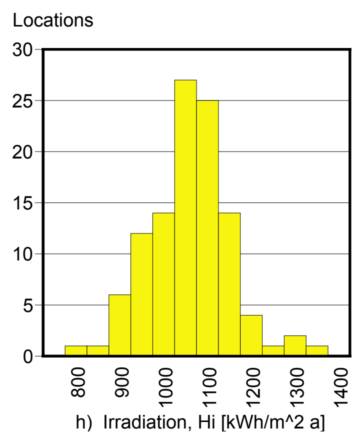




*Figures 9.1 to 9.9*
*Graphical representations of the German grid-connected PV systems.*



## 5.3. Italy

The total cumulative installed power in Italy was 20 MW at the end of 2001. Four different primary applications for photovoltaic power systems can be identified:

**Stand-alone domestic PV systems (5.3 MW).** This kind of application has been mainly promoted in the early phase (1983 – 1990) of the Italian photovoltaic programme through 80% incentives in order to provide electricity to 5000 isolated households (300 W – 1 kW) in rural remote areas in Southern Italy.

**Stand-alone economic industrial PV applications (6.3 MW)**, still dominate with a share of about 30% Italy's cumulative installed capacity.

**Grid-connected centralized PV systems (6.7 MW)**, high growth rate at the beginning of the 1990's. The basic scope was identification and validation of satisfactory solutions for power generation by means of medium and large size grid-connected PV plants, for utility applications, ranging from 100 kW to 3.3 MW.

**Grid-connected distributed PV systems (3.7 MW)**, which are a relatively recent application, enjoying strong growth (120%) over the last year as benefiting incentives, in the framework of the Italian Roof-top Programme, aimed at increasing this kind of plant. Most plants were installed during the last two years and it is expected that these systems will increase in the coming years to an installed power of around 20 MW, that will lead to a doubling of the total cumulative installed power in Italy.

### Data Source

Experimental and demonstration activities on PV plants are carried out directly by ENEA (Italian Agency for New Technology, Energy and Environment) both at its own test facilities and demonstration installations, by CESI (Institute for Research and Certification of electrical components and systems) in its laboratories and on several PV plants owned by ENEL (Italian national electric utility) and located all over the Italian territory. These activities are performed in the framework of two major Italian initiatives:

the **PV Demonstration Programme** and the **Roof-Top Programme.**

The Italian experimental, demonstration and monitoring activities have been mainly focused on grid-connected centralized and distributed PV systems, as a consequence the PV plants in the IEA PVPS Performance Database are typical and representative only for grid-connected PV systems and correspond to about 25% of the total cumulative installed power in Italy.

### Monitoring data

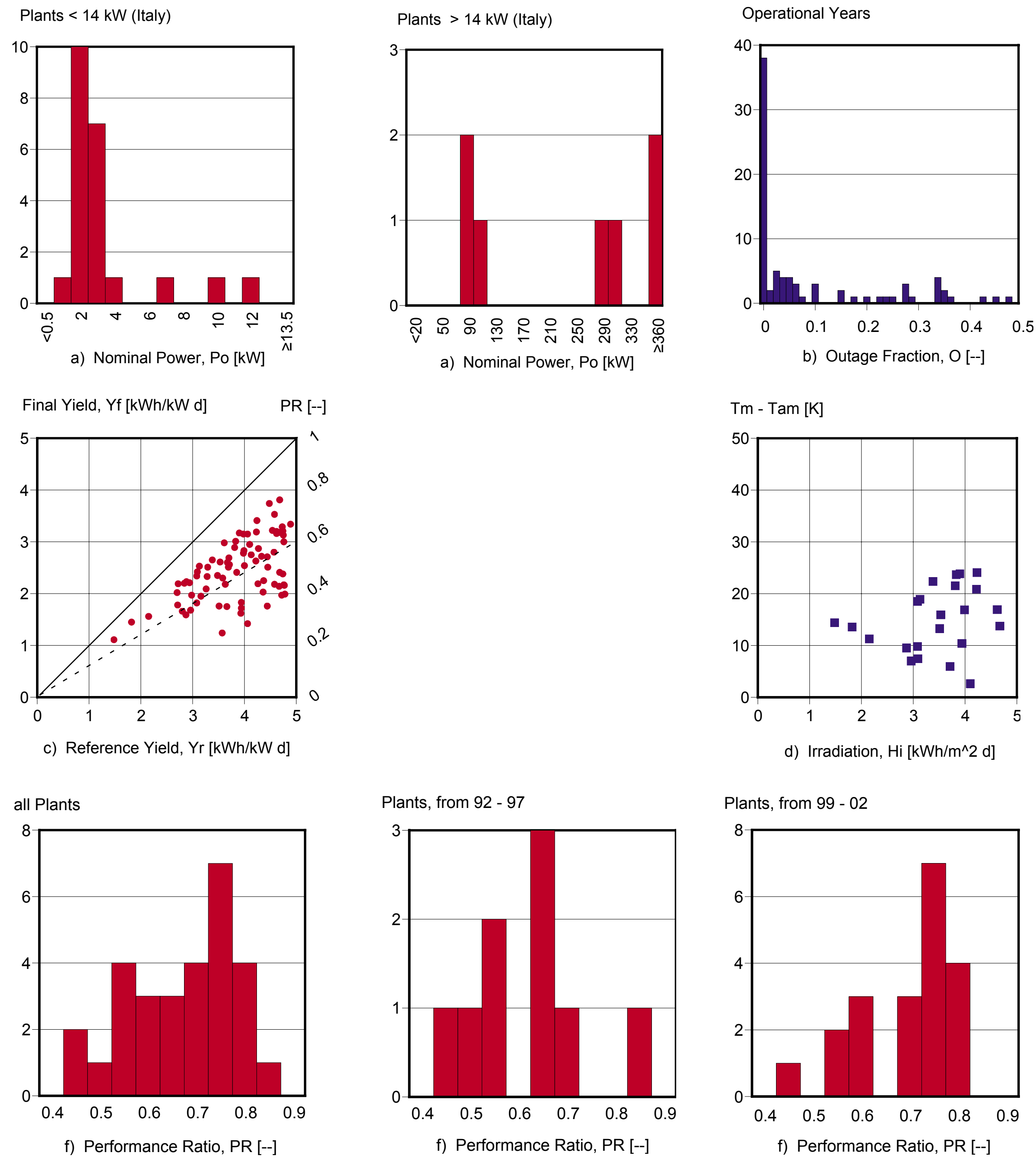
In the distribution of nominal power of the 29 grid-connected PV plants can be identified 7 large size systems ranging from 100 to 3000 kW and 19 small size systems ranging from 1 to 4 kW. The monitoring data available covers 1 to 11 years of plant monitoring or a total of 70 operational years.

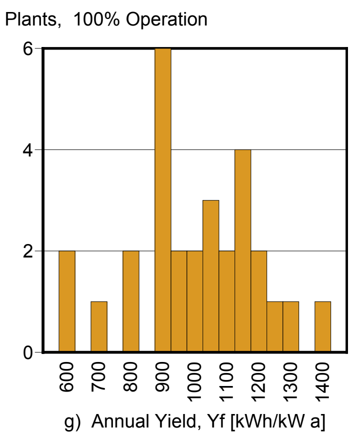
Concerning the outage fraction of the large size systems, values ranging from 0 to 0.5 (with a mean value of 0.2) have been recorded due to both failures and a high plant unavailability because of inverter unreliability, experimental activities and measurements campaigns. Better values of outage fraction (around 0) have been obtained, according to the expectations, for the 19 small size plants, due to improved components and know-how.

The distribution of the mean annual performance ratio of the 29 systems shows annual values mainly ranging from 0.5 to 0.8. In particular, lower values are related to the early large size systems (Figure 10, type f, 1992-1997) which were installed for experimental purposes. Both small size systems and later installed large size plants (Figure 10, type f, 1999-2002) show good performance ratio values, confirming their design characteristics.

