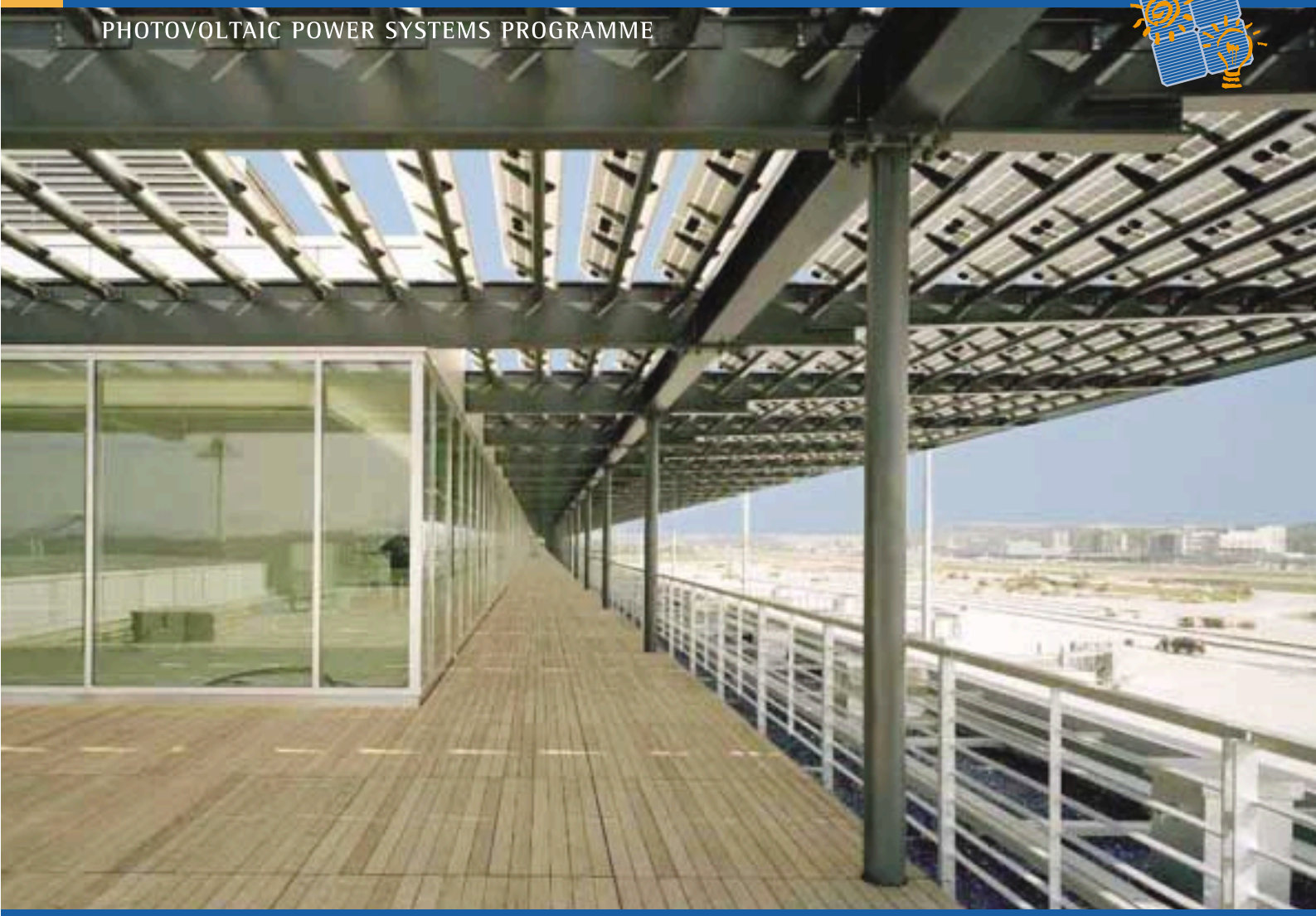
IEA INTERNATIONAL ENERGY AGENCY

PHOTOVOLTAIC POWER SYSTEMS PROGRAMME



PVPS

annual report 2002

IMPLEMENTING AGREEMENT
ON PHOTOVOLTAIC POWER SYSTEMS

PHOTOVOLTAIC POWER SYSTEMS PROGRAMME

ANNUAL REPORT 2002

PREFACE

2002 has been a remarkably productive year for the Photovoltaic Power Systems Programme IEA PVPS. All current tasks have produced important work and published a number of new reports. Several Tasks have held workshops in conjunction with their meetings, thereby increasing the exchange of information and interaction with the target audience of our work. Following the formal closing of Task 5 on the design and grid interconnection of building integrated and other dispersed photovoltaic systems and Task 7 on photovoltaic power systems in the built environment, a wealth of new information is now available on these two important projects. The dissemination of these results as well as those of all other current projects is ongoing, both through the IEA PVPS website (www.iea-pvps.org) as well as through targeted distribution within our member countries. I do like to emphasize the important role of dissemination by well defined means which determines the ultimate impact of our collaborative work.

During the year, the second term 1998 - 2002 of the IEA PVPS Programme was successfully concluded with an impressive list of achievements: more than 50 PVPS reports, books and databases, 10 PVPS newsletters, 25 workshops and conferences with a total attendance of about 1 600 participants, a PVPS website and other means of information dissemination are some of the data which quantitati-vely characterise the results of 5 years of collaborative R&D work.

According to the procedures of the IEA, the Executive Committee provided the higher committees – the Renewable Energy Working Party (REWP) and the Committee on Energy Research and Technology (CERT) with an End-of-Term report in which the work and the achievements over the past term were summarised. Both the REWP and the CERT approved this report, congratulated IEA PVPS on its achievements and agreed to another 5 year extension of the IEA PVPS Programme as proposed by the Executive Committee.

The PVPS Executive Committee will not limit itself to a mere continuation of the collaborative R&D activities but has decided to adapt its strategy to selected current issues of the photovoltaic technologies and their markets. This strategy will be characterised by three main lines which emphasize the role of PVPS in the new term:

- A stronger focus on the requirements for successful implementation of PV power systems in different applications;
- Working with a broader set of stakeholders, organisations and industry (including co-operation with other IEA implementing agreements);
- Supporting the transition towards self-sustained markets.

This brings me to the immediate future of our collaborative programme. In order to formalise the intentions mentioned above, the Executive Committee will adopt a new, detailed strategic plan which will describe the objectives, activities and expected outcomes in relationship to the needs, opportunities and means.

On the occasion of its 10th anniversary, IEA PVPS will hold an international conference in May 2003 in Osaka, Japan. This conference will provide a unique opportunity to share information and exchange views on PV policies and markets with important stakeholders from all over the world. We will use this opportunity to review our activities over the past decade and to present and discuss our future strategy. The conference outcomes are thus also intended to have a direct impact on our future work.

Finally, the PVPS Executive Committee is preparing a new project – Task 10 – which will be a follow-up of Task 7 on photovoltaic power systems in the built environment. This new Task is intended to translate the strategic issues highlighted above to concrete activities.

IEA PVPS continues to be committed to an ambitious role with true contributions to the sustained deployment of photovoltaic technologies. I take this opportunity to thank all Executive Committee members, Operating Agents and Task Experts which help to make this ambitious target become reality.

Stefan Nowak
Chairman

TABLE OF CONTENTS

PHOTOVOLTAIC POWER SYSTEMS PROGRAMME

IEA

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

Collaboration in research, development and demonstration of new technologies has been an important part of the Agency's Programme. The IEA R&D activities are headed by the Committee on Research and Technology (CERT), supported by a small secretariat staff, with headquarters in Paris. In addition, four Working Parties on End Use, Renewable Energy, Fossil Fuels and Fusion, are charged with monitoring the various collaborative energy agreements, identifying new areas for co-operation and advising the CERT on policy matters. The Renewable Energy Working Party (REWP), recently chaired by the first PVPS chairman, Mr. Roberto Vigotti, oversees the work of eight renewable energy agreements, of which PVPS is one of the youngest, and is supported by a Renewable Energy Unit at the IEA secretariat in Paris.

IEA-PVPS

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

The overall programme is headed by an Executive Committee composed of representatives from each participating country, while the management of individual research projects (Tasks) is the responsibility of Operating Agents. By the end of 2002, nine Tasks were established within the PVPS programme, of which one was completed in 1997 (Task 6), two were completed in 2001 (Task 5 and Task 7) and one is not operational (Task 4). A new task is in preparation (Task 10), which will be a follow-up to Task 7.

The twenty-one PVPS members are: Australia, Austria, Canada, Denmark, European Union, Finland, France, Germany, Israel, Italy, Japan, Korea, Mexico, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom and the United States. Turkey has shown an interest to revive its membership.

The mission of the IEA-PVPS programme is:
To enhance the international collaboration efforts through which photovoltaic solar energy becomes a significant renewable energy source in the near future.

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 primary scope of the programme has been the information exchange about activities already in progress in the respective national programmes. However the real added value of the co-operation has been the informal co-ordination and initiation of new activities such as market surveys, the analysis of the operation and performance of a large number of PV systems already installed in the world, and the provision of the lessons learned, as well as the guidelines for appropriate design improvements.

IEA-PVPS OBJECTIVES

The IEA-PVPS programme aims to realise the above mission by adopting the following objectives related to reliable PV power system applications for the target groups: utilities, energy service providers and other public and private users:

1. To contribute to the cost reduction of PV applications

National R, D&D programmes, utility investments in PV projects, industrial R&D and expansion of PV manufacturing capacity are examples of activities with a direct effect on the cost of PV systems and their application. International co-operation can indirectly contribute to cost reduction by undertaking or supporting activities such as: sharing objective information, creating networks and providing guidelines.

2. To increase the awareness of their potential and value

Key issues for the awareness of the potential and value of PV power systems among target groups are: cost/performance indicators, market developments, innovations and breakthroughs, new applications and services, national and international programmes and initiatives, financing schemes, developments and standards.

3. To foster their market deployment by removing technical and non-technical barriers

Critical technical and non-technical barriers for the large-scale deployment of PV power systems in various market segments have been identified, as described in Chapter 1. International co-operation adds value in the assessment of some of these barriers, such as: standardisation in design, utility disinterest and concerns, networks of installers, technical risks etc.

4. To enhance technology co-operation with non-IEA countries

Stand-alone systems in remote areas of the world represent a fast growing market segment and their large-scale introduction is supported by bilateral and multilateral agencies and development banks. The large-scale introduction is hampered by various barriers such as acceptable accessible financing structures, institutional and social problems, infrastructure issues and sometimes technical problems. PVPS expertise can be instrumental to help overcome some of these barriers.

TABLE 1 - STRATEGIES AND DELIVERABLES OF THE FOUR IEA-PVPS OBJECTIVES

OBJECTIVE	STRATEGIES	DELIVERABLES
1 – To contribute to the cost reduction of the PV power systems applications	• To collect, analyze and disseminate information on the technical performance and cost structure of PV systems and their applications. • To share the knowledge and experience gained in monitoring selected national and international PV projects. • To provide guidelines for improvement of the design, construction and operation of photovoltaic power systems and subsystems. • To contribute to the development of improved photovoltaic systems and subsystems.	• Reliable information on the technical performance and cost structure of PV systems, in an accessible form. • Recommended practices for improved design, construction and operation and maintenance of PV systems, in an accessible form. • Technical guidelines fot the interconnection to the grid of small dispersed systems as well as large and very large PV systems. • Recommended practices for the main components of PV systems.
2 – To increase the awareness of the potential and value of PV power systems	• To collect and analyze information on key awareness issues, such as markets, applications, barriers and success stories; • To present/publish the reliable and relevant parts of this information in appropriate forms (brochures, reports, books, internet, etc.); • To disseminate these information products, relevant for the deployment of PV systems, to target groups; • To monitor the use of this information and the effects on the awareness among target groups; • To bring actors of different groups together, and to encourage the creation of national and international networks.	• The PVPS Newsletter informing the main target groups on the results of the collaborative work of the PVPS programme and on other important issues regarding the deployment of PV power systems programme. • An overview of activities, available information and contact points of the PVPS programme on the Internet. • A Flyer describing the objectives and the structure of the programme and containing a list of the contact persons in each country. • Executive Conferences • International workshops on important specific (technical and non-technical) issues • Input to national workshops by participation of PVPS experts.
3 – To foster their market deployment by removing technical and non-technical barriers	• To involve and support utilities and other public and private users in the process of identification, selection and implementation of high priority activities aimed at removing the barriers concerned. • To develop methods for the evaluation of the value and benefits of PV systems and to facilitate their introduction. • To develop strategies for the deployment of PV in a competitive electricity market and to facilitate their introduction. • To assess the evolution of the identified barriers for PV power-systems in the light of economics and competition in the electricity sector.	• Recommended practices for grid-connected and stand-alone systems, especially for utilities regarding the implementation of these applications. • Guidelines for monitoring practice and analysis of PV systems, to optimize equipment choices and improve the quality of monitoring. • Overview of PV financing methods in OECD countries. • Survey of taxation, customs duties and building regulations for PV components and systems in OECD countries. • Planning methods to evaluate and maximize the benefits of grid-connected photovoltaic systems to the electric grid and to the customers. • Specific studies on important issues.
4 – To enhance technology co-operation with non-IEA countries	• To stimulate the awareness and interest of multilateral and bilateral agencies and development banks on the technical and economic potential and best practice of PV systems. • To stimulate co-operation between IEA PVPS members and selected non-IEA countries. • To increase awareness on the opportunities of PV systems amongst targeted groups in developing countries via workshops, missions and publications. • To stimulate PVPS membership of selected non-IEA countries. • To promote adequate measures for quality assurance and standards.	• Internal staff workshops for multilateral agencies and development banks. • Workshops in non-IEA countries, co-ordinated with bilateral and/or multilateral agencies, development banks and/or NGO's. • Studies and publications on PV systems applications in developing countries. • Contact point for ad-hoc advice to staff of multilateral agencies and development banks. • Best practice deployment and implementation guide for successful PV system operation. • Active PVPS membership and/or participation of selected non-IEA countries.

In Table 1 the strategies and deliverables for each of these objectives are given.

IEA PVPS Executive Committee Sophia Antipolis, October 2002.

IEA-PVPS TASKS

In order to obtain these objectives, specific research projects, so-called Tasks, are being executed. The management of these Tasks is the responsibility of the Operating Agents. Within the IEA PVPS the following Tasks have been established:

- Task 1. Exchange and dissemination of information on PV power systems;
- Task 2. Operational performance, maintenance and sizing of PV power systems and subsystems;
- Task 3. Use of PV power systems in stand-alone and island applications;
- Task 4. Modelling of distributed PV power generation for grid support (not operational);
- Task 5. Grid interconnection of building integrated and other dispersed PV systems (concluded in 2001);
- Task 6. Design and operation of modular PV plants for large scale power generation (concluded in 1997);
- Task 7. PV power systems in the built environment (concluded in 2001);
- Task 8. Very large scale PV power generation systems;
- Task 9. Deployment of PV technologies: co-operation with developing countries;
- Task 10. In preparation. Follow-up of Task 7.

The **Operating Agent** is the manager of his or her Task, and responsible for implementing, operating and managing the collaborative project. As such the Operating Agent compiles a status report, with results achieved in the last six months, as well as a work plan for the coming period. These are being discussed at the Executive Committee meeting, where all participating countries have a seat. Based on the work plan, the Executive Committee decides whether activities in the coming period should continue, or intensify, or stop.

In case the Executive Committee decides to continue the activities within the Task, the participating countries in this Task commit their respective countries to an active involvement by national experts. In this way, a close co-operation can be achieved, whereas duplication of work is avoided.

TASK STATUS REPORTS

TASK 1 – EXCHANGE AND DISSEMINATION OF INFORMATION ON PHOTOVOLTAIC POWER SYSTEMS

IEA PVPS Website, Homepage.

OVERALL OBJECTIVE

The objective of Task 1 is to promote and facilitate the exchange and dissemination of information on the technical, economic, environmental and social aspects of PV power systems.
Task 1 activities support the broader PVPS objectives that relate to contributing to cost reduction of PV power applications, increasing awareness of the potential and value of PV power systems, fostering the removal of both technical and non-technical barriers and enhancing technology co-operation.

All countries participating in the PVPS Programme are members of Task 1. To meet the Task 1 objective and deliver the expected outcomes, Task 1 participants focus on understanding the needs of their target audiences for the various Task 1 deliverables and establishing mechanisms for communication both within and outside the PVPS Programme. The development of the public website www.iea-pvps.org will continue to be influenced by the requirements for information that are identified and revised by Task 1 participants and others.

Task 1 activities are organized into the following subtasks:

SUBTASK 1.1: Status Survey Reports

A published **International Survey Report** is compiled from the **National Survey Reports** produced annually by all countries participating in the IEA-PVPS Programme. These previously internal national reports can now be found on the public website.
The International Survey Report presents the current status and interprets trends relating to systems and components being used in the various PV power systems markets, as well as changing applications within those markets. This is reported in the context of the business environment, policies and relevant non-technical factors in the participating countries.

International Survey Reports were initially produced every two years, but a shorter report is now produced annually to provide more timely information. The first issue was printed in March 1995 and a further six issues had been published by the end of 2002.

SUBTASK 1.2: Newsletter

A newsletter, PV Power, is prepared and distributed each six months presenting highlights of the IEA-PVPS Programme as well as general features of interest about PV systems and components and market applications. Task 1 participants provide material of interest to the newsletter editor and ensure that the newsletter reaches its target audience in the respective countries.

Seventeen issues of the newsletter had been published by the end of 2002.

SUBTASK 1.3: Special Information Activities

A variety of activities, including workshops and documents, provide analysis and summary assessment of special topics. These are directed at technical, economic, environmental and social aspects of PV systems and applications and are usually managed by a specific country or a group of countries from the Task 1 membership.
Activities to date include workshops and published reports on "Environmental aspects of PV power systems", "Photovoltaics in competitive electricity markets" and "Added values of photovoltaic power systems". Other activities include "Buy back rates for grid-connected photovoltaic power systems", "Photovoltaic components and systems: Status of R&D in IEA countries, 1985-1995" and "Photovoltaics in cold climates".

SUMMARY OF TASK 1 ACCOMPLISHMENTS FOR 2002

For all activities Task 1 emphasizes the importance of meeting the needs of the various target audiences and this focus has continued in general throughout the year. The public PVPS website enables PVPS information to be provided quickly and at a reasonable cost. The ongoing development of the website remains a priority activity for Task 1, and is carried out within the framework of the guiding principles and agreed policy for the website. The website (and its various links) also provides other PVPS participants with valuable information on the programme as a whole, enhancing inter-task communication.

SUBTASK 1.1: Status Survey Reports

The seventh issue of the International Survey Report was published in September 2002 and analyzed data collected between 1992 and the end of 2001. The report was prepared under the supervision of Task 1 by an independent consultant on the basis of the National Survey Reports (NSRs) prepared by Task 1 participants. Eighteen out of twenty countries produced the required NSR (or at least provided information). Fourteen of these countries provided material close to the agreed date.

These National Survey Reports are funded by the participating countries, provide a wealth of information and are a key component of the collaborative work carried out within the PVPS Programme. The International Survey Report is funded by the PVPS Common Fund and is distributed by Task 1 participants to their identified national

target audiences and at selected conferences and meetings.
The report is available on the public website, can be downloaded as a complete document, and figures / tables can be downloaded separately.

SUBTASK 1.2: Newsletter

Editorial policy for the newsletter continued to emphasize that projects and products must be tangible to be included.

Issue 16 of the newsletter was published in June 2002. Issue 17 was published in December 2002. Current and back issues of PVPower are available on the public website.

SUBTASK 1.3: Special Information Activities

During 2002 work continued at a low level on a number of activities (ongoing and new) that fall under the umbrella of special information activities. The significant issue affecting the ability to progress these activities is that they are all without a "lead country" providing the required resources. The activities include innovative marketing and financing, cost of energy from PV, value of PV business activity and the value chain of the PV industry. The agreed position is that, without the resources required to carry out the detailed analyses that some of these topics require, Task 1 will build on existing activities by collecting and disseminating related information to target audiences via established channels.

SUMMARY OF TASK 1 ACTIVITIES PLANNED FOR 2003

The issue of market implementation is an important focus for the PVPS Programme, including all Task 1 activities. Task 1 will continue to identify, collect and disseminate relevant information that, although not necessarily part of an established activity or task, may subsequently be included in PVPS publications, or lead to development of a special information activity or provide input to a new task.

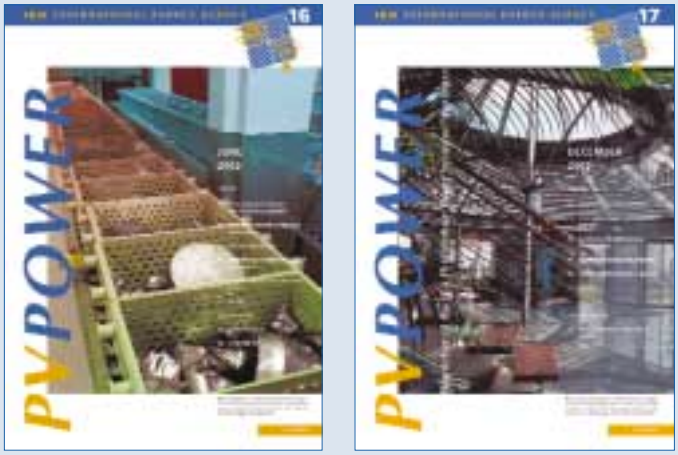
SUBTASK 1.1: Status Survey Reports

The target date for publication of the eighth issue of the International Survey Report is August 2003. Changes to the format, content, technical writing and production of the eighth issue will be finalized during the March 2003 Task 1 meeting.

National Survey Reports will be completed by the end of May 2003 so that the information can be incorporated in and analyzed for the International Survey Report.

SUBTASK 1.2: Newsletter

Task 1 participants will continue to review and update the target audience within their country, and to seek feedback regarding preferred format (e.g. electronic or printed) and content from these audiences.
PVPower Nos. 18 & 19 will be published in April 2003 and October 2003 respectively, maintaining current editorial policy.



Newsletter PV Power issues 16 and 17.

SUBTASK 1.3: Special Information Activities

- Costs and Prices – Without a country to lead this activity the emphasis will now be on providing a framework for accessing the wealth of cost and price information, trends and methodologies that can be found throughout the tasks of the PVPS Programme and also related organizations. This will be readily accessible from the homepage of the website.
- Added Values of PV – This activity will be ongoing, with the priority now on collecting and disseminating information on marketing and promotional approaches that highlight the added values of PV previously documented by the PVPS Programme.

INDUSTRY INVOLVEMENT

Task 1 activities continue to rely on close co-operation with government agencies, PV industries, electricity utilities and other parties, both for collection and analysis of quality information and for dissemination of PVPS information to target audiences. This is achieved through the networks developed in each country by the Task 1 participants. It is recognized that the target audience for PVPS information has broadened considerably. A communication survey, carried out within countries during 2002, will guide communication strategies at the country and programme levels.

Workshops are considered an effective means of attracting industry involvement in the PVPS programme, and are developed whenever possible.

KEY DELIVERABLES (2002 AND PLANNED)

The following were published and also made available on the public website during 2002:

Trends in photovoltaic applications in selected IEA countries between 1992 and 2001 Report IEA-PVPS T1-11: 2002;
Newsletter – PVPower issues 16 and 17.

Individual National Survey Reports are now included under "Country information" on the public website, with tables and graphs able to be downloaded. Guidelines for the NSRs are produced and updated each year.

LIST OF PARTICIPATING COUNTRIES, KEY TASK 1 PARTICIPANTS IN 2002 AND THEIR ORGANISATIONS

In many cases the following participants were supported by one or more experts from their respective countries.

COUNTRY	NAME	ORGANISATION
Australia	Greg Watt	Australian PVPS Consortium
Austria	Hubert Fechner	Arsenal Research
Canada	Gordon Howell	Howell-Mayhew Engineering Inc.
Denmark	Peter Ahm	PA Energy A/S
European Union	Rolf Öström	DG Research
Finland	Leena Grandell	MOTIVA
France	André Claverie	ADEME
Germany	Peter Sprau	WIP
Israel	Yona Siderer	The Ben-Gurion National Solar Energy Centre
Italy	Salvatore Guastella	CESI - ENEL
Japan	Osamu Ikki	Resources Total System Co. Ltd.
Korea	Kyung-Hoon Yoon	KIER
Mexico	Jaime Agredano Diaz	IIE
Netherlands	Job Swens	NOVEM
Norway	Bruno Ceccaroli	SCATEC AS
Portugal	Pedro Paes	LABELEC SA
Spain	no participation	
Sweden	Lars Stolt	Uppsala University
Switzerland	Pius Hüsser	Nova Energie GmbH
United Kingdom	Paul Cowley	IT Power
USA	Charles Linderman	Edison Electric Institute.

Updated contact details for Task 1 participants can be found on the IEA-PVPS website www.iea-pvps.org.

During 2003 it is planned to produce the eighth issue of the International Survey Report, PVPower issues 18 and 19, a selection of examples of innovative marketing / financing of PV and PV-specific portfolio standards, a broad range of country information on the public website and development of "key topic" (such as costs and prices) support on the website.

MEETING SCHEDULE (2002 AND PLANNED 2003)

The 20th Task 1 Participants' meeting was held in Bodo, Norway, 13-15 March 2002.
The 21st Task 1 Participants' meeting was held in Basel, Switzerland, 11-13 September 2002.
The 22nd Task 1 Participants' meeting will be held in Basingstoke, UK, 5-7 March 2003.
The 23rd Task 1 Participants' meeting will be held in Sweden, 10-12 September 2003.

TASK 2 - OPERATIONAL PERFORMANCE, MAINTENANCE AND SIZING OF PHOTOVOLTAIC POWER SYSTEMS AND SUBSYSTEMS

OVERALL OBJECTIVE

The overall objective of Task 2 is to provide technical information on operational performance, long-term reliability and sizing of PV systems to target groups. The target groups of Task 2 are other Tasks of PVPS and PV experts, research laboratories, utilities and manufacturers, system designers, installers, standardisation organisations and vocational schools. Task 2 is a technical Task with a horizontal role to deliver services to the other Tasks within the PVPS programme.

Task 2 officially started its work on April 16, 1999, for a period of five years (second phase). Task 2 activities are organised into the following Subtasks:

SUBTASK 1: International Database

Participants collect information on the technical performance, reliability and costs of PV power systems and subsystems by means of published and unpublished written materials, available monitoring data from national programmes and personal contacts. The information is then entered into a database providing technical data on operational performance, long-term reliability and sizing of PV systems. To ensure consistency, a data collection format and a set of standard definitions have been developed and agreed to.

The Task 2 Performance Database allows the user to select PV system data, monitoring data and calculated results as well as to export these data into spreadsheet programmes. The Task 2 database is being updated regularly including new PV system data from national representatives and other sources. The product is distributed in a non-commercial way as widely as possible. Dissemination of the database and collated information is carried out through national channels of the participating countries, by organising national and international workshops, by presenting the products at conferences and seminars and last, but not least, by using the effective means of Internet.

SUBTASK 2: Analysis of Photovoltaic Systems

Participants analyse performance and maintenance data for photovoltaic power systems and components in their respective countries, both in order to ensure the quality and comparability of data entered in the database and to develop analytical reports on key issues such as operational performance, reliability, expected output and sizing of PV systems. Activities to date include conference presentations and published reports on "Statistical and Analytical Evaluation of PV Operational Data", "Analysis of the Operational Performance of the IEA Database PV Systems" and "Operational Performance, Reliability and Promotion of Photovoltaic Systems".

SUBTASK 3: Measuring and Monitoring

Participants assessed which current procedures for measuring the performance of photovoltaic power systems and subsystems are most effective, which can be improved, and which are best avoided. Activities included a published handbook covering monitoring techniques, normalised evaluation of PV systems and national procedures in IEA member countries. The internal PVPS Task 2 report "Measuring and Monitoring Approaches" was published in November 1998 and has been distributed to other PVPS Task participants, a PV researcher and to individuals who have made a special request.