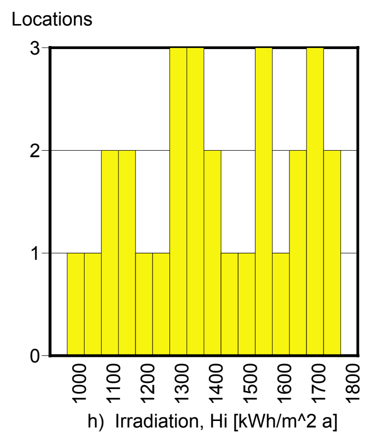
In conclusion, the data collected in the Performance Database have confirmed a significant increase of plant performance, with respect to the first large size prototypes installed in the eighties. However these early plants, more devoted to experimentation can still provide useful information on components lifetime, outage causes and maintenance procedures. High performance values have been reached by the new PV systems, realized for demonstration purposes in the framework of the Italian Rooftop Programme, because of the acquired know-how and the careful selection of both components and design criteria. As a consequence the results of the monitoring data (performance, outage, annual yield) typically represent the outcome of experimental and demonstration projects.

## 5.3. Italy (cont.)




*Figures 10.1 to 10.10 Graphical representations of the Italian grid-connected PV systems.*



## 5.4. Japan

**PV in Japan**

As the result of successful governmental promotion programmes, Japan is now leading the world in PV module production and PV installation. At the end of 2002, the total output of the PV systems installed in Japan exceeded 640 MW, including about 430MW residential systems introduced by the subsidy programme. The total number of residential PV houses is estimated to exceed 150 000 at the end of Fiscal Year 2003.

A large part of the PV plants in the Performance Database represents the typical PV installations in Japan, namely the grid-connected residential PV systems with the nominal output of 3 to 4 kW. Typical PV systems installed in public facilities such as municipal buildings and sports facilities with the nominal output of 10 to 50 kW are also included in the database.

**Monitoring programmes**

Almost all of the monitoring data included in the Performance Database were obtained through some sort of governmental programme, namely the field test programme by NEDO and the residential PV monitoring programme in the “New Sunshine Programme”.

**Monitoring data**

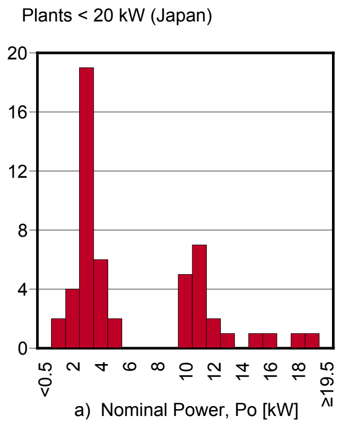
The total number of PV systems included in the database is 94. 82 grid-connected PV systems with total power output of 1 803 kW (Figures 11, type a), 9 stand-alone PV systems with total output of 81.1 kW (Figures 16, type a) and 3 stand-alone hybrid PV systems with total power output of 787 kW (Figure 17, type a) are included in the database.

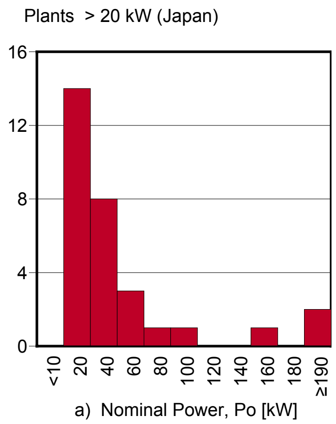
Roughly speaking, the performance of the PV systems included in the database represents the average value of the actual Japanese PV systems for that period. Some residential systems with multiple orientation arrays are intentionally included in the Performance Database and their performance ratio is lower than the performance ratio of a typical single oriented array PV system.

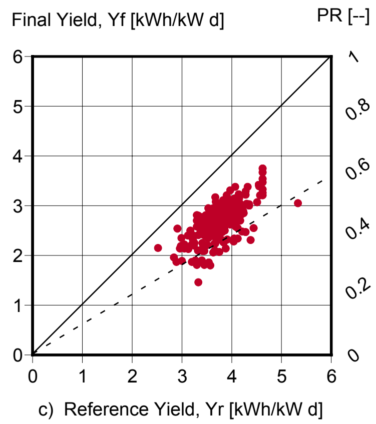
**Conclusion**

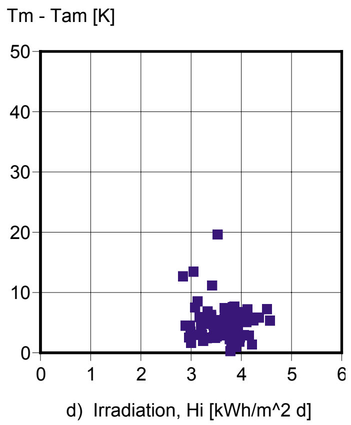
For the PV systems of the Field Test Programme, no significant changes in performance are identified for the systems installed from 1994 to 1996. The annual performance results of 85 residential systems in the year 2000 are showing a large dispersion in annual final yields and performance ratios. As an average, an annual PR value of PR 0.74 is obtained [5].

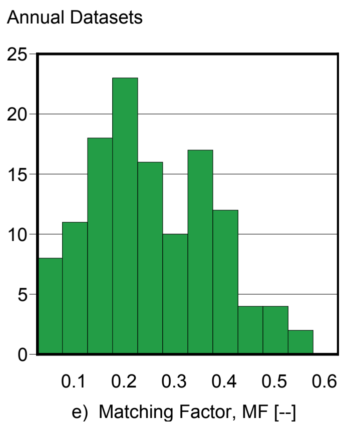
## 5.4. Japan (cont.)

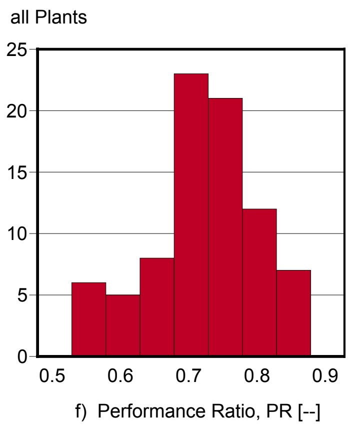


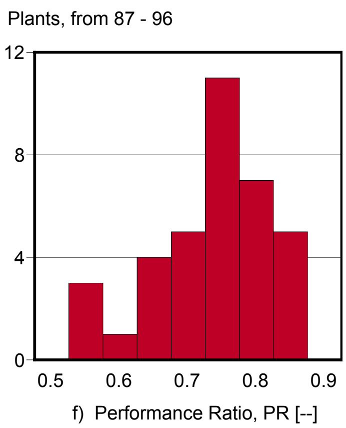



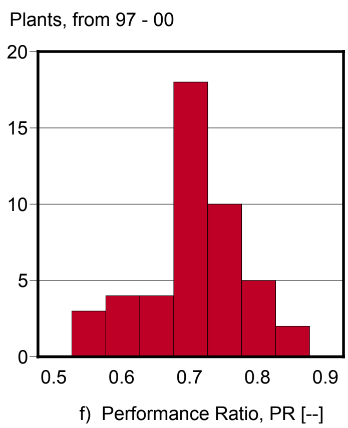



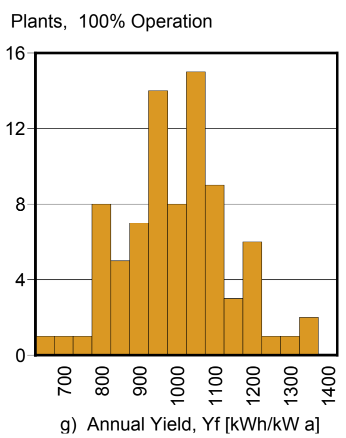



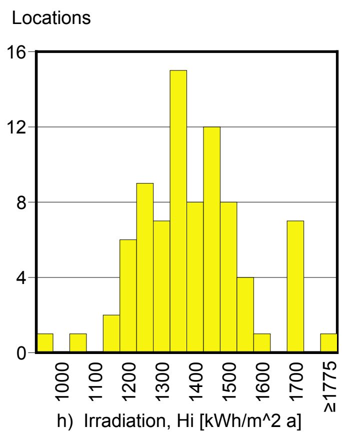




*Figures 11.1 to 11.10 Graphical representations of the Japanese grid-connected PV systems.*