Subtask 3 was terminated during the first phase of Task 2. Activities on monitoring and maintenance are continued with less emphasis within Subtask 2.

SUBTASK 4: Improving PV System Performance

Participants are developing recommendations on sizing of PV power systems and suggest improvements for better PV system performance. Participants identify tools to process and analyse data for performance prediction and sizing purposes. Applied energy management schemes are analysed from the energy and operating cost points of view. Participants take account of the work performed in other Subtasks and in collaboration with Task 3 and Task 7.

SUMMARY OF TASK 2 ACCOMPLISHMENTS FOR 2002

During 2002, Task 2 focused on the dissemination of the updated Performance Database and other Task 2 products. The public Task website enables downloads and technical information to be provided quickly and cost-effective to the users. The volume of visitors to the Task website, their countries and sectors as well as the number of PVPS Task 2 products retrieved are being tracked to measure the extent to which the website is visited and the products are used (see Figure 1).

An international symposium on *Research, Marketing and Dissemination of Photovoltaic* was held in Vienna on 13th September 2002 in conjunction with the PVPS Task 2 meeting. More than 120 persons from the solar and building industry, utilities, system designers, local governmental bodies and from research participated in the symposium "Electricity from the Sun" with presentations on the subjects: "RTD Activities and Trends", "Training and Education", "Marketing and Promotion Activities".

SUBTASK 1: International Database

The **Task 2 Performance Database** was updated and released in April 2002 as a tool for planning, sizing and improving PV systems with respect to operational performance and reliability.
The Performance Database (45 MB) is available on CD-ROM and can be downloaded from the Task website "http://www.task2.org". Instruction manual, installation guide, database flyer and electronic user support are additionally provided to the database users (see Figure 2).

During 2002, Task 2 focused on the dissemination and promotion of the Task 2 database making announcements on public PVPS and Task

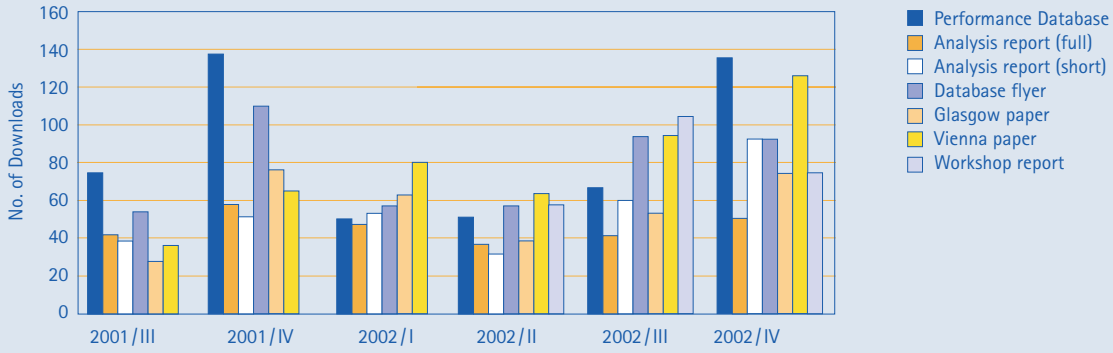


Fig. 1 - Statistics on information retrieval of different Task 2 products (database, reports, conference proceedings) from public website.

websites, placing articles in national and international PV magazines and newsletters as well as presenting the database programme at PV conferences, seminars and in workshops. As a result, over 1 000 database users from 52 different countries and a broad range of sectors are making best use of the Task 2 database for their applications in research, production, planning & consulting and education.

Data collection and acquisition were kept at low level during 2002. Available datasets from Task 2 members and other sources were entered into the Performance Database to result in high quality data of 316 PV systems of different system technologies, located in 12 countries. The Task 2 database update of April 2002 provides 10 269 monthly datasets from grid-connected and stand-alone PV systems of a total power of 10,8 MWp.

Fig. 2 - IEA-PVPS Task 2 Performance Database programme update, April 2002, available on CD-ROM and for Internet download.

SUBTASK 2: Analysis of Photovoltaic Systems

A public report was prepared from the contributions of the Task 2 workshop held on the occasion of the European PV Solar Energy Conference (PVSEC) in Munich, Germany, in October 2001. The report "Operational performance, reliability and promotion of photovoltaic systems" was published in June 2002 and distributed to more than 360 interested readers in the form of hard copies and electronic documents (see Figures 1 & 3).

PV system performance analysis has been continued and worked up in selected activities, as follows:

- **Availability of Irradiation Data (France)** – A draft report was produced that provides information on irradiation data to be used to assess the performance of PV systems;
- **Tools for Checking the Performance of PV systems (France)** – Work has been performed to validate the use of coefficients able to give information of stand-alone system operation;
- **Shadings Effects on PV System Performance (Japan)** – **Work initiated.** Preliminary investigation in the literature was made to specify the approach;
- **Temperature Effects on PV System Performance (Switzerland)** – Work is underway. Based on collected hourly data, temperature gains and losses were calculated for selected examples;
- **Long-term Performance and Reliability Analysis of PV Systems (Germany)** – Work is underway. Case studies on long-term performance trends, on reduced yield analysis and on components failures were elaborated;
- **Country Report on PV System Performance (Switzerland)** – Work ongoing.

SUBTASK 4: Improving PV System Performance

Different documents on simulation tools have been collected and evaluated. The overview on simulation tools will be continued and improved. Regarding energy management strategies (EMS), a draft version of a review on "Energy Management Strategies for Hybrid Energy Systems" has been prepared in collaboration with Task 3.

SUMMARY OF TASK 2 ACTIVITIES PLANNED FOR 2003

Task 2 activities for 2003 will focus on the effective dissemination of technical PVPS information, which has been elaborated in all Subtasks. The Internet option will be the preferred way of distribution. For the national distribution of the Performance Database, Task 2 will locate and activate distribution channels and contacts in its member countries. Offering workshops and seminars relevant for target groups will be enhanced, as these activities seem to be attractive and of importance for the PV industry.

Task 2 intends to present its activities and results at the World Conference on Photovoltaic Energy Conversion (WCPEC-3) in Osaka, Japan in May 2003. Contributions on performance analysis and reliability, understanding of temperature effects and on subsidies versus rate based incentives will be prepared and given in oral and visual presentations.

SUBTASK 1: International Database

The target date for publication of the third version of the Performance Database is May 2003. New monitoring data including

Fig. 3 - Report on Operational Performance, Reliability and Promotion of Photovoltaic Systems published in June 2002.

2002 data and new data sets of PV systems in additional countries of interest will be submitted and entered before the Task 2 March meeting. The checked and updated Performance Database will be available for Internet downloads and on CD-ROM at the World Conference on Photovoltaic Energy Conversion in May 2003. Registered users will be informed about the release of this database update that can be incorporated into the existing programme.

SUBTASK 2: Analysis of Photovoltaic Systems

The activities of PV system performance analysis will be continued:

- **Availability of Irradiation Data (France)** – Work will be finalized and published as report;
- **Tools for Checking the Performance of PV Systems (France)** – Work will be substantially completed with some input from new systems available in the Performance Database;
- **Shadings Effects on PV System Performance (Japan)** – Work will be nearly completed and summarized into final report;
- **Temperature Effects on PV System Performance (Switzerland)** – Results will be published as electronic document;
- **Long-term Performance and Reliability Analysis of PV Systems (Germany)** – Case studies are to be completed. Recommendations and results of case studies will be summarized and published in final report;
- **Country Report on PV System Performance (Switzerland)** – Work will be continued and published if availability of data allows.

SUBTASK 4: Improving PV System Performance

Task 2 will continue the work on PV systems performance assessment checking the relevance of matching factor and usage factor and defining the minimum parameters required for performance assessment. A specific methodology on sizing of PV hybrid systems, based on the analysis of operational data, will be developed to improve PV hybrid system operation. Other case studies will be selected to enlarge the EMS analysis and give the results the widest signification possible.

INDUSTRY INVOLVEMENT

Task 2 benefits from its co-operation with PV industries, electricity utilities and other agencies, both for collection and analysis of PV system data and for dissemination of technical information to target audiences.
Task 2 will continue to develop and organize PV workshops to involve industry and other parties in the PVPS activities. In September 2002, an international symposium on Research, Marketing and Dissemination of PV was organized in Vienna by Task 2 and Arsenal Research in cooperation with IEA–PVPS, the Austrian Ministry of Transport, Innovation and Technology and with the Austrian PV industry.

PV industries, engineering & consulting companies and utilities are important and well-represented user groups of the Task 2 Performance Database, who are gaining valuable information from the data provided.

KEY DELIVERABLES (2002 AND PLANNED 2003)

The following report was published and made available on public websites during 2002:

- Operational Performance, Reliability and Promotion of Photovoltaic Systems. REPORT IEA–PVPS T2-03: 2002.

The following deliverables have been developed and produced during 2002:

- Task 2 Performance Database programme update with collected data from 316 PV systems, released in April 2002;

- POSTER: *Performance Analysis, Reliability and Sizing of Photovoltaic Systems.* Visual presentation at the PV in Europe Conference, Rome, Italy, October 2002;

- Draft report on *Review of Energy Management Strategies for Hybrid Energy Systems* was prepared by Task 2 and Task 3. It will be updated and finalized for publication.

During 2003, it is planned to produce and disseminate a third version of the Task 2 Performance Database to be released in May 2003 and an updated brochure on Task 2 activities and results. Both will be available at the World Conference on Photovoltaic Energy Conversion and at the IEA PVPS International Conference in Osaka, Japan, May 2003. It is also planned to prepare and publish four conference proceedings on performance analysis & reliability, understanding of temperature effects and on subsidies versus rate based incentives. The Task 2 conference contributions will be given in three oral and one visual presentation.

Public reports and other materials are available on the PVPS website "http://www.iea-pvps.org".
The Performance Database programme, database updates and Task 2 publications can be downloaded from the Task website "http://www.task2.org".

Fig. 4 - Task 2 September meeting in Vienna, Austria.

TABLE 1 - LIST OF PARTICIPATING COUNTRIES, TASK PARTICIPANTS IN 2002 AND THEIR ORGANISATIONS

COUNTRY	PARTICIPANT	ORGANISATION
Austria	Mr. Michael Heidenreich	Arsenal Research
France	Mr. Didier Mayer	Ecole Des Mines de Paris
Germany	Mr. Reinhard Dahl (OA)	Projekttraeger Juelich (PTJ) Forschungszentrum Juelich GmbH
	Ms. Ulrike Jahn	Institut für Solarenergieforschung GmbH Hameln / Emmerthal (ISFH)
	Mr. Wolfgang Nasse	Solar Engineering GmbH
Italy	Mr. Salvatore Castello	ENEA C.R. Casaccia
Japan	Mr. Koichi Sakuta	National Institute of Advanced Industrial Science and Technology (AIST)
(until June 2002)	Mr. Tadatoshi Sugiura	JQA Organization
(from August 2002)	Mr. Kazuo Hasegawa	Japan Electrical Safety & Environment Technology Laboratories (JET)
Switzerland	Mr. Luzi Clavadetscher Mr. Thomas Nordmann	TNC Consulting AG TNC Consulting AG

TABLE 2 - MEETING SCHEDULE (2002 AND PLANNED 2003)

TASK 2 MEETING	DATE	PLACE
6th Task 2 Participants` Meeting	21-23 March, 2002	Naples, Italy
7th Task 2 Participants` Meeting	11-14 September, 2002	Vienna, Austria
8th Task 2 Participants` Meeting	19-21 March, 2003	Sophia-Antipolis, France
9th Task 2 Participants` Meeting	17-19 September, 2002	Berlin, Germany

TASK 3 - USE OF PHOTOVOLTAIC POWER SYSTEMS IN STAND-ALONE AND ISLAND APPLICATIONS

OVERALL OBJECTIVE

The main objective of Task 3 is to improve the technical quality and cost-effectiveness of PV systems in stand-alone and island applications. This work considers all types of stand-alone photovoltaic systems, ranging from small PV kits to power stations supplying micro-grids.

The objective of the current Task 3 programme is **to contribute to the cost reduction of systems** through collaborative activities focused on **technical issues**, divided into the following two main categories:

1. Subtask 1: Quality assurance: quality assurance schemes for improved reliability and lower global life cycle costs.
2. Subtask 2: Technical issues: technical recommendations for the cost reduction of systems.

The main targets are **technical groups** such as:

- Project developers
- System designers
- Industrial manufacturers
- Installers
- Utilities
- QA organisations
- End users

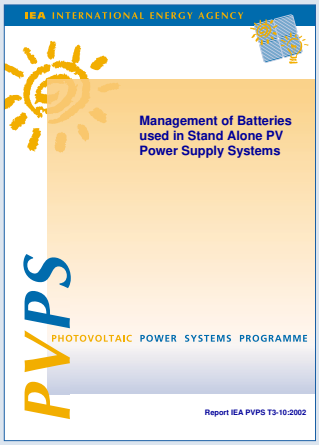
The method of work consists of a practical approach through identification, selection, and observation of case studies. After the analysis of the collected data, a collaborative work programme will be developed to make recommendations. In relation to the large range of stand-alone PV applications, it is necessary to take into account systems operating in industrialised and southern countries.

SUBTASK 1: Quality Assurance

Activity 11: Critical Review of Implementation of Quality Assurance Schemes

Objective

All phases in the life cycle of stand-alone PV systems must be considered as potential sources of failure to ensure the good management of the quality of installed systems. To provide both end-users and programme managers with guidance for the quality assurance of systems, projects and programmes, participants share their experience on **methodological and practical aspects** concerning quality assurance.
For this topic, participants aim to develop **quality assurance schemes** that will lead to a **warranty of service** for the end user at reasonable costs (that means as low as possible).



Report IEA PVPS, Management of Batteries

Major Activities in 2002

The results of the survey undertaken in 2000 form the basis for a document which is available on the Task 3 website. Following this action, Task 3 participants completed this first basis on current guidelines as developed in their respective countries.

Activity 12 : Technical Aspects of Performance Assessment on Field

Objective

Implementation of Quality Assurance procedures is often difficult in the field, particularly when the procedures are too complicated or otherwise inappropriate. This is especially the case when considering the installation, operation and maintenance phases.
In addition, the performance assessment of installed stand-alone PV systems depends on both technical and non technical criteria, such as economic and social criteria.
Even when methodological and conceptual aspects of the performance assessment have been implemented, realistic methods and concrete supports must be recommended for use in the field and laboratory.

Major Activities in 2002 and Foreseen Activities in 2003

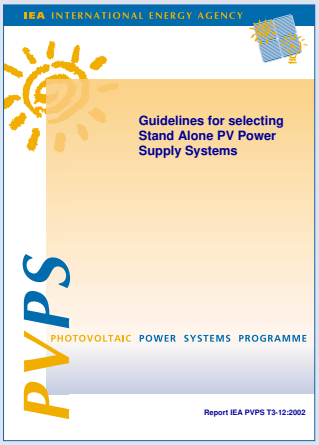
The aim is to provide new project managers with realistic and efficient recommendations, based on Task 3 experience, concerning management of the quality of SAPV systems. The main objective is to make potential actors aware that there is more attention to give to the management of the quality of a system than simply to manage a good design ; a lot of effort must be implemented in each step of a project.
A final document **"Management of the Quality in SAPV Systems"** including a collection of quality management data as observed in the field was prepared in 2002 and will be published in 2003.
In this report are introduced real practices and both success and failure stories, collected through feed back from case studies.

SUBTASK 2: Technical Issues

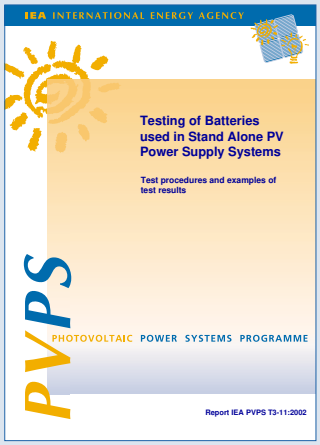
Activity 21: Hybrid Systems

Objective

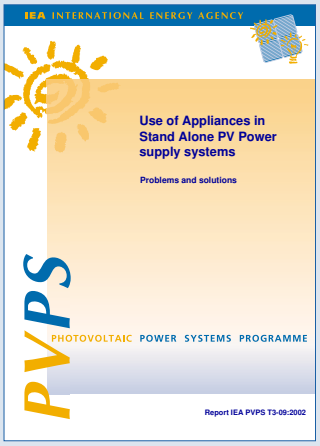
This subtask aims to be a technical contribution to cost reduction through standardisation and modularity in order to facilitate large scale dissemination of PV Hybrid systems.



Report IEA PVPS, Selecting Systems



Report IEA PVPS, Testing of Batteries



Report IEA PVPS, Use of Appliances

Major Activities in 2002

Guidelines were prepared to assist people with a limited background in this industry to navigate through the mine field of market hype and misinformation to determine for themselves, a system configuration that approximates their specific needs. The choice of a system to service specific needs is complicated. In the first place, no two applications are identical while in the second there is a large range of available system architectures from which to choose. When the lack of broad community experience with the relevant technologies, and the immature nature of the supporting industry to the situation are added, the need for a simple set of Guidelines to help prospective users to choose or identify the technologies that might be appropriate for their situation becomes obvious.

The final result is the **Report IEA PVPS T3-12: 2002 "Guidelines for selecting SAPV Systems."** Its objective is to provide a facility that assists prospective users of PV, to identify the system configuration that reflects the best commercial practice for their application.

On the other hand, to address the current work plan, Task 3 needed to be able to analyse the performance of case studies to determine what comprises a successful, or conversely, an unsuccessful installation. This requires a monitoring process conducive to equitable comparison of system performance. In this way, the activity of experts was to prepare proposals for performance indicators of SAPV systems and monitoring guidelines, setting out how to equitably monitor system performance for a range of SAPV system.

The current work is to produce **"Guidelines for performance assessment of SAPV systems."** The objectives of this cooperative work are:

- To prescribe a process that, if followed, will reassure investors, project managers, performance auditors, equipment manufacturers, and servicing firms, that the performance data they use are robust, equitable and representative;
- Underpin a case study record that provides prospective PV users with relevant, comparative information about PV technology and its applications;
- In conjunction with the above, establish a more qualitative set of performance indicators that will enable the layperson to shortcut the scientific approach to performance assessment.

Deliverables Under Preparation

Another technical report entitled **"Guidelines for Monitoring Equipment and Protocols for SAPV Systems,"** is under preparation and will be published in 2003.

Activity 22: Storage

Objective

This subtask aims to be a technical contribution to cost reduction of the storage function in PV and PV Hybrid systems by decreasing investment costs and increasing performance (capacity, lifetime,...) through design, selection procedures of storage systems, and energy management recommendations.

One of the main objectives of this activity is to show that there should be a correlation between the type of batteries and the type of application and to recommend, in a situation of call for tender, how to specify the best battery for a given application.

Major Activities in 2002

A technical work programme was undertaken concerning test of batteries to be used in SAPV systems. The main objectives are to:

- Provide project managers of photovoltaic applications with data to assist in battery selection and to help professionals involved in the design of PV systems;
- Focus the activities of laboratories involved in the design of PV systems;
- Make more battery test data available.

The Final result is the **Report IEA PVPS T3-11: 2002 "Testing of Batteries used in SAPV Systems".**

The objective of another activity is to gather information of possible alternatives to lead-acid batteries for short, middle and long term storage (main performance, field of applications, estimated costs). Some Task 3 participants are involved in a European project whose aim is to build a state of the art from the existing and innovative technologies in the context of renewable energies.

Deliverables Under Preparation

Collaborative work was developed to assess various strategies regulation. A document untitled **"Management of batteries used in SAPV systems"** will be published in 2003 . The purpose is first to describe the main characteristics and possibilities of the most frequently used type of battery management. Then, the innovative character of the document is the presentation of new management methods that are intended to offer a better and more precise management.

Activity 23: Load/Appliances: Load Management and New Applications

Objective

This subtask aims to be a technical contribution to cost reduction by showing the cost efficiency of a "good" load management strategy and well adapted appliances designed for low energy power systems. This subtask is an integrating issue which calls for inputs from the other technical issues (2.1 and 2.2) but also from economic and possibly social analysis coming from Task 9, in order to be able to install a PV system that is not only technically good but also credible and well accepted by the end user.
The goal is also to propose design recommendations for very dedicated applications of PV systems.

Major Activities in 2002

A survey of main recurrent technical difficulties with DC and AC appliances as seen in the field was achieved. The final result is the **Report IEA PVPS T3-09: 2002 "Use of Appliances in SAPV Systems: Problems and Solutions."**
This survey considers some of the poor compliances of the technical characteristics of DC and AC appliances with the power and energy management design of a stand-alone PV system. The cooperative work is to share experience by collecting many examples (of difficulties experienced and adopted solutions) as really seen in the field, that could be used as a reference by designers, installers and operators to prevent problems on existing or future systems.

Another activity has been continued relative to the Demand Side Management (DSM). DSM for Renewable Energy Systems involves the change of consumers energy use habits not only by using high efficiency appliances, decreasing the peak of the load curve, but also by using energy in a way that the load is well matched with the renewable source. This is different from classic DSM methodologies where the objective is essentially to have more or less a flat load curve by smoothing daily peaks and valleys of shifting energy-use to off-peak hours.

Deliverable under Preparation

A technical report relative to **"Demand Side Management in SAPV Systems"** will be ready in 2003. The goal is to propose a relevant methodology for SAPV systems to implement DSM.

OTHER ACTIVITIES

Other Activities in 2002

- Update of Task 3 website: "www.task3.pvps.iea.org";
- In collaboration with the NEDO, participation in a Workshop held in Kyoto, September 2002: "Activity and prospect of the Stand Alone PV generation systems";
- Participation in the "XI Congresso Ibérico e VI Congresso Ibero-Americano de Energia Solar", September 2002, Portugal.

Foreseen Activities in 2003

- Task 3 Workshop for Dissemination of Results of the Present Programme, March 2003, Switzerland;
- Participation to the ISES Solar World Congress, June 2003, Sweden;
- Contribution to a Workshop on Hybrid Systems, September 2003, Germany.

MEETING SCHEDULE

Meetings Held in 2002

- 20th Task 3 Experts Meeting, March 2002, Spain.
- 21th Task 3 Experts Meeting, September 2002, Japan.

Meetings Planned in 2003

- 22th Task 3 Experts Meeting, March 2003, Switzerland.
- 23th Task 3 Experts Meeting, September 2003, Germany.

PUBLICATIONS

Reports 2002:

- Report IEA PVPS T3-09: 2002: Use of appliances in SAPV systems: problems and solutions.
- Report IEA PVPS T3-10: 2002: Management of batteries used in SAPV systems.
- Report IEA PVPS T3-11: 2002: Testing of batteries used in SAPV systems.
- Report IEA PVPS T3-12: 2002: Guidelines for selecting SAPV systems.

Reports to be published in 2003

The following reports will be submitted to the Executive Committee:

- Report IEA PVPS T3-13: 2003: Guidelines for performance assessment of SAPV systems.
- Report IEA PVPS T3-14: 2003: Guidelines for monitoring equipment and protocols for SAPV systems.
- Report IEA PVPS T3-15: 2003: Management of the quality in SAPV systems.

PARTICIPATING COUNTRIES AND PARTICIPANTS

COUNTRY	NAME	ORGANISATION
Australia	Keith Presnell	Centre for Energy Research NT
Canada	Dave Turcotte	CANMET
France	Philippe Malbranche	GENEC
	Philippe Jacquin (OA)	PHK Consultants
Germany	Ingo Stadler	IEE-RE
Italy	Francesco Minissale	Conphoebus
Japan	Noboru Yumoto	YN International
Norway	Arve Holt	IFE
Portugal	Antonio Joyce	INETI
Sweden	Peter Krohn	Vattenfall Utveckling AB
Switzerland	Michel Villoz	Dynatex SA
United Kingdom	Alison Wilshaw	IT Power Ltd

TASK 5: GRID INTERCONNECTION OF BUILDING INTEGRATED AND OTHER DISPERSED PHOTOVOLTAIC POWER SYSTEMS

OVERALL OBJECTIVE

The objective of Task 5 was to develop and verify technical requirements, which served as the technical guidelines for grid interconnection with building-integrated and other dispersed PV systems. The development of these technical requirements included safety and reliable linkage to the electric grid at the lowest possible cost. The systems to be considered were those connected with a low-voltage grid, which were typically of a size between one and fifty peak kilowatts.

MEANS

Participants carried out five subtasks; Subtasks 10, 20, 30, 40 and 50 in order to achieve these objectives. The objectives of each subtask were as follows:

Subtask 10: Review of Previously Installed PV Experiences (From 1993 to 1998).
To review existing technical guidelines, local regulations and operational results of grid interconnection with building- integrated and other dispersed PV systems to aid Subtask 20 in defining existing guidelines and producing concepts for new requirements and devices.

Subtask 20: Definition of Guidelines to be Demonstrated (From 1993 to 1998).
Utilizing the results of Subtask 10 and a questionnaire, existing technical guidelines and requirements to be demonstrated will be defined, and concepts for new requirements and devices will be developed; with safety, reliability, and cost reduction taken into consideration.

Subtask 30: Demonstration Test Using Rokko Island and/or Other Test Facilities (From 1993 to 1998)
To evaluate, by demonstration tests, the performance of existing and new technical requirements and devices defined in Subtask 20.

Subtask 40: Summarizing Results (From 1993 to 2001).
To summarize the results of Task 5 and to produce a general report for all participating countries of Task 5, as well as for the ExCo members.

Subtask 50: Study on Highly Concentrated Penetration of Grid Interconnected PV Systems (From 1999 to 2001).
To assess the net impact of highly concentrated PV systems on electricity distribution systems and to establish recommendations for both distribution and PV inverter systems in order to enable widespread deployment of solar energy.

OVERVIEW OF PAST ACTIVITIES

Subtask 10

Surveys of the existing guidelines and regulations for grid connection of PV systems and the difference of electrical distribution systems in Task 5 participating countries were completed as a Task 5 internal report open to IEA member countries. The report on inverter and related protection equipment was distributed to Task 5 participants as an internal Task working document. The summary of PV operating experiences of participating countries was included in the Task 5 summary report.

Subtask 20

Research results on subjects important for the interconnection of PV systems were summarized as an official IEA report. The following topics are covered in the report:

- Harmonics
- AC-Module
- Multiple Inventers and AC Grid
- Grounding of Equipment in PV Systems
- Ground-fault Detection and Array Disable for PV Systems
- Overvoltage Protection
- Electro Magnetic Compatibility
- External Disconnect
- Reclosing
- DC Injection and Isolation Transformer

Subtask 30

Demonstration tests for harmonics, islanding, PV output variation etc. were conducted using the Rokko Test Facility in Japan. The Subtask 30 Report, summarizing demonstration test results by using the Rokko Test Facility, was completed and published as an official IEA-PVPS report. Contents of the report include: harmonics caused by PV inverters, measurement of islanding, distribution line short circuit fault, AC/DC mixing fault, the effect of a PV system's output fluctuation and other topics.

Subtask 40

The Summary Report of Task 5 Activities from 1993 to 1998 was produced as official IEA-PVPS report. Status reports and other management reports for the Executive Committee were also prepared in this subtask.

Subtask 50

Surveys for the latest PV system grid interconnection technologies were conducted and reported. These surveys included PV system grid-interconnection and design guidelines or national standards, updated information of inverters and interconnection devices and PV system testing certification and utility inspection and maintenance methods.

Research on islanding related problems has been conducted in highly penetrated PV systems conditions. The probability of load and PV system output matching was determined using real measurement and the risk of islanding was defined. Islanding detection methods and test circuits for islanding detection performance were summarized and reported.