## 5.5. Netherlands

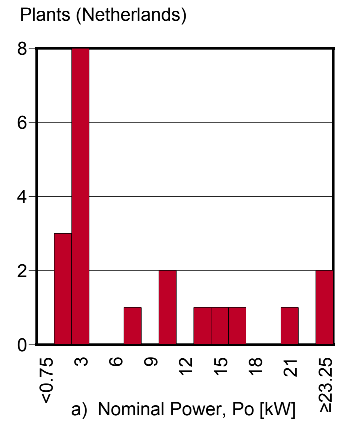
In total twenty grid-connected PV systems with a total nominal power of 536 kW including two large centralised systems of 205.2 kW and 213.7 kW are represented in the database. The 18 smaller decentralised systems represent a small sample of domestic systems in the Netherlands. The location of the reported systems is evenly distributed across the country and the annual irradiation in the array plane ranges from 900 to 1400 kWh/m$^2$ and the annual yield peaks at about 800 kWh/kW.

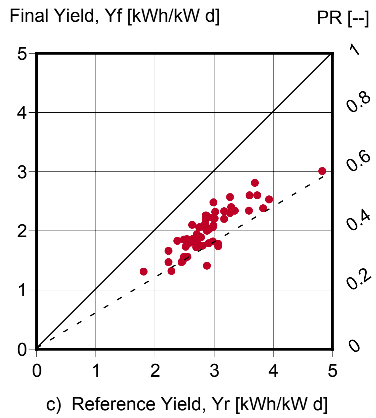
The module temperature is not available and the outage fraction is zero for all the monthly datasets for the grid-connected PV systems.

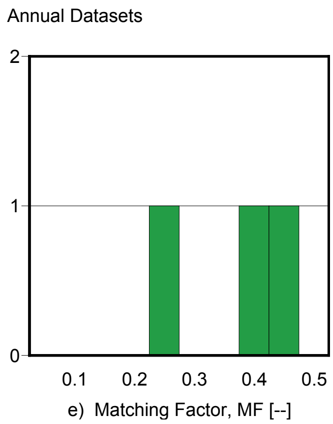
The operational data in the database ranges for system built between 1992 and 1999 and are mainly from the national programme for that period carried out under management of the Netherlands Agency for Energy and the Environment (NOVEM). NOVEM acts on behalf of several Dutch government departments, in particular the Ministry of Economic Affairs and of Housing, Planning and Environment, as well as the International Organizations such as the International Energy Agency and the European Union.

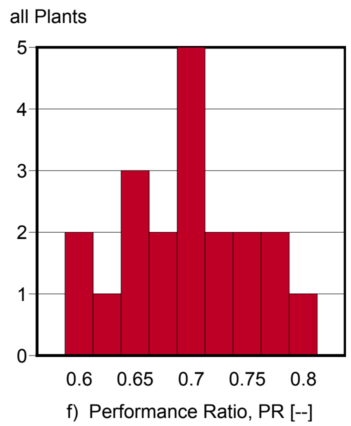
The Netherlands were participating in Task 2 until 2002.

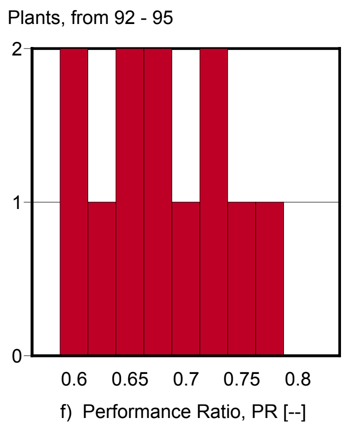
## 5.5. Netherlands (cont.)

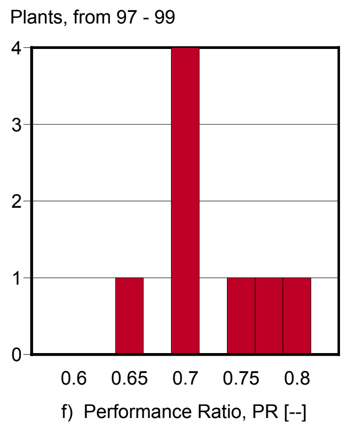


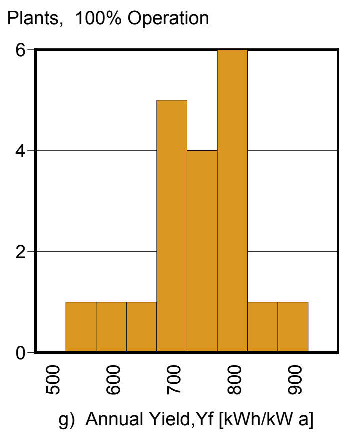



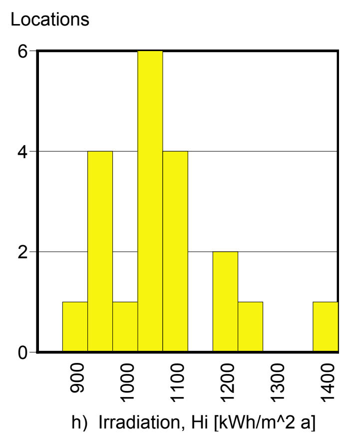




*Figures 12.1 to 12.8*
*Graphical representations of the Dutch grid-connected PV systems.*



## 5.6. Switzerland

### PV in Switzerland

Since 1989 until the end of the year 2001 about 1 450 PV plants with a total of 14.9 MW were connected to the national grid. Until the end of 2002, these plants produced the total PV Energy of estimated 58.3 GWh in 13 years.

### The Plants

The data of the Swiss 62 plants with a total nominal power of 1 964 kW in the IEA PVPS Performance Database represent about 4.3 % of the number of plants or 13.2 % of the peak power of all the Swiss grid-connected PV systems built between 1989 and 2001.

All 62 plants contained in the database are grid-connected PV systems and include 22 R & D PV systems from the national programme “PV in Vocational Schools”. The other 40 plants are from various programmes sponsored by the Swiss Federal Office of Energy. The typical use for all the plants is classified as “power station” because the energy from the grid ($E_{FU}$) is not monitored in these projects. Therefore the matching factor (MF) is not applicable because the array fraction (FA) = 1.

### Monitoring Data

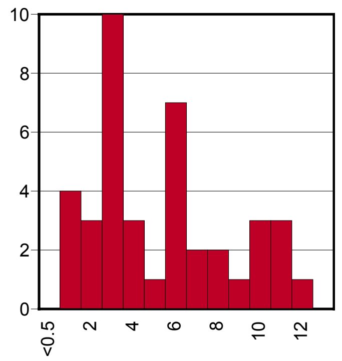
The nominal power ($P_0$) of the 62 grid-connected PV plants ranges from 1.3 kW to 560 kW (Figures 13, type a) and monitoring data is available from 1990 to 2002. The monitoring data available for each plant covers 1 to 13 operational years of plant monitoring or a total of 301 years of plant operation with a monitoring fraction of less than 0.95. All plants are monitored in real time, the outage (O) (Figure 13, type b) and all the temperatures ($T_{am}$, $T_m$) (Figure 13, type d) are always recorded.

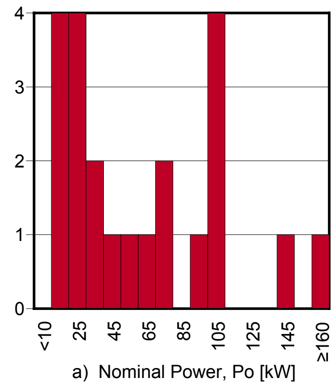
In this monitoring period (1990 - 2002) the 62 PV plants produced 9 776 MWh or 14 % of the total Swiss PV energy production for the same period.

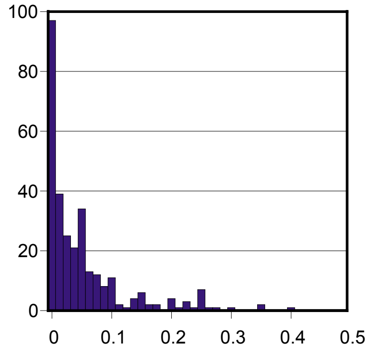
### Conclusions

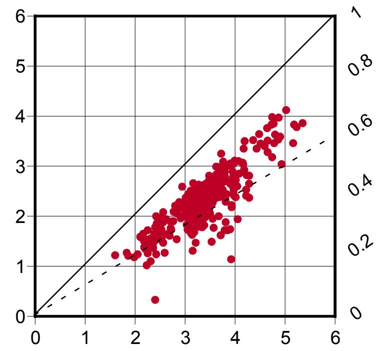
Performance results (Figures 13, type f) for early and for later installed PV systems show an improved peak performance ratio for the PV systems built between 1996 and 2002. The graph for that period also contains data from seven systems with a low performance ratio due to either a high outage, module failures or partial shading.

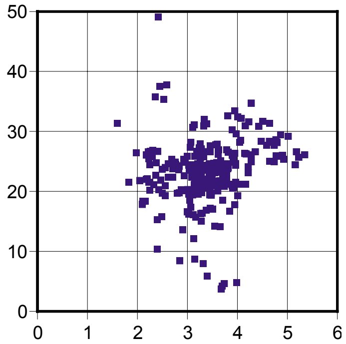
## 5.6. Switzerland (cont.)

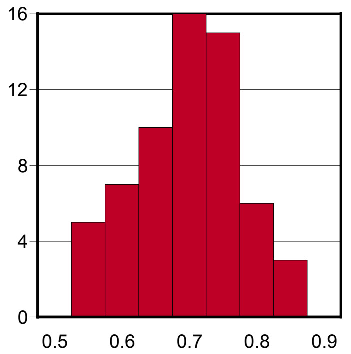


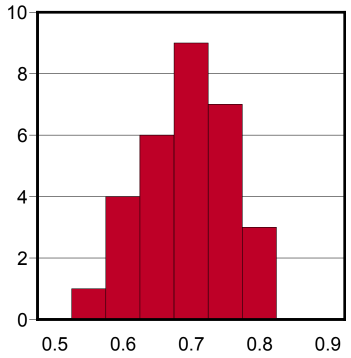



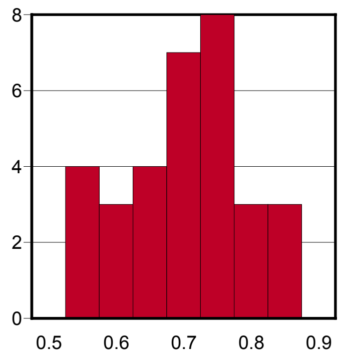



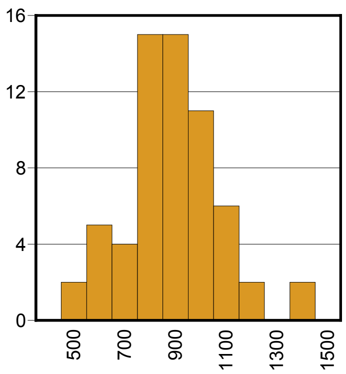



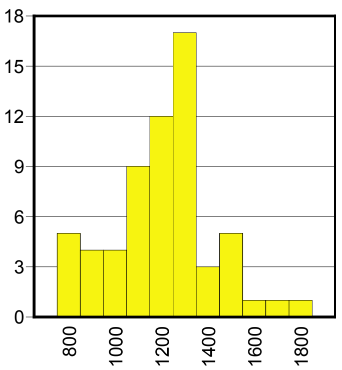




*Figures 13.1 to 13.10 Graphical representations of the Swiss grid-connected PV systems.*



## 5.7. Other countries

There are 16 grid-connected PV systems from 8 other than Task 2 member countries with a total nominal power of 246 kW and 38 annual datasets in the PVPS Performance Database.

Table 4 Grid-connected PV systems from other countries represented in the PVPS Performance Database.

Other

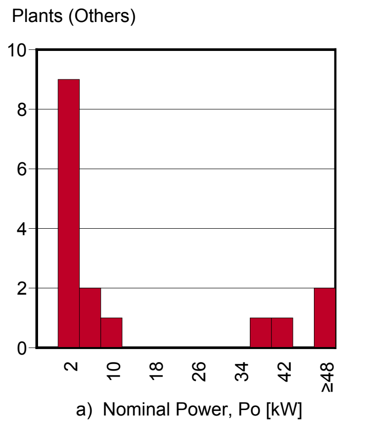
| Country | Plants | $P_0$ [kW] |
|---|---|---|
| Belgium | 1 | 5.2 |
| Israel | 4 | 12.6 |
| Mexico | 3 | 5.2 |
| Poland | 1 | 1.0 |
| Portugal | 1 | 5.0 |
| Spain | 1 | 42.0 |
| Sweden | 3 | 62.5 |
| United Kingdom | 2 | 112.7 |
| total | 16 | 246 |

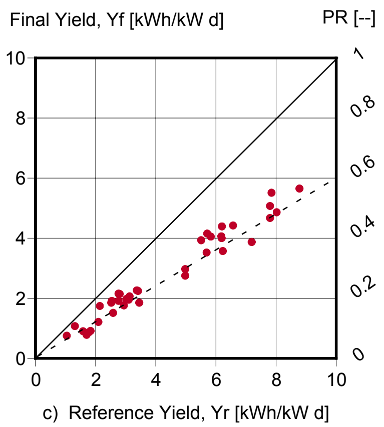
The locations of these plants range from Sweden to Israel to Mexico, resulting in a wide range of annual irradiation values in the array plane ($H_{I,y}$) from 700 to 3 100 kWh/m$^2$ (Figure 14, type h) and of annual yield values ($Y_{f,y}$) from 300 to 2100 kWh/kW (Figure 14, type g).

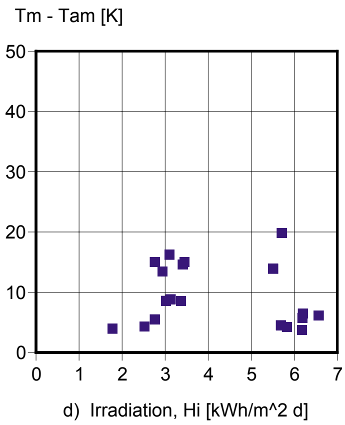
The three systems with an annual irradiation ($H_{I,y}$) larger than 2 700 kWh/m$^2$, are two single axis tracking systems and one double axis tracking system located in Israel.

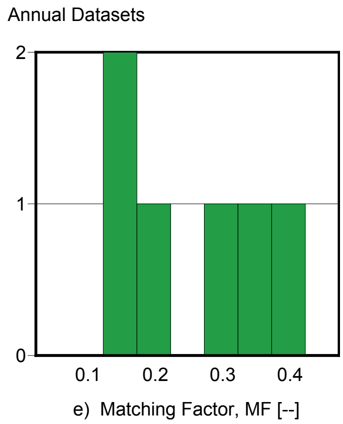
The module temperature is not available and the outage fraction (O) is zero for most of the monthly datasets for these grid-connected PV systems.