Important factors to decide on the limit of PV system penetration in distribution networks were listed and analysis based on distribution line voltage limit was conducted. Measures to stretch the limit of

PV penetration and some financial aspects of PV penetration were also discussed.
The power value and capacity value of PV system penetration were evaluated using different customer load profiles.

OVERVIEW OF 2002 ACTIVITIES

The main activities of Task 5 were completed with the Final Task Meeting and two-day Workshop held in Arnhem, The Netherlands, in January 2002. In the workshop, Task 5 findings for the Subtask 50 activities including islanding detection methods, probability of islanding and risk analysis for islanding were presented and discussed on the first day. On the second day, PV related guidelines and standards, inverter technology, the impact of PV penetration and the value of PV were presented and discussed.

After the workshop, Task 5 participants carried out the preparation of PVPS Task 5 reports.

SUMMARY OF TASK 5 - SUBTASK 50 CONCLUSIONS

The main outcomes of Subtask 50 activities are described below.

Activity 51

1. Revised Survey for the Grid-Interconnection Guidelines or Standards

The main conclusion of this survey is that many countries recognized that it is required to have the PV specific or inverter interfacing specific standard for grid-interconnection of PV systems apart from the standard for ordinary rotating generators grid-interconnection standards. Requirements for the safe and reliable grid-interconnection of PV systems are the common issues for the standards, although there are differences in the approach because of the difference of technical boundary conditions (layout of grid, grounding philosophy etc.) in different countries. Therefore, even if it will be difficult to achieve full harmonization of international standards, it seems possible to reach a consensus in at least 90 % of all topics.

2. Revised Survey for the Inverter Technologies and Related Control and Protection Interfacing Technologies

The technology for inverter circuits fell into almost the same configuration and controlling concept within the different manufacturers. Improvement of performance was observed with higher conversion efficiency, lower harmonic current injection, higher power factor operation etc. Moreover, reduction of cost, volume and weight of inverters have been achieved, when compared with the survey of three years ago. Sufficient control of power and protection from grid fault has been achieved by using software-based operations that allow low cost control and the protection of the inverter. Finally, the difference between countries and manufacturers became smaller.

3. Recommendations for the Certification Tests for Safe and Reliable Installation of Grid-Interconnected PV Systems

Recommended test items for manufacture product certifications, laboratory type tests, utility onsite initial starting tests and periodic inspections were listed with the objective of the tests, testing procedures, notes and criteria for each test. Examples of testing circuits were also listed. These results will serve as a good reference for the certification of PV systems and will be useful for manufacturers, utilities, testing laboratories and standard making bodies.

Activity 52

1. Probability of Islanding by PV System Penetration in Practical Distribution Systems

By actual measurement of the distribution line load variation and the PV output variation, the probability of load matching or occurrence of islanding was estimated. It was found that load matching never occurs when the total capacity of PV systems are under the minimum load of distribution system during daytime, corresponding to around 400 Wp PV system installation per every house. Large scale penetration of a PV system causes the possibility of load matching and the chance is highest when PV systems are installed around 900 Wp per every house. However, the actual probability is very small, even when the large margin of load mismatch was considered. The probability of load matching for more than 1 second is less than 1,0E-5/sec and load matching for more than 5 seconds is less than 1,0E-6/sec; this corresponds to 130 and 13 times per year. Load matching greater than 10 seconds will occur very seldom. Considering that the probability of loss of main (LOM) is about 6,3E-8/sec (twice per year), the probability of islanding is far more reduced to 8,3E-6/year. As a conclusion, islanding is no issue for the probability base.

2. Risks Associated with Islanding

The final risk associated with islanding was calculated by considering the protection failure caused by operator failure, inverter protection failure, insufficient installation etc. As a result, it was found that the risk of electric shock associated with islanding is far less than the risk that already exists for network operators and customers. The additional risk presented by islanding does not materially increase the existing risk, as long as the risk is managed properly.

3. Islanding Detection Methods

Various types of islanding detection methods were summarized; including voltage and frequency detection, passive methods (frequency change rate, voltage phase jump and voltage harmonic change etc.) and active methods (impedance measurement, frequency shift etc.). The theory of operation, strengths and weakness and more importantly, the non-detection zone (NDZ) of each method were described. The non-detection zone means the condition in which the detection system cannot detect islanding because of the sensitivity and the theory of operation. The non-detection zone decides the allowable load mismatch for islanding operation and the effect on the probability of islanding. Testing circuit configurations and the procedures of testing were also recommended.

TASK 5 PARTICIPANTS

COUNTRY	PARTICIPANT	ORGANIZATION
Australia	Phil GATES	Energy Autralia
Austria	Gerd SCHAUER	Verbundgesellschaft
	Christoph PANHUBER	Fronius KG Austria
Denmark	Arne Faaborg POVLSEN	Elsamprojekt A/S
Germany	Hermann LAUKAMP	FhG-ISE
Italy	Francesco GROPPI	Enel S.p.A.
Japan	(Task V OA) Tadashi KANBAYASHI	NEDO
	(Task V Chairman) Tadao ISHIKAWA	CRIEPI
Mexico	Oscar E. AERTEAGA	Electrical Research Institute
The Netherlands	Bas VERHOEVEN	KEMA
Portugal	Pedro SASSETTI-PAES	EDP
Switzerland	Sergio TAIANA	EWZ
United Kingdom	Alan COLLINSON	EA Technology Ltd.
United States	Ward BOWER	Sandia National Labs.

Activity 53, 54

1. Maximum Penetration Capacity of PV Systems in Distribution Networks

The maximum penetration capacity of PV systems in distribution networks were evaluated by considering the distribution line voltage criteria. Allowable penetration capacity depends on the load profile of the distribution system, especially by the minimum load during daytime. At the minimum load condition, no PV penetration is expected in the most severe case. However, only a slight increase of load allows for a significant increase of PV penetration.

2. The Value of PV Systems

The value of PV systems was evaluated by the flattening effect of the load curve and the reduction of joule loss of distribution lines. It was found that the value of PV systems is greatly dependant on the load profile of distribution line in which PV systems are interconnected. The load profile for an urban area, which has peak consumption in the daytime, for example, an office building, has the advantage of PV penetration; while the load profile for a residential area has little advantage of PV penetration.

In conclusion, IEA PVPS Task 5 has performed important studies on topics related to grid interconnected PV systems. The reports published by Task 5 will serve as valuable information dissemination tools for utility people, PV industries, standard making bodies and customers. These reports will aid in them in understanding the problems and finding solutions for grid interconnection of PV systems. One example is that the grid interconnection guideline or standard of participating countries has been improved to distinguish the PV systems or inverter interface generation systems from rotating generators since the difference of protection requirements has been learned. Although there are differences of grid conditions by countries, requirements for the protection of grid connection for PV systems fall into almost the same concept. One of the most important points that Task 5 showed was that the probability of islanding is very small and costly protection systems for preventing islanding are not needed any more.

At the end of Task 5, the need for wider research in grid connection issues including all kinds of distributed generation systems in one distribution network was recognized. Similar to the way PV systems can be influenced by the presence of other types of generators, future distribution systems are expected to encounter analogue situations. While the international collaboration within Task 5 has contributed strongly to the understanding of such situations for PV power systems, in the future, such issues are best dealt with as a cross-cutting issue for international cooperation between different energy technologies.

INDUSTRY INVOLVEMENT

Activities of Task 5 were conducted in the cooperation with well-balanced members from utilities or electric industries groups, national research groups, PV specialists and inverter manufacturers groups.

REPORTS PRODUCED IN 2001

The following reports were published in 2002. These reports can be downloaded from the PVPS web site (http://www.iea-pvps.org/):

- Report IEA PVPS T5-06: 2002; "International Guideline for the Certification of PV System Components and Grid-Connected PV Systems".
- Report IEA PVPS T5-07: 2002; "Probability of Islanding in Utility Networks Due to Grid Connected PV Power Systems".
- Report IEA PVPS T5-08: 2002; "Risk Analysis of Islanding of PV Power Systems Within Low Voltage Distribution Networks".
- Report IEA PVPS T5-09: 2002; "Evaluation of Islanding Detection Methods for PV Utility Interactive Power Systems".
- Report IEA PVPS T5-10: 2002; "Impacts of Power Penetration from PV into a Power System".
- Report IEA PVPS T5-11: 2002; "Power Value and Capacity Value of PV Systems".

MEETING SCHEDULE

Past Meetings(1/2002-12/2003)

17th Expert Meeting (Final Task Meeting) was held on 21-23 January 2002 in The Netherlands (with a workshop on 24- 25 January 2002)

IEA PVPS TASK 7 - PHOTOVOLTAIC POWER SYSTEMS IN THE BUILT ENVIRONMENT

1. OVERALL OBJECTIVES

The objective of Task 7 was to enhance the architectural quality, the technical quality and the economic viability of PV systems in the built environment. The objective is also to assess and remove non-technical barriers for their introduction as an energy-significant option.

It is expected that successful integration of PV systems into the built environment (BIPV) will contribute significantly to the future spread of PV.

For this, active involvement of urban planners, architects and building engineers is required. Task 7 motivates the collaboration between these groups and PV system specialists, utility specialists, PV and building industry and other professionals involved in photovoltaics. Task 7 considers all grid connected systems other than classified as "ground based arrays". Primary focus of this Task is on the integration of PV into the architectural design of roofs and facades of residential, commercial and industrial buildings and other structures in the built environment (such as noise barriers, parking areas and railway canopies), and on other market factors, both technical and non-technical, that need to be addressed and resolved before wide spread adoption of PV in the built environment will occur.
Task 7 officially started on January 1, 1997 and finished end 2001. In 2002 the last reports and deliverables were published. At the end of 2002 there remains only one outstanding issue: the publication of the book "Designing with Solar Power". This book is expected in spring 2003.

SUBTASK 1: ARCHITECTURAL DESIGN OF PHOTOVOLTAIC POWER SYSTEMS IN THE BUILT ENVIRONMENT

1.1 Objective

Participants worked on the improvement of the architectural design of PV systems as an integral element in buildings and other structures in the built environment. For this purpose, existing PV projects were documented. In addition, case studies were followed and evaluated by the Task Participants. Many of these case studies were realised as demonstration projects.

A selection of outstanding examples (both from existing projects as well as from the case studies) will be published as a book.
As a sideline, design tools for architects were also developed.

1.2 Activities

1.1 Documentation of high quality projects
1.2 Case studies
1.3 Book of examples
1.4 Design tools

1.3 Conclusive results for 2002

- Database of over 400 PV projects www.pvdatabase.com (act. 1.1)
- Seven criteria to assess the architectural quality of BIPV systems (act. 1.1)
- Case studies: intenal report, book available in Italian (act. 1.2)
- High Quality book "Designing with Solar Power" (250 p. on BIPV architecture) (act. 1.3)
- PVSyst 3.0 design tool to design and evaluate PV systems (act. 1.4) - "www.pvsyst.com"
- Allsol design tool to design the overall solar energy system of a building (act. 1.4)

SUBTASK 2: SYSTEMS TECHNOLOGIES FOR PHOTOVOLTAIC POWER SYSTEMS IN THE BUILT ENVIRONMENT

2.1 Objectives

Participants worked on the development of new concepts for Photovoltaic Power Systems in the built environment that can enhance the electrical performance or the performance of the PV system as a building component. New concepts, developed by the Participants shall enhance market opportunities for the industry. This Subtask aims for a number of standardised and certified PV elements for integration in buildings and other structures in the built environment. The Subtask will also provide a number of options to effectively utilise PV electricity and to connect PV systems safely and reliably to the electricity grid, as far as this topic is not addressed by Task 5 of the PVPS Implementing Agreement.

2.2 Activities

2.1 Commercial buildings
2.2 Residential buildings
2.3 Non-building structures
2.4 Guidelines and certification
2.5 PV/T (PV and thermal systems)
2.6 New electrical concepts
2.7 Reliability
2.8 Interconnection issues
2.9 Electrical design issues

2.3 Conclusive results for 2002

- Database of over 100 PV products: "www.pvdatabase.com" (act. 2.1/2.2)
- Workshop BIPV Integration Concepts, 11/12 February 1999, Switzerland, Lausanne (act. 2.1/2.2)
- Workshop on PV Design, 9 May 2001, The Netherlands, Amsterdam Sustain 2001 (act. 2.1/2.2)
- IEA Joint Working Group on new PV/T system technology (act. 2.5)
- Photovoltaic Building Integration Concepts; Product Review & Proceedings of IEA PVPS Task 7 Workshop (act. 2.1/2.2)
- PV in Non Building Structures - design issues (act. 2.3)
- PV/T report, inventory & road map (act. 2.5)
- New electric concepts (act. 2.6)
- Reliability (act. 2.7)

Integration concepts from the training and education package for architects. (photo M. ART/ECN)

SUBTASK 3: NON-TECHNICAL BARRIERS IN THE INTRODUCTION OF PHOTOVOLTAIC POWER SYSTEMS IN THE BUILT ENVIRONMENT

3.1 Objectives

Participants assessed the non-technical barriers to be removed to make PV in the built environment an energy-significant power supply option. The purpose of this Subtask was to identify the barriers on one side and the (technical, economic, market) potential of PV in the built environment on the other. The main result of this Subtask will be an executive IEA report on strategies for barrier removal and utilisation of the PV potential.

3.2 Activities

3.1 Barrier assessment
3.2 Potential
3.3 Economics
3.4 Strategies

3.3 Conclusive Results for 2002

- Literature survey and analysis of non-technical problems for the introduction of building integrated photovoltaic systems (act. 3.1)
- Potential for building integrated photovoltaics (act. 3.2)
- Guidelines for Economic Evaluation of building integrated PV power systems (act. 3.3)
- Market Deployment Strategies for PV systems in the built environment (act. 3.4)
- Institutional Issues: Non technical barriers to the commercialisation of PV power systems in the built environment (task 3)

SUBTASK 4: DEMONSTRATION AND DISSEMINATION OF PHOTOVOLTAIC POWER SYSTEMS IN THE BUILT ENVIRONMENT

4.1 Objectives

The results of the other Subtasks were brought to the market by dissemination of collected information and the demonstration of new concepts. Demonstration of mounting and system concepts takes place through the EPFL Demosite. Results are disseminated by the use of different media (ranging from papers, books, and brochures to new media such as a CD-ROM or a WWW-site). Dissemination will also occur through the second and third International Solar Electric Buildings Conferences and national workshops in conjunction with the semi-annual meetings of the Task. Furthermore, the possibility of a training and education program was assessed and resulted in a CD-ROM.