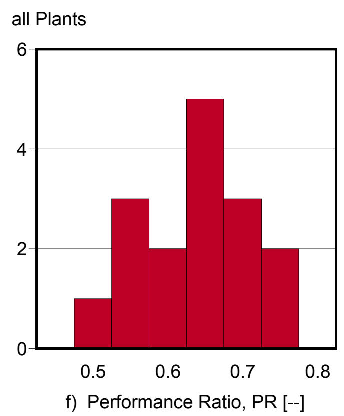
## 5.7. Other countries (cont.)

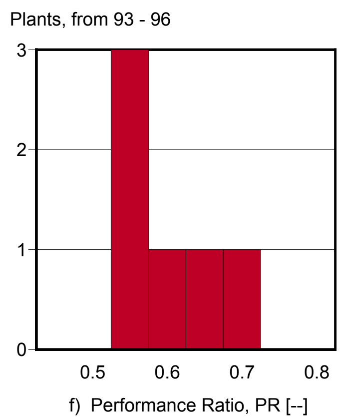


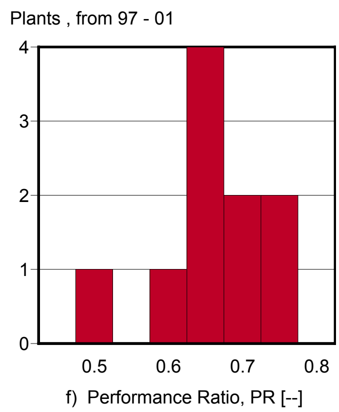



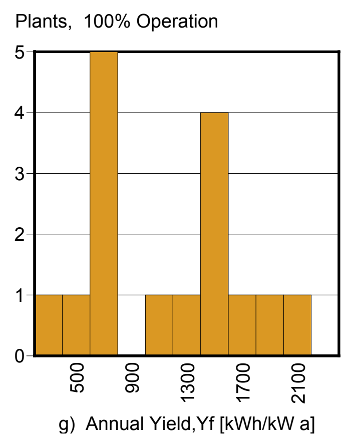



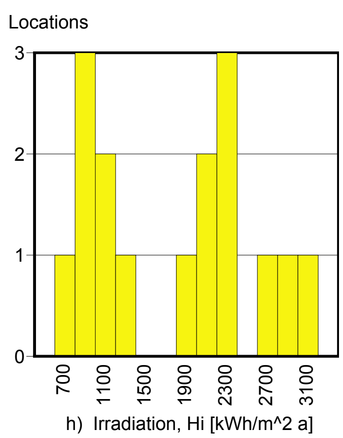




*Figures 14.1 to 14.9 Graphical representations of the other grid-connected PV systems.*



## 5.8. Facade PV systems

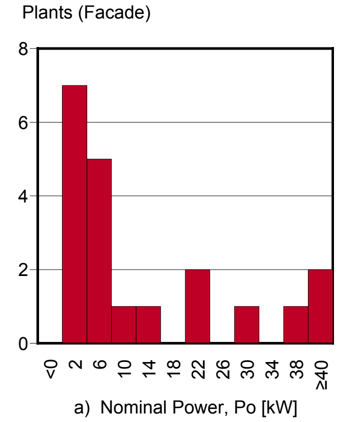
There are 20 grid-connected facade PV systems from six countries with a total nominal power of 321 kW and 78 annual datasets in the database. These grid-connected PV systems are also included in the country reports of the previous pages.

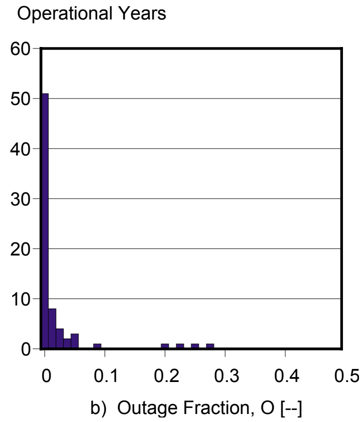
Table 5 Facade mounted grid-connected PV systems represented in the PVPS Performance Database.

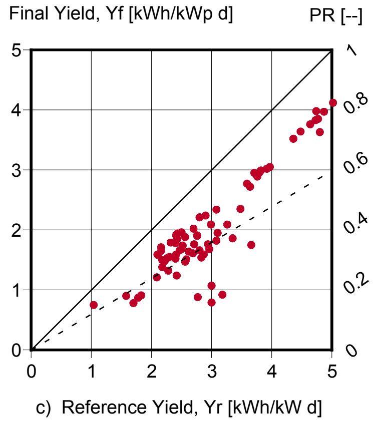
| Facade | Country | Plants | $P_0$ [kW] |
|---|---|---|---|
| | Germany | 3 | 13.3 |
| | Italy | 4 | 14.4 |
| | Netherlands | 1 | 20.8 |
| | Sweden | 1 | 10.9 |
| | Switzerland | 9 | 149.1 |
| | United Kingdom | 2 | 112.7 |
| | total | 20 | 321 |

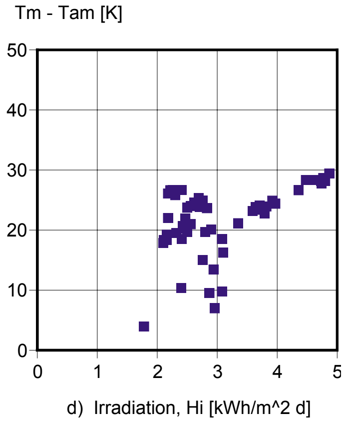
Because of the vertical mounting of the PV array the values of irradiation ($H_{I,y}$) and the yield ($Y_{f,y}$) are lower for these types of plants than for sloped PV systems (Figures 15, type g and h). The annual yield ($Y_{f,y}$) peaks at 600 kWh/kW, except for two Alpine facade systems located in Switzerland (Figure 15, type g).

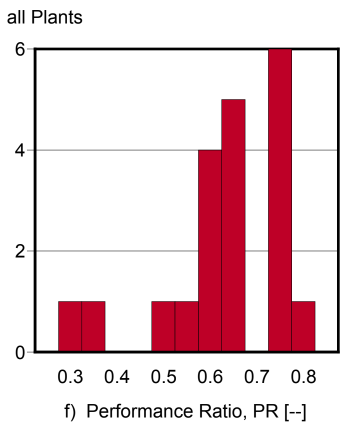
## 5.8. Facade PV systems (cont.)

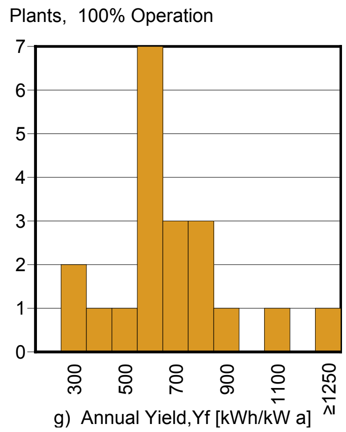


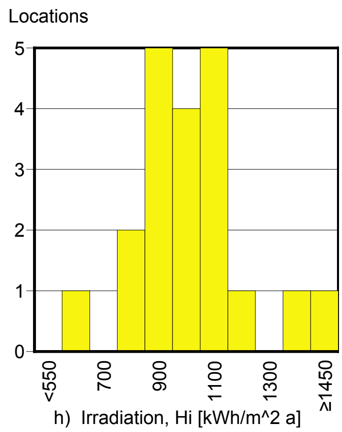




*Figures 15.1 to 15.7 Graphical representation of the facade mounted grid-connected PV systems.*