4.2 Activities

4.1 Demosite
4.2 Conference
4.3 Competition
4.4 Dissemination
4.5 Training and education

4.3 Conclusive Results for 2002

- Demosite in CH with real-life PV projects, also shown at "www.demosite.ch" (act. 4.1)
- 2nd International Solar Electric Building Conference, 8-10 March 2000, Australia, Sydney (act. 4.2)
- Task 7/Task 10 Workshop on the PV in Europe Conference, 7-11 October 2002, Rome, Italy (act. 4.2))
- Task 7 Session on Italian Solar Architecture and Urban Planning Conference - 700 attendants (act. 4.2)
- PV design competition (act. 4.3)
- Internet -site "www.task7.org" (act. 4.4)
- Slide series (act. 4.4)
- Various presentations on (inter)national conferences (act. 4.4)
- Training & Education package on CD ROM (act. 4.5)

5. DELIVERABLES - WHERE TO GET THEM?

All reports are available for download at IEA PVPS website: "www.iea-pvps.org".
In addition, all reports and many other deliverables are summarized on CD-ROM, which can be ordered at Novem, The Netherlands.

Task 7, Project Results and Documents

To be ordered at:
Novem, Publication Centre
PO Box 8242
3503 RE Utrecht
The Netherlands
Tel.: 31 30 2393493
Email: publicatiecentrum@novem.nl

Furthermore, each of the following reports can be ordered at the addresses as shown:

IEA PVPS T7 – 1999 to 2002: report no.

1. Literature Survey and Analysis of Non-technical Problems for the Introduction of BIPV Systems, B. van Mierlo & B. Oudshoff, IVAM Environmental Research, 1999. To be ordered at IVAM Environmental Research, NL, Fax: 31 20 52 55 850

2. PV in Non Building Structures – A Design Guide, M.A. Romero, EcoCode-Miljö och Architectur, 1999. To be ordered at Energiebanken, SE, Fax: 466 52 13 427

Fig. 1 - Over 500 architects and students were present on the Italian Solar Electricity and Urban Planning Conference. This was an excellent opportunity to disseminate Task 7 results. (photo Michiel van Schalkwijk)

3. Photovoltaic Building Integration Concepts; Product Review & Proceedings of IEA PVPS Task 7 Workshop, P. Ruyssevelt, et al., Halcrow, 2000. To be ordered at Halcrow, UK, Fax: 44 17 938 15 020

4. Potential for Building Integrated Photovoltaics, M. Gutschner, Nowak Energy Technologies AG, 2001. To be ordered at NET, CH, Fax: 41 26 49 40 034

5. Guidelines for the Economic Evaluation of Building Integrated Photovoltaics, P. Eiffert, National Renewable Energy Laboratories, 2002. To be ordered at NREL, USA, website: "www.nrel.gov/buildings/highperformance".

6. Market Deployement Strategies for Photovoltaics in the Built Environment, R. Haas, Technische Universität Wien, 2002. To be ordered at Technische Universität Wien, AT, Fax : 43 15 88 01 37 397

7. Innovative Electric Concepts, H. Wilk, Energie AG, 2002. To be ordered at Energie AG, AT, Fax: 43 73 29 00 03 309

8. Reliability of Photovoltaic Systems, H. Laukamp, Fraunhofer Institute für Solar Energiesysteme, 2002. To be ordered at Fraunhofer Institute für Solar Energiesysteme, GE, Fax: 49 761 45 88 217

9. Lessons Learned on Building Integrated PV: Case Studies & Electrical Design Issues, C. Abbate Officine di Architettura di Cinzia Abbate & P. Drewes, Sol Source Engineering, 2002. To be ordered at Abbate Officine di Architettura di Cinzia Abbate, IT, Fax: 39 066 97 83 038

Italian publication:
"L'integrazione architettonica del fotovoltaico:esperienze compiute" a cura di Cinzia Abbate

Can be ordered through:
Gangemi Editore
Piazza San Pantaleo 4
00186 Rome Italy
or "www.gangemieditore.it"

10. PV/Thermal Solar Energy Systems, Status of the Technology and Roadmap for Future Development, H. Sorensen, Esbensen Consulting, 2002, To be ordered at Esbensen Consulting Engineers, DK, Fax: 45 332 67 301

11. Executive Summary Report – Non-technical Barriers to the Commercialisation of Photovoltaic Power in the Built Environment, P. Eiffert, National Renewable Energy Laboratories, to be ordered at NREL, USA, website: "www.nrel.gov/buildings/highperformance"

12. Training & Education CD - ROM, H.Kaan, Energy Centrum Nederland, 2002. To be ordered at:

    Novem, Publication Centre
    PO Box 8242
    3503 RE Utrecht
    The Netherlands
    Tel.: 31 302 39 34 93
    Email: publicatiecentrum@novem.nl.

13. Designing with Solar Power – A Source Book for Building Integrated PV, D. Prasad & M. Snow, University of New South Wales, Australia, 2002. To be ordered at: The Image Publishing Group Pty Ltd, Austrialia, Fax: 61 39 56 14 860.

6. PARTICIPANTS

In total, 14 countries participated in Task 7, with representatives from all targeted groups: architects, building and PV industry, PV and building specialists and utilities. A list of participants is shown in the table on the following page.

7. TASK MEETINGS IN 2002

Workshop at the PV in Europe Conference
October 7, 2002
Rome, Italy

8 CONTACT INFORMATION

Operating Agent ad interim:

M. van Schalkwijk
Ecofys, Utrecht, the Netherlands
E-mail: M.vanSchalkwijk@ecofys.nl

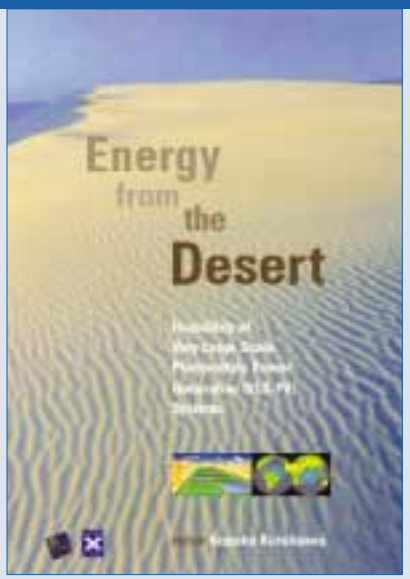
Websites:

Task 7 deliverables: www.iea-pvps.org
Task 7 website: www.task7.org
Task 7 demosite: www.demosite.ch
PV Projects database: www.pvdatabase.com

TABLE: LIST OF TASK 7 PARTICIPANTS

COUNTRY	PARTICIPANT	ORGANIZATION
Australia	Deo Prasad Mark Snow	National Solar Architecture Research Unit National Solar Architecture Research Unit
Austria	Reinhard Haas Karin Stieldorf Heinrich Wilk	Technische Universität Wien Inst. für Hochbau für Architekten Energie AG Oberösterreich
Canada	Per Drewes Raymond Cole	Sol Source Engineering University of British Columbia
Denmark	Kaj Isaksen Henrik Sörensen	VELUX Esbensen Consulting Engineers
Finland	Peter Lund	Helsinki University of Technology
Germany	Ingo Hagemann Hermann Laukamp	Architekturbüro HAGEMANN Fraunhofer-Institut für Solare Energiesysteme
Great Britain	Rod Hacker David Lloyd Jones Donna Munro Paul Ruyssevelt	Halcrow Gilbert Associates Studio E Architects Energy for Sustainable Development Energy for Sustainable Development
Italy	Cinzia Abbate Niccolo Aste Valerio Calderaro Angelo Sarno	Officine di Architettura di Cinzia Abbate Politecnico di Milano University of Rome/Fac. Arch. ENEA
Japan	Ito Tadashi Shogo Nishikawa Jiro Ohno Hideji Osawa	Kajima Corporation Kandenko Co., Ltd. Nihon Sekkei Inc. NEDO
Spain	Nuria Martín Chivelet	Ciemat-IER
Sweden	Mats Andersson	Energibanken
Switzerland	Christian Roecker Daniel Ruoss Peter Toggweiler	EPFL -LESO-PB ENECOLO ENECOLO
The Netherlands	Henk Kaan Tjerk Reijenga Frederik Leenders Tony Schoen Michiel van Schalkwijk	Energieonderzoek Centrum Nederland BEAR architecten Ecofys Ecofys (until 2002) Ecofys (starting 2002)
USA	Patrina Eiffert Steven Strong	National Renewable Energy Laboratory Solar Design Associates Inc.

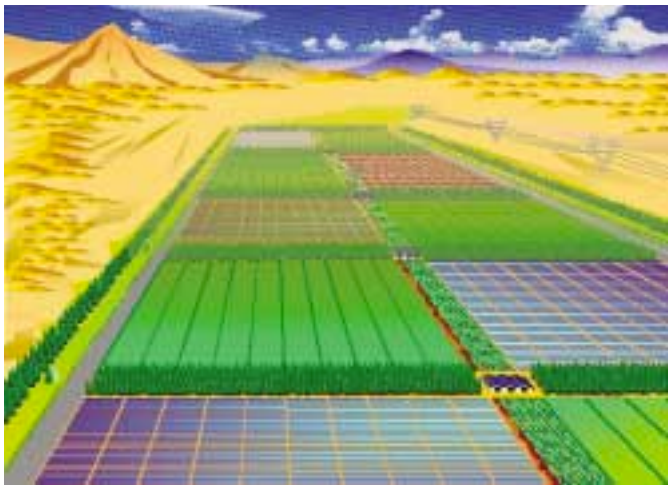
TASK 8 - STUDY ON VERY LARGE SCALE PHOTOVOLTAIC POWER GENERATION SYSTEM



Task 8 Technical Report (published by James and James)

OVERALL OBJECTIVES

The objective of Task VIII is to examine and evaluate the potential of Very Large Scale Photovoltaic Power Generation (VLS-PV) Systems, which have a capacity ranging from multi-megawatt to gigawatt, by identifying the key factors that enable VLS-PV system feasibility and clarifying the benefits of this system's application to neighbouring regions. The potential contribution of system application to protection of the global environment and renewable energy utilization in the long term also will be clarified. Mid- and long-term scenario options for making VLS-PV systems feasible in certain areas will be proposed.



MEANS

To complete the overall objectives, participants carry out three Subtasks in series:

Subtask 1: Conceptual Study of the VLS-PV System
Subtask 2: Case Studies for Selected Regions for Installation of VLS-PV System
Subtask 3: Comprehensive Evaluation of the Feasibility of VLS-PV System

SUBTASK 1: CONCEPTUAL STUDY OF THE VLS-PV SYSTEM

Objective

The conceptual configuration of VLS-PV systems is developed from the viewpoint of technological/economical feasibility and the life cycle of the systems. The criteria for selecting regions for case studies of the installation of VLS-PV systems are also identified and then the regions for case studies will be nominated.

Major Activities in the Past

Background data for case studies to be undertaken in Subtask 2 were collected, and recent international activities on global environmental issues such as COP and IPCC were investigated. In addition, existing researches for added values of PV systems were reviewed.

SUBTASK 2: CASE STUDIES FOR SELECTED REGIONS FOR INSTALLATION OF VLS-PV SYSTEM

Objective

Employing the results from Subtask 1, case studies on VLS-PV systems for the selected regions are undertaken. In the case studies, the effects, benefits and environmental impacts are evaluated.

Major Activities in the Past

The following case studies were completed: preliminary cost analysis of VLS-PV System in world major deserts, life-cycle analysis of VLS-PV systems on the Gobi desert, case studies on the Sahara desert in terms of network concept and technology transfer, and case studies of sun-tracking concentrator PV system on the Negev desert.

SUBTASK 3: COMPREHENSIVE EVALUATION OF THE FEASIBILITY OF VLS-PV SYSTEM

Objective

Joint assessment of the results from the Subtask 2 is carried out by summarizing similarities and differences in the impact of VLS-PV system installation in different areas. Mid- and long-term scenario options that will enable the feasibility of VLS-PV system are proposed.

Major Activities in the Past

Three sustainable scenario studies were developed showing that "sustainable local economic growth", "sustainable technological-environmental development and non-technological demonstration" and "financial (stakeholder) support" are possible when a long-term perspective is developed and maintained. In addition, recommendations for various stakeholders were summarized.

OTHER ACTIVITIES

Publication of the Technical Report - The final draft of Task VIII technical report entitled "ENERGY FROM THE DESERT" has been completed. This report, which will have more than 200 pages, will be published by James and James in May, 2003.

Extension of Task VIII Workplan – A 3-year extension of Task VIII activity, which focuses on practical project proposal suitable for selected regions, was discussed and approved. The tentative extended workplan consists of the following two subtasks: "Subtask 4: Practical Project Proposals for Initial Stage of VLS-PV Systems for Some Desert Areas", and "Subtask 5: General Instructions for Practical Project Proposals to Realize VLS-PV Systems in the Future."