# 6. Reports of stand-alone PV systems

## 6.1. Stand-alone PV systems

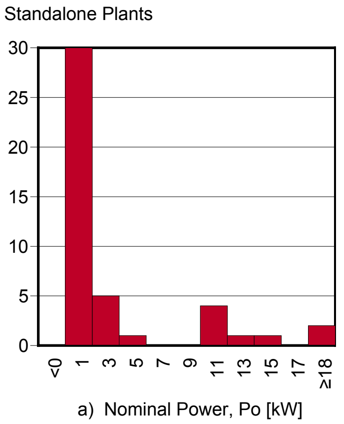
There are 43 stand-alone PV systems from six countries with a total nominal power of 182 kW and 55 annual datasets in the database. They include 35 small rural domestic and professional PV systems and 8 larger professional or R&D PV systems. Some Japanese systems are tunnel lighting applications. The resulting performance ratio (PR) for these systems depends greatly on the sizing and the type of application. Because of the wide geographical variation of the plant locations, the values for the annual yield ($Y_{f,y}$) and the irradiation ($H_{I,y}$) vary accordingly (Figures 16, type g and h). For the stand-alone and stand-alone hybrid PV systems the performance ratio is not sufficient to characterise the performance of stand-alone systems. Thus the production factor (PF) was introduced (see **3.1.2** and Figure 16, type i). The production factor is an indicator to the proper sizing in respect to the load.

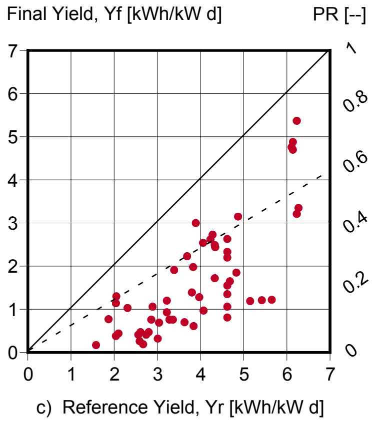
Table 6 Stand-alone PV systems represented in the PVPS Performance Database.

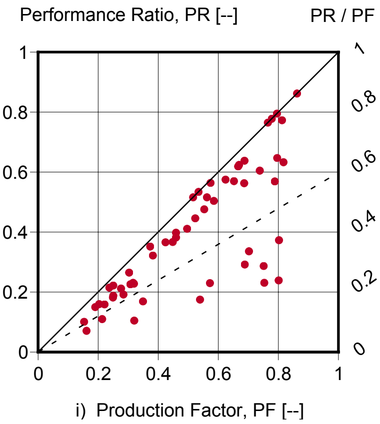
| Stand-alone | Country | Plants | $P_0$ [kW] |
|---|---|---|---|
| | Austria | 1 | 5.0 |
| | France | 25 | 22.3 |
| | Israel | 3 | 1.1 |
| | Italy | 1 | 71.4 |
| | Japan | 9 | 81.1 |
| | Netherlands | 4 | 0.9 |
| | total | 43 | 182 |

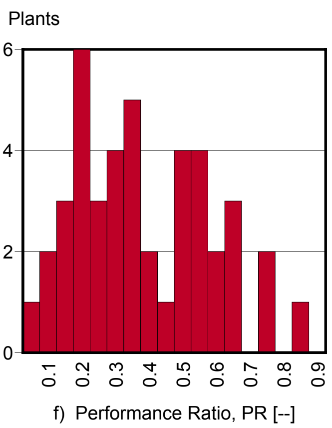
The module temperature is not available and the outage fraction is zero for most of the monthly datasets for these stand-alone PV systems.

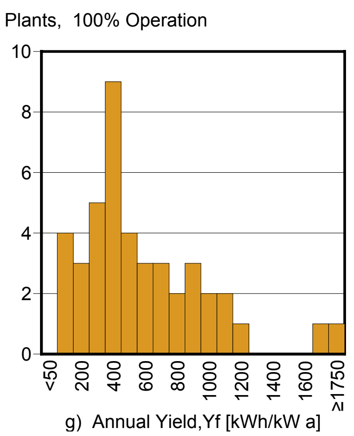
## 6.1. Stand-alone PV systems (cont.)



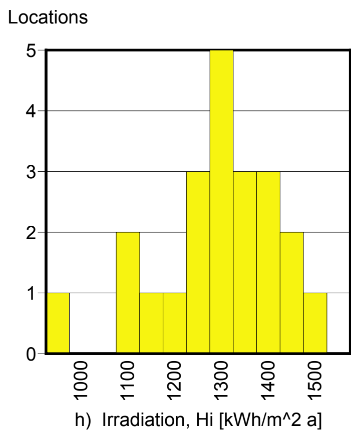




*Figures 16.1 to 16.6*
*Graphical representations of the stand-alone PV systems.*



## 6.2. Stand-alone hybrid PV systems

There are 13 stand-alone hybrid PV systems from three countries with a total nominal power of 798 kW and 24 annual datasets in the Performance Database (Figure 17, type a).

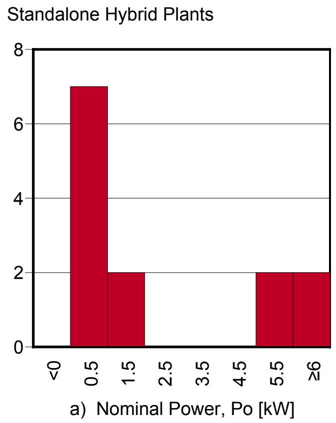
Table 7 Stand-alone hybrid PV systems represented in the PVPS Performance Database.

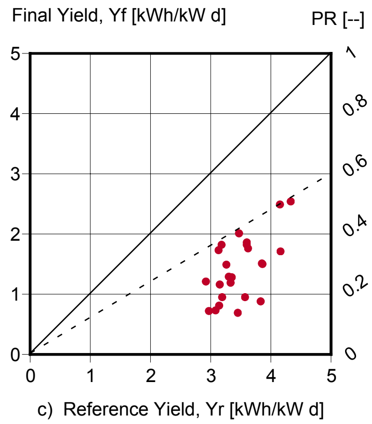
| Stand-alone hybrid | Country | Plants | $P_0$ [kW] |
|---|---|---|---|
| | France | 9 | 6.4 |
| | Germany | 1 | 5.1 |
| | Japan | 3 | 787 |
| | total | 13 | 798 |

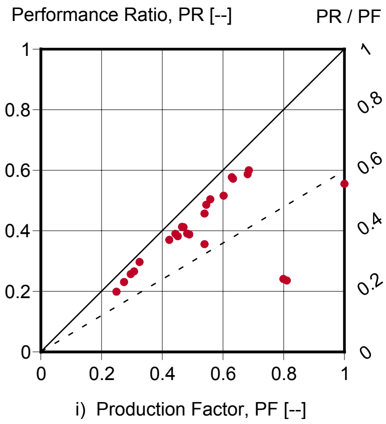
One of the three Japanese systems, is a 750 kW hybrid PV-diesel stand-alone plant and is located on Miyakojima island. It was constructed in 1992 under the “Sunshine Project” governmental programme. The system supplies electricity to the local community. The other two Japanese stand-alone hybrid PV systems are, one with a wind generator and the other with a micro-hydro generator.

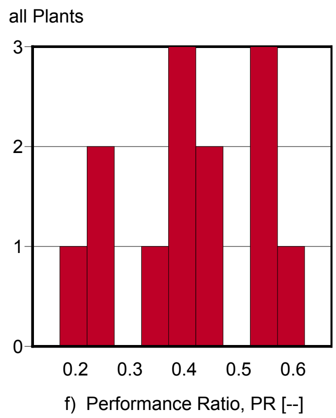
The module temperature is not available and the outage fraction is zero for all of the monthly datasets for these stand-alone hybrid PV systems.