COUNTRY	PARTICIPANT	ORGANIZATION
Israel	Mr. David Faiman	The Ben-Gurion National Solar Energy Centre
Italy	Mr. Pietro Menna Mr. Fabrizio Paletta	ENEA ENEL-SRI PAL
Japan	Mr. Kosuke Kurokawa Mr. Kazuhiko Kato Mr. Keiichi Komoto Mr. Kenji Otani Mr. Isaburo Urabe	Tokyo University of Agriculture and Technology NEDO Fuji Research Institute Corporation AIST Photovoltaic Power Generation Technology Research Association
Korea	Mr. Jinsoo Song	Korea Institute of Energy Research
The Netherlands	Mr. Leendert Verhoef Mr. Peter van der Vleuten	Verhoef Solar Energy Free Energy International bv
Spain	Mr. Jesus Garcia Martin Mr. Alfonso de Julian Palero Mr. Luis Alberto Calvo	IBERDROLA IBERDROLA IBERDROLA
United States	Mr. David Collier	SMUD

DELIVERABLES

Internal Publication

Report: A Preliminary Analysis of Very Large Scale Photovoltaic Power Generation (VLS-PV) Systems: Report IEA-PVPS VI-5 1999:1

External Publication

Official brochure: "A DESERT PRODUCES ENERGY",
Book: "ENERGY FROM THE DESERT" (Task VIII technical report, to be published in May 2003 by James and James)
Report: Executive Summary of Task VIII Technical Report (to be published in May 2003)

PARTICIPANTS

As shown on the table, currently there are seven countries participating in Task VIII, with representatives from research institutes, universities, utilities, PV consultancy and industry.

MEETING SCHEDULE

Meetings Held

1st Task VIII Participants Meeting, June 28-29, 1999, Paris (France)
2nd Task VIII Participants Meeting, December 1-2, 1999, Utrecht (The Netherlands)
3rd Task VIII Participants Meeting, April 30, 2000, Glasgow (UK)
International Workshop, May 2, 2000, Glasgow (as a side event of EUPSEC-16)
4th Task VIII Participants Meeting, September 15-16, 2000, Sacramento (USA)
5th Task VIII Participants Meeting, June 9-10, 2001, Cheju Is. (Korea)
International Symposium, June 11, 2001, Cheju Is (as a side event of PVSEC-12)
6th Task VIII Participants Meeting, 2-4 September 2001, Ulan Bator (Mongolia)
7th Task VIII Participants Meeting, 27 February – 1 March 2002, Utrecht (The Netherlands)
8th Task VIII Participants Meeting, 12-13 September 2002, Warsaw (Poland)

Meetings Planned

International Symposium, 18 May 2003, Osaka (as a side event of WCPEC-3)
9th Task VIII Participants Meeting, 4-5 July 2003, Brussels (Belgium)

TASK 9 - DEPLOYMENT OF PHOTOVOLTAIC TECHNOLOGIES: COOPERATION WITH DEVELOPING COUNTRIES

Fig. 1 - PV providing electricity for a rural school in Northern Provence, South Africa.

OBJECTIVE

The conventional electricity grid will not reach the estimated 1.64 billion people in developing countries without access to electricity in the foreseeable future. Renewable energy, and in particular PV, can contribute directly to the alleviation of poverty through the provision of electricity for basic services. PV systems can provide power for a wide range of applications including: systems for use in social services, such as health clinics (refrigeration for vaccines, sterilisation and lighting), schools and community centres; domestic solar home systems that provide electricity for lighting and low power appliances such as a radio; community battery-charging units; and water-pumping for the provision of water for drinking, livestock and in some cases irrigation requirements. In many areas the technology is cost-competitive with traditional alternatives, such as kerosene lamps and small diesel generators.

The objective of Task 9 is to increase the rate of successful deployment of PV systems (i.e., the rate of rural electrification) in developing countries. This is being promoted through enhanced co-operation and flow of information between the IEA PVPS Programme and developing countries, development banks, multilateral and bilateral aid agencies, and other targeted groups within developing countries. Task 9 has drawn upon other similar existing programmes and networks and is building upon these to provide an effective and efficient programme that addresses the needs and potential of developing countries, multilateral and bilateral donor agencies and development banks.

APPROACH

In order to achieve its objective, the collaborative work is organised into three Subtasks with the following objectives:

Subtask 10: Deployment Infrastructure: contributes to overcoming the critical barriers to widespread PV deployment and implementation through the development, dissemination and application of a series of Recommended Practice Guides (RPGs) to promote the necessary infrastructure requirements in developing countries.

Subtask 20: Support and Co-operation: stimulates awareness and interest amongst the multi- and bilateral agencies, NGOs and other target sectors on the technical and economic potential and opportunities arising from energy/PV. This will enable decision-makers to obtain the expertise and knowledge that is required for the appropriate deployment of PV.

Subtask 30: Technical and Economic Aspects of PV in Developing Countries: identifies the various technical supply options available and considers the issues relating to the preparation, design and implementation of PV deployment programmes.

The Experts appointed to the Task cover a broad range of experience, including technical PV experts, development economists and sociologists, and other renewable energy technologists. The Task also includes representatives of the World Bank, the Global Environment Facility and the United Nations Development Programme, and developing country representatives also participate.

Fig. 2 - PV powered shop in India.

SUBTASK 10: DEPLOYMENT INFRASTRUCTURE

Aim

To develop and disseminate a coherent series of Recommended Practice Guides (RPGs) to promote the necessary infrastructure requirements in developing countries to help overcome the critical barriers to widespread PV deployment and implementation.

Activities

11. Information Compilation and Analysis
12. Recommended Practice Guide Preparation
13. Dissemination and Promotion of Recommended Practice Guides

Activity 11: Information Compilation and Analysis

A revised format for the document Photovoltaics in Developing Countries : An Overview has been prepared. The document will be a short (20 page) overview of the issues to be considered when a developing country PV deployment programme is being developed. It states the key points and the messages of Task 9. Publication of the overview document is planned for March 2003.

Twelve case studies have been compiled by the Task Experts to provide supporting information, covering PV experience in Brazil, Argentina, Chile, China, India, Indonesia, Jordon, Kenya, Kiribati, Morocco, Mozambique, Namibia, Philippines, the Sahel nations, Sri Lanka, Syria, Tunisia and Zimbabwe. The issues are dealt with more thoroughly in the individual Recommended Practice Guides being developed in Activity 12.

Activity 12: Recommended Practice Guides

The *Financing Mechanisms for SHS in Developing Countries: the Role of Financing in the Dissemination Process RPG* was published in October 2002 and final drafts of four other RPGs have been prepared. Their publication is planned for March 2003. The status of the RPGs is summarised below.

- Financing Mechanisms for SHS in Developing Countries: the Role of Financing in the Dissemination Process
  -Published
- Summary of Models for the Implementation of Solar Home Systems in Developing Countries
  -Expected publication date: March 2003
- PV for Rural Electrification in Developing Countries - A Guide to Capacity Building Requirements
  -Expected publication date: March 2003
- PV for Rural Electrification in Developing Countries – A Guide to Institutional and Infrastructure Frameworks
  -Expected publication date: March 2003
- The Role of Quality Management, Hardware Quality and Accredited Training in PV Programmes in Developing Countries: Recommended Practices
  -Expected publication date: March 2003

Activity 13: Dissemination and Promotion of Recommended Practice Guides

One RPG has been published on the Task 9 website and was distributed at a Task 9 workshop in Switzerland in October 2002. Further workshops are being planned where the RPGs will be disseminated to a wide audience.

All the RPGs will be freely available from the internet or on CD-Rom. This will also facilitate easy and regular updating of the Guides. The work of Task 9 was also presented at the PV in Europe Conference in Rome in October 2002.

Work Planned for 2003

Publication of the remaining four Recommended Practice Guides, the Case Studies and the Overview Document will take place in March / April 2003.

Further dissemination of the documents will be through the internet and activities in Subtask 20. Any feedback received will be incorporated into revisions of the RPGs. Dissemination is to be co-ordinated with PVPS Task 1.

SUBTASK 20: SUPPORT AND CO-OPERATION

Aim

To stimulate awareness and interest amongst the target sectors on the technical and economic potential, opportunities and recommended practice of PV systems. This will enable decision-makers to obtain the expertise and knowledge that is required for appropriate PV system deployment.

Fig. 3 - A solar home system in China.

Activities

21. Support to Multilateral and Bilateral Donors and Development Banks
22. Cooperation with REWP and IEA/OECD

Activity 21: Support to Multilateral and Bilateral Donors and Development Banks

The Operating Agent presented the work of Task 9 to the Swedish International Development Co-operation Agency in January 2002. As a result of this a Swedish representative attended the 7th Task 9 Experts Meeting and Sweden is considering formalising its participation in Task 9.

A second workshop on "PV Deployment in Developing Countries" was held for the Swiss Agency for Development and Co-operation (SDC) and the Swiss State Secretariat for Economic Affairs (SECO) on 4th October 2002 in St.Gallen, Switzerland.

Activity 22: Co-operation with REWP and IEA/OECD

Task 9 is planning a final workshop in China to act as a high profile event to disseminate the work of Task 9 and to promote the RPGs to as wide an audience as possible.

Work Planned for 2003

Two workshops are planned for 2003. A workshop for the Asian Development Bank (ADB) will be held in conjunction with the 8th Task 9 Experts' Meeting in Hanoi, Vietnam in March 2003. The workshop is being jointly organised by CORE (The Council for Renewable Energy in the Mekong Region). A number of people at the ADB have expressed their interest in attending the meeting, as has ACE (Asean Centre for Energy). Funding for the workshop has been confirmed by Ademe and GTZ.

A second workshop on PV will be held for ECOWAS (The Economic Community of West African States) in late 2003.

SUBTASK 30: TECHNICAL AND ECONOMIC ASPECTS OF PV IN DEVELOPING COUNTRIES

Aim

To investigate the techno-economic aspects and potential of PV systems in developing countries. The objectives are to identify the various technical supply options available and consider the issues relating to the preparation, design and implementation of PV deployment programmes.

Activities

The subtask has the following two activities:

31. Programme Design and Implementation
32. Proposal Preparation

Activity 31: Programme Design and Implementation

Activity 31 is considering issues relating to the preparation, design and implementation of PV deployment programmes: the various technical supply options - stand-alone systems, diesel hybrid village/mini grid systems and grid-connected systems; and the availability and use of new analysis tools. This will provide guidance for programme planners on the various rural electrification approaches and the technical supply options available. A draft version of the Recommended Practice Guide, provisionally titled: Programme Design and Implementation is under preparation.

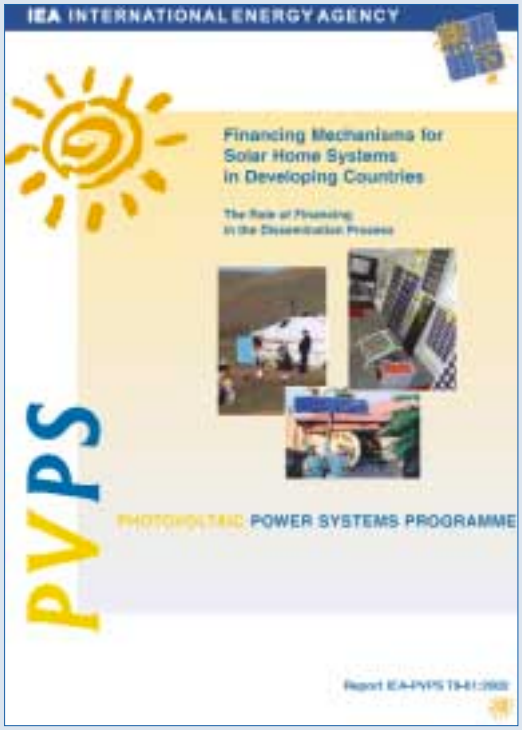


Fig. 4 - Task 9 Report: Financing Mechanisms for Solar Home Systems in Developing Countries, 2002.

Activity 32: Proposal Preparation

Activity 32 will provide guidance to potential developers on the potential sources of finance for PV deployment programmes and the processes involved in accessing this finance. The processes by which finance can be obtained from the World Bank Group, bi-lateral donors, utilities etc. will be identified and summarised in a Recommended Practice Guide, provisionally titled: Funding Sources. The first draft of the guide is being prepared.

Work Planned for 2003

The documents will be published in 2003 and will be launched, with the RPGs from Subtask 10, at an international workshop. Further dissemination of the documents will be through the internet, activities in Subtask 20 and in co-ordination with Task 1.

Task Meetings

1st Experts Meeting, 14-16th October 1999, Utrecht, The Netherlands.
2nd Experts Meeting, 8-9th February 2000, Washington DC, The USA.
3rd Experts Meeting 2-3rd October 2000, Marrakech, Morocco.
4th Experts Meeting, 26-27th March 2001, ASEAN Centre for Energy, Jakarta, Indonesia.
5th Experts Meeting, 12-13th September 2001, Ottawa, Canada.
6th Experts Meeting, 25-28th February 2002, Oaxaca, Mexico.
7th Experts Meeting, 3-5th October 2002, St.Gallen, Switzerland.

Planned Meetings in 2002

8th Experts Meeting, 25-26th March 2003, Hanoi, Vietnam.
9th Experts Meeting, Late 2003 in association with ECOWAS (venue to be confirmed).
10th Experts Meeting, Early 2004 in China in conjunction with final conference.

TASK 9 PARTICIPANTS

COUNTRY	NAME	AFFILIATION
Australia	Gordon Thompson	CASE
Australia	Geoff Stapleton	GSES
Canada	Gerry Collins	CIDA
Denmark	Peter Ahm	PA Energy A/S
Denmark	Jean Paul Laude	DANIDA
Finland	Heikki Tikkanen	NAPS Systems Oy
Finland	Heikki Neuvonen	NAPS Systems Oy
France	Bernard Chabot	ADEME
France	Anjali Shanker	IED
France	Lara Bertarelli	IED
Germany	Rolf Posorski	GTZ
Italy	Mr Groppi	CESI
Japan	Takayuki Tani	Institute of Energy Economics
Japan	Takayuki Nakajima	Japan Photovoltaic Association
Japan	Kazuo Yoshino	Yoshino Consult
Japan	Hideo Senba	Shikoku Research Institute
Japan	Hiroyuki Watanabe	Watanabe PV Office
Switzerland	Alex Arter	ENTEC
Sweden	Anders Arvidson	Stockholm Environment Institute
United Kingdom	Bernard McNelis	IT Power
United Kingdom	Jonathan Bates	IT Power
United Kingdom	Rebecca Gunning	IT Power
United Kingdom	Zhu Li	IT Power
USA	Mark Fitzgerald	ISP
USA	Roger Taylor	NREL

AUSTRALIA

DR HARRY SCHAAP, ELECTRICITY SUPPLY ASSOCIATION OF AUSTRALIA

Fig. 1 - Plug & Power TM on Campbell High School in Australia's capital, Canberra, with the Australian War Memorial in the background. This is the first completely modular PV system to be installed on an Australian school and allows progressive expansion module-by-module in the years ahead.