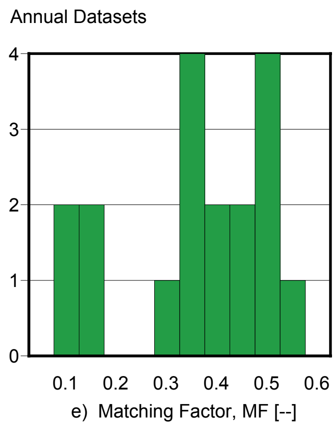
## 6.2. Stand-alone hybrid PV systems (cont.)

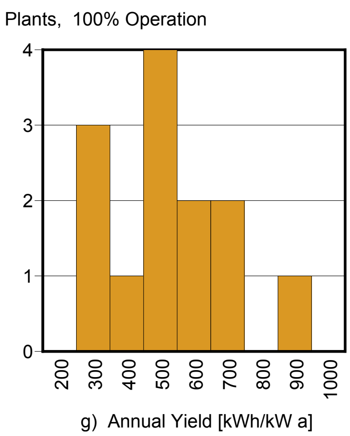


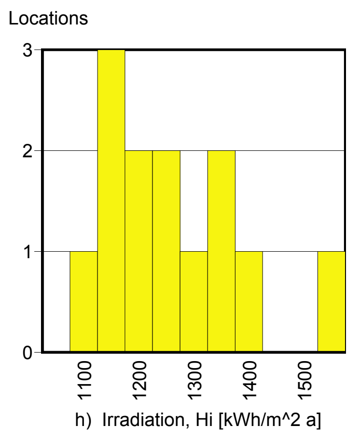




*Figures 17.1 to 17.7*
*Graphical representations of the stand-alone hybrid PV systems.*



## 6.3. France

Until the end of 1996 the PV sector in France was dedicated to off-grid applications namely via the ADEME/EDF agreement supporting domestic applications projects in the 600 W to 1 500 W range. This domestic off-grid sector represented 75% of the national market while the rest was taken by professional applications such as rural telecommunications, remote control monitoring devices, etc.

The stand-alone domestic applications on isolated sites still represent an important market share have registered already in 2003 a 20% decrease when compared to 2002. Market saturation in the French overseas department can explain this decline. On the contrary, the grid-connected market demonstrates a better share with 2.2 MW installed in 2003.

### The Photovoltaic Systems

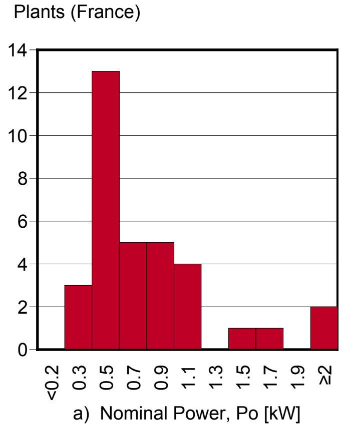
The data of the 34 French plants with a total power of about 29 kW in the PVPS Task 2 Performance Database come mainly from the stand-alone domestic PV programme, half of them having been installed in the overseas islands. Some of the plants have professional applications such as telecommunication relays and sheepfolds in the French southern Alps. Most of the systems are in the range from 300 W to 1 200 W.

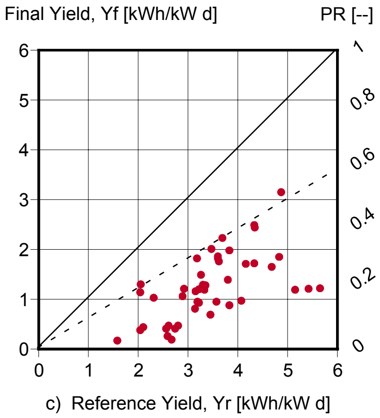
### Monitoring Data

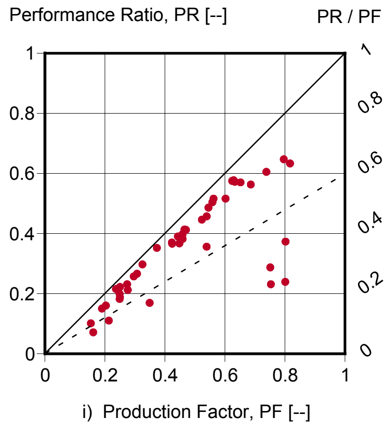
Reliable data of 34 stand-alone PV systems for monitoring periods between 1994 and 1996 providing 45 annual datasets are available. At some sites, there were already a diesel unit which has been used as a back-up system. Unfortunately, it has not been planned to follow their consumption on the monitoring device installed for the PV systems. Only monthly data were recorded allowing nevertheless to draw some important figures on operational performance data for stand-alone systems.

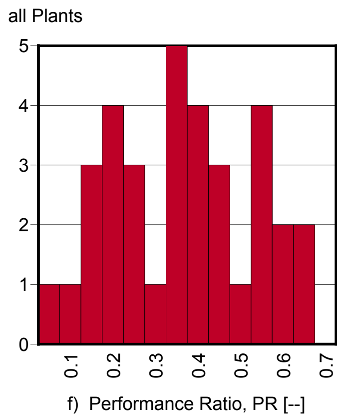
The histograms (Figures 18, type f and g) show the wide distribution of the performance ratio (0.2 - 0.65), as well as of the annual yield (100 - 1 100 kWh/kW). An oversizing of the PV system as regards to the user demand can explain, most of time, the poor value of the PR. The closer to the potential of the system the demand is, the higher the performance, reaching a PR of about 0.6 on a yearly basis. In that sense, undersizing a PV installation with diesel as a back-up allows a better reap benefit of the solar system. Performance ratio (PR) are in the range of 0.5 to 0.6 for hybrid systems, PV only (or oversized PV hybrid) show PR in the 0.3 to 0.5 range.

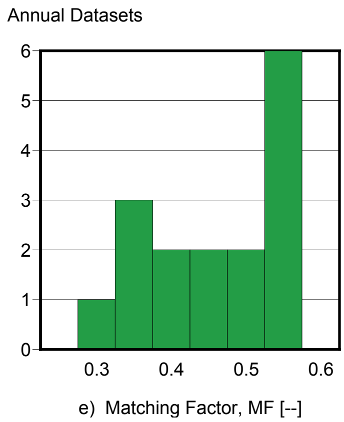
## 6.3. France (cont.)

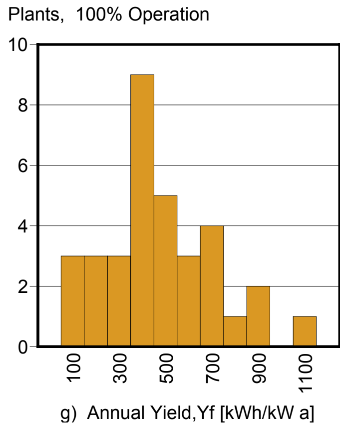


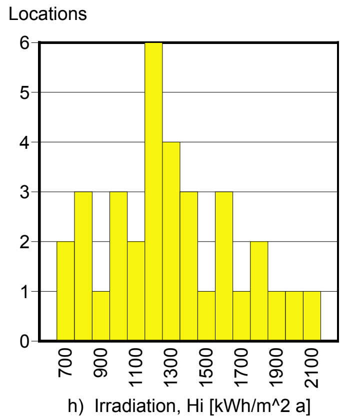




*Figures 18.1 to 18.7*
*Graphical representations of the French stand-alone PV systems.*



# 7. Conclusions

As it is within the scope of Task 2 to disseminate results of PV system performance to the target groups, this report is thought as a supplement to the IEA PVPS Performance Database. Most of the 395 PV systems analysed perform well and represent the state of the art for a particular period and the monitoring data is of good quality.

**Grid-connected PV systems**

The comparison of the performance results for the early and later installed grid-connected PV systems show a trend towards higher values for the newer systems (Figures 4.2 and 4.3). This trend can be observed for most of the representations of the performance ratio (Graph type f). For some countries the sample is too small to show an obvious trend of improvement over time.

The value of the annual final yield ($Y_{f,y}$) peaks at 800 kWh / kW for all the grid-connected PV systems and varies over a wide range, depending on the location, type of module and the type of mounting (Figure 5.1 and graph type g). The outage fraction is only available for all of the Swiss plants and only for a small number of plants from the other countries and is therefore not always representative. Overall, the effective annual mean module temperature ($T_{m,mean}$) is about 25 K above the ambient mean ($T_{am,mean}$). This value varies according to the type of mounting. The module temperature is only available for about 30% of the systems analysed. The overall annual inverter efficiency covers a range from 0.8 to 0.98 and peaks at 0.9 .

**Facade integrated PV systems**

The value of the annual final yield ($Y_{f,y}$) for the facade mounted system peaks at around 600 kWh / kW for 7 of the 20 systems and varies according to the location of the plant. Some system show a higher than average ($\Delta T$), the effective annual mean module temperature ($T_{m,mean}$) above the ambient mean temperature ($T_{am,mean}$). This has to do with the type of the construction of the PV facade [4].

**Stand-alone and stand-alone hybrid PV systems**

The available data for the stand-alone and stand-alone hybrid PV systems is only a small sample for this type of plant. Most of the systems are smaller than 1000 W and are mainly for domestic and professional use. The annual final yield ($Y_{f,y}$) covers a range from 100 to 1200 kWh / kW , with the exception of two Alpine systems. This annual yield varies depending on the sizing in respect to the load. Professional systems tend to be oversized, resulting in a lower annual yield.

The PV systems in the IEA PVPS Performance Database analysed for this report are mainly located in central Europe and in Japan. Therefore this report is only representative in respect to these locations. Some PV systems are located in the alpine regions, southern Europe, the French overseas departments, Israel and Mexico, but the number of these systems is too small to be analysed as a group.

Two questions remain: 1) are there any less successful PV systems? and 2) are the early systems represented in the database still performing well?

The author wishes to thank this colleagues from IEA PVPS Task 2 for supplying the data and photographs for this report.

## 8. References and Task 2 publications

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[5] IEA PVPS Task 2,
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JRC, E.S.A.S. I-21020 Ispra Italy.

# Annex

## Annex A - Overview of recorded and derived parameters

Table 8 Recorded and derived parameters for performance evaluation and normalised representation

| Typ of graph | Parameter | Symbol | Equation | Unit |
|---|---|---|---|---|
| | **Plant data** | | | |
| a) | Nominal power | $P_0$ | at STC | W |
| | Array area | $A_A$ | | $m^2$ |
| | STC reference inplane Irradiance | $G_{STC}$ | 1 000 | W |
| | Nominal array efficiency at STC | $\eta_{A0}$ | $P_0 / (A_A \bullet G_{STC})$ | — |
| | **Recorded parameters** | | | |
| | Irradiation | $H_I$ | | kWh / $m^2$ |
| | Ambient temperature | $T_{am}$ | | °C |
| | Module temperature | $T_m$ | | °C |
| | Non-availability to load | $t_{NAV}$ | | h |
| | Energy from PV array | $E_A$ | | kWh |
| | Potential energy from PV array | $E_{pot}$ | | kWh |
| | Energy to inverter | $E_{II}$ | | kWh |
| | Energy from inverter | $E_{IO}$ | | kWh |
| | Energy from backup | $E_{BU}$ | | kWh |
| | Net energy to storage | $E_{TS}$ | | kWh |
| | Net energy from storage | $E_{FS}$ | | kWh |
| | Energy to utility grid | $E_{TU}$ | | kWh |
| | Energy from utility grid | $E_{FU}$ | | kWh |
| | **Derived parameters** | | | |
| | Energy to all loads | $E_L$ | $E_{lac} + E_{ldc}$ | kWh |
| | Total input energy | $E_{in}$ | $E_A + E_{BU} + E_{FU} + E_{FS}$ | kWh |
| | Useful energy from system | $E_{use}$ | $E_L + E_{TU}$ | kWh |
| | PV array fraction | $F_A$ | $E_A / E_{in}$ | — |
| | PV contribution od Euse | $E_{use,PV}$ | $F_A \bullet E_{use}$ | kWh |
| b) | Outage fraction | O | $t_{NAV} / \tau$ | — |
| | Reference Yield | $Y_r$ | $\int_{day} G_I \, dt / G_{STC}$ | kWh / kW |
| | Array Yield | $Y_A$ | $E_{A,d} / P_0$ | kWh / kW |
| c) | Final Yield | $Y_f$ | $E_{use,PV,d} / P_0$ | kWh / kW |
| | Array capture losses | $L_c$ | $Y_r - Y_A$ | kWh / kW |
| | System losses | $L_s$ | $Y_A - Y_f$ | kWh / kW |
| f) | Performance ratio | PR | $Y_f / Y_r$ | — |
| e) | Matching factor | MF | $PR \cdot F_A$ | — |
| i) | Production factor | PF | $Y_A / Y_r$ | — |
| | Usage factor | UF | $E_A / E_{pot}$ | — |
| | Overall PV plant efficiency | $\eta_{tot}$ | $E_{use,PV,\tau} / \int\tau \, G_I \cdot A_A \, dt$ | % |
| *) | Mean array efficiency | $\eta_{A,mean}$ | $E_A / \int\tau \, G_I \cdot A_A \, dt$ | % |
| *) | Efficiency of the inverter | $\eta_I$ | $E_{IO} / E_{II}$ | % |
| d) | Mean module temperature | $T_{m,mean}$ | $\sum (G_I \cdot T_m) / \sum G_I$ | °C |
| h) | Annual irradiation, in plane of array | $H_{I,y}$ | $\int_{year} G_I \, dt$ | kWh / $m^2$ |
| | Annual reference yield | $Y_{r,y}$ | $\int_{year} G_I \, dt / G_{STC}$ | kWh / kW |
| | Annual array yield | $Y_{A,y}$ | $E_{A,y} / P_0$ | kWh / kW |
| g) | Annual final yield | $Y_{f,y}$ | $E_{use,PV,y} / P_0$ | kWh / kW |

*) only applied in the overview of GCS

## Annex B - Glossary of terms and abbreviations

| | |
|---|---|
| ADEME | French Agency Environment and Energy Management |
| BFE | Bundesamt für Energie (Swiss Federal Office of Energy) |
| BIPV | building integrated photovoltaics |
| BMU | German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety |
| EDF | Electricité de France (French utility company) |
| ENEA | Ente per le Nuove Tecnologie L´Energia E L`Ambiente (Italian Agency for New Technologies in Energy and the Environment |
| ENEL | Italian utility |
| EU | European Union |
| EURALP | Austrian-Italian cross-border co-operation project (EU) |
| GC-BIPV | grid-connected building-integrated PV |
| GCS | grid-connected systems |
| HIP-HIP | House Integrated PV - High Tech in Public (EU-Project) |
| HTRP | 100 000-Roofs-PV-Power-Programme (Germany) |
| IEA | International Energy Agency |
| IEC | International Electrotechnical Commission |
| MULTIBAT | European battery management project |
| MW | megawatt |
| NEDO | New Energy and Industrial Technology Development Organization (Japan) |
| NOVEM | Netherlands Agency for Energy and the Environment |
| OECD | Organisation for Economic Co-operation and Development |
| REL | Renewable Energy Law (Germany) |
| PV | photovoltaics |
| PVPS | photovoltaic power systems |
| R&D | research & development |
| SAS | stand-alone systems |
| VSE | Swiss Electricity Producer and Distributor Association |
| VDEW | Vereinigung Deutscher Elektrizitätswerke e.V. (Association of German Electric Utilities) |