GENERAL FRAMEWORK

The use of photovoltaic power systems (PV) in Australia has continued to increase, with a number of programmes influencing the different market segments. Although not largely targeted by such programmes, off-grid non-domestic applications continue to dominate Australia's cumulative installed capacity (about 57 % by 2002, down from about 75 % in the mid 1990's), with an annual growth rate that increased significantly during 2001 to around 12 %. Off-grid domestic applications have enjoyed strong growth over the last decade and are now benefiting from the government support programmes aimed at increasing the use of BIPV and replacing diesel use with renewables. These applications accounted for 33 % of the cumulative installed capacity by 2002, almost the same as the previous year.

Grid-connected installations have remained steady at about 10 % of the total installed capacity compared with less than 1 % five to six years ago. The national BIPV support programme (which commenced in 2000) and the renewable energy target for electricity retailers and major energy users (implemented in 2001), discussed later in this report, are seen by many as important factors in keeping this market segment growing strongly. The Australian electricity industry – mainly the retailing businesses - continues to play a role in both remote area power supply and grid-connected PV although the degree of interest varies between businesses. This interest is largely stimulated by customer contestability and the operation of greenhouse gas reduction agreements or licence conditions in a number of states.

The public is generally supportive of PV and interested in its use, if affordable. This is clearly evidenced by the large number of grant applications received for government programmes. Even with the grants, PV is still an expensive option for grid-connected households.

NATIONAL PROGRAMME

The Australian Government has initiated a number of measures to support renewable energy in general and, in some cases, PV in particular.

Mandatory Renewable Energy Target (MRET) – this target seeks to increase the contribution of renewable energy sources in Australia's electricity mix by 9 500 GWh per year by 2010. From 1 April 2001, electricity retailers and large energy users (known as liable parties) must purchase increasing amounts of electricity from renewable sources. A trade in Renewable Energy Certificates (RECs) and financial penalties for non-compliance are features of this scheme.

Supporting the Use of Renewable Energy for Remote Power Generation (RRPGP) – this programme commenced in 2000 and will make 264 million Australian dollars available until 2010 for the conversion of remote area power supplies (including public generators and mini-grids) from diesel to renewable energy sources, and for new renewable installations that would otherwise have been fueled by diesel. The RRPGP may provide up to 50 % of the capital value of the replacement or new renewable generation for off-grid users of diesel-based power generation. This includes remote pastoral properties, indigenous and other small communities and enterprises such as tourist facilities and mining operations. The programme is administered by state governments and a number of states also provide additional financial support for off-grid renewables.

Supporting the Use of Solar Photovoltaic Electricity on Residential and Community Buildings, the PV Rebate Program (PVRP) – this four year programme commenced at the beginning of 2000 with 31 million Australian dollars available as rebates to householders or community building owners who install grid-connected or stand-alone photovoltaic power systems. Under the PVRP, householders are eligible for a rebate of 5 AUD/W (minimum capacity of 450 W), capped at 7 500 AUD (or 1,5 kW). Extensions to an existing system can also attract a rebate. Community buildings attract the same rebate except it is capped at 10 000 AUD (or 2 kW). In the state of NSW, the Sustainable Energy Development Authority boosts these householder rebates for new systems exceeding the cap, and provides support to other installations on buildings that may otherwise not be funded. In the state of Queensland, the Environment Protection Authority contributes 7 700 AUD per system under its "Cool Schools Programme."

2002 saw the finish of significant five-year Australian Government support programmes for renewable energy that were initiated in 1997, most notably the *Supporting Renewable Energy Commercia-lization Activities, the Renewable Energy Commercialization Program (RECP) competitive grants scheme.*

R&D , D

Australian Government annual funding for PV R&D, D had decreased to about 16,7 million Australian dollars by 2002 (compared to 24,6 million Australian dollars for the previous year), including the market incentives. Funding from the state governments for the same period was around 0,9 million Australian dollars, also significantly less than for the previous year.

Fig. 2 - 148 kW installation on an inner city commercial and residential development in Sydney.
(photo courtesy of Energy Australia)

PV research is undertaken at several universities across Australia, funded by state and federal governments, as well as by private investors, and by all PV companies. Public funding in 2001 was around one million AUD. Industry funding for university research and for in-house R&D was around 10 million AUD, largely for new production processes and new products. R&D includes Centre for PV Engineering, University of NSW, research into improved crystalline and thin-film silicon cell efficiencies, as well as theoretical research into so-called "third generation photovoltaics"; Centre for Sustai-nable Energy Systems, Australian National University, in conjunction with energy utility Origin Energy, development of a new thin film PV technology, using the epilift process; Murdoch University development of methods to produce low cost silicon from a number of new sources for both wafer based and thin-film silicon solar cells.

Australia has a degree course specifically in PV Engineering at the University of NSW, as well as one in Renewable Energy Engineering at Murdoch University, which includes PV topics. Trade level courses are also being provided through the national Technical and Further Education sector. Short courses, diplomas and other post-graduate education are also offered, many of which were supported by the Australian Cooperative Research Centre for Renewable Energy (ACRE). However, the Government has decided not to continue ACRE funding after the middle of 2003.

IMPLEMENTATION

Installed PV capacity in Australia rose by 4 370 kWp in the year up to the beginning of 2002. Installations continue to be dominated by the off-grid market for agricultural/industrial use and private dwellings. Important industrial uses include telecommunications systems, shipping, rail and road signalling, water pumping, cathodic protection, billboards and electric fences.

By the end of October 2002, some 3 749 kW of PV had been installed on households / community buildings Australia-wide – largely as a result of almost three years of operation of the PVRP. However, only 1 152 kW were grid-connected; the remaining 2 597 kW were off-grid. Looking in more detail at the figures for one state, NSW, a total of 1 130 kW were installed by end of October 2002 – 229 kW grid-connected and 901 kW off-grid (up from 19 kW and 50 kW respectively pre-PVRP).
RRPGP sub-programmes have been approved and are being funded in most states and territories, including Western Australia's Remote Area Power Supply and Renewable Energy Water Pumping Program-mes, Northern Territory's Renewable Energy Rebate Programme, Queensland's Working Property Rebate and Renewable Energy Diesel Replacement Schemes, Indigenous Renewable Energy Services Project (Bushlight) and programmes in NSW and South Australia.

Green Power sales from thirteen Green Power retailers were recorded at a little more than 106 GWh in the third quarter of 2002, up on the figure for the same period in 2001 and with about 10 % more customers than 2001. However, only half the retailers include PV electricity in their Green Power offering, with PV electricity accounting for only 0,1 % of total green electricity purchased by the retailers. One third of the Green Power sales are from energy retailer EnergyAustralia's *PureEnergy* product (which contains 0,67 % PV electricity). About 67 000 customers are signed up for some type of Green Power product (close to 1 % of residential customers nationwide). Currently 80 % of Green Power must be sourced from new generators (up from 70 % in 2001).

Although maintaining a general interest in PV, only a small number of electricity retailers are currently installing PV systems. Some retailers own and operate systems installed during the 1990's.
The current biggest utility programme is the Northern Territory Power and Water Authority programme aimed at installing 225 kWp and 55 kWp systems for peak load reduction in its diesel power stations. If successful, more such systems are planned.

INDUSTRY STATUS

PPV cell and module production levels rose during 2001, following the disruption experienced in 2000 by the merger and factory relocations of BP Solar and Solarex. In 2001 PV cell production in Australia rose 82 % to 10 MWp, bringing Australia's production share up to 2,8 % of the international market (compared to Australia's GDP share of about 1 %). Cell production capacity rose to 10,5 MW. Module production also rose slightly to 6 MW with a capacity of 6,5 MW. Production of multi and single crystalline PV cells and modules from the new BP Solar plant is increasing significantly, to 20 MWp capacity in 2002 and then increasing to 40 MWp in coming years.

About two-thirds of Australia's cell production is crystalline silicon, with the remainder being multi-crystalline silicon. While there remains a strong market for special purpose small modules in the agricultural / industrial market, production trends are towards larger modules. Over 60 % of Australian product is exported.

Fig. 3 - Power And Water Corporation's Bulman Solar Power Station. 56 kW of amorphous Silicon PV is displacing diesel fuel at this remote community in Arnhem Land, Northern Territory. The installation was commissioned in November 2002 with the aid of the Northern Territory Centre for Energy Research.
(photo courtesy of Wolfgang Meike, NT Centre for Energy Research)

Sustainable Technologies International is manufacturing Titania Dye Sensitized products (first phase capacity of 500 kWp) with in-house manufacturing of all the key materials for DSC technology: titania paste, dye, electrolytes, catalytic paste, interconnecting material and internal sealants. The manufacturing process includes laser isolation of the conductive glass, screen printing of working electrode and counter electrode, deposition of sealants and interconnection on the substrates, bonding the substrates and filling with a proprietary electrolyte. External sealing finalizes manufacture of tiles which are then interconnected and laminated into Solar Wall Panels to suit end-user requirements, primarily for façade integration.

Meanwhile, Pacific Solar continues the development of its thin-film CSG product. Pilot production is already underway and construction of a full-scale production facility is scheduled to begin in 2003. It continues to develop and market its Plug&Power™ ac module system for grid-connected rooftop applications and now has nationwide sales and distribution.

Solar Systems is continuing to expand the installation of its successful CS500 solar concentrator PV dishes in remote communities. These parabolic solar tracking dishes consist of 112 mirrors concentrating to the equivalent of 500 suns onto 24 kW water-cooled upgradeable receiving modules. All up cost, including all remote infrastructure costs, is less than 10 AUD per watt. Some 960 kW of dishes are being progressively installed producing more than 2 000 MWh per year. Solar Systems expects to contract a further 2 500 kW in 2003.

A number of Australian inverter manufacturers continue to supply inverters for both the grid and off-grid markets. These include Advanced Energy Systems, Enertec, Latronic Sunpower, Plasmatronics, Powercor Australia, Power Solutions Australia and Selectronics. Typical sizes are in the 1 – 10 kW range, although larger systems are also made. Some of these companies, as well as a number of others, also manufacture charge controllers and regulators for PV systems. Pacific Solar has developed its own module inverter, the IPC-1, for use in its Plug&Power ac module systems. It is now commercially produced in Sydney, with 1 000 units manufactured in 2001, its first year of full production.

MARKET DEVELOPMENT

Growth in the local market remained constant at 15 % and a total installed capacity of 33 580 kWp was reached by the start of 2002.

Australia's vast size and sparse population have made effective remote area telecommunications, power supplies, water pumping, navigation aids and transport route signaling critical and expensive. PV continues to provide an important commercial alternative to diesel and central grid supplies for such applications. While the telecommunications market has been stable for the last few years, major new projects are now beginning to come on stream, which will see this market sector remaining strong over coming years. The water pumping market has been boosted by recent government grants and is now taking off strongly, even where grants are no longer available. Increased activity is also evident in the medium sized centralised system market for off-grid communities and commercial enterprises. Installations include flat plate and concentrator systems for aboriginal communities and for tourist facilities.

While non-domestic off-grid applications have traditionally been the major Australian market for PV, the previous year saw more than 80 % of the new installed capacity on buildings (Government support for rooftop PV systems has seen an increase in building integrated installations for homes, schools and other community buildings, both grid-connected and off-grid). However, over the year until end 2001, the figure for buildings dropped to close to 50 %. With its relatively low electricity tariffs, PV remains an expensive option for grid applications in Australia and with government grants for grid-connected systems set to cease within the coming year or so, there is concern that this market sector may well stall.

With respect to promoting grid-connected PV, it is worth noting that before the PVRP commenced, NSW saw about 500 kW of PV installed by one utility, EnergyAustralia, as part of its then newly-developed Green Power scheme (*PureEnergy*) and a further 630 kW of PV were installed in one project, the Newington Solar Village in Sydney. These figures provide an interesting background when considering the merits of the PVRP in NSW.

As anticipated, the "lowest cost" approach to renewable energy implementation under the MRET has done little to stimulate the PV market, and may even have had a negative impact through the change in attitude to Green Power displayed by some businesses. MRET will be reviewed by the Government in 2003 and some issues pertinent to PV have already been flagged for discussion, for example a portfolio approach which could create a separate tranche for PV, allowing PV to earn more RECs per MWh generated compared to other technologies, and allowing PV electricity to be sold as Green Power plus earning RECs.

Fig. 4 - Welford power system in Queensland. Design & main structures by Ergon Energy stationpower. 6,3 kW PV array. Battery 120 V/1400 Ah. Inverter - 2 x 5 kW units operating in parallel to ensure continued operation. Installed May 2002.

FUTURE OUTLOOK

The mid-term outlook for PV applications in Australia remains healthy. The near-term may be more problematic, depending on how current initiatives cease, are re-designed or continued, particularly for grid-connected applications.

Local government initiatives are increasing and are resulting in greater knowledge about PV and its potential in the built environment.

Support for Green Power schemes continues to grow modestly, however it still remains to be seen how these schemes will be impacted by other policy measures.

There continues to be a lack of PV installations for grid support or other distributed system benefits and it remains a challenge in Australia with its sparse population and extensive electricity distribution network to promote the real value of distributed generation sources such as PV through appropriate regulation and market mechanisms. However, investigations are now underway into the use or value of PV for peak load reduction or grid support. The installation of PV systems is becoming more of a straightforward and accepted practice in Australia but work is still needed to develop uniform installation and connection guidelines, straightforward contracts and financial arrangements that more positively encourage PV use.

AUSTRIA

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS
DIPL.-ING. HUBERT FECHNER AND DIPL.-ING. ROLAND BRÜNDLINGER, ARSENAL RESEARCH

Fig. 1 - Austria's largest PV-installation: 235 kWp in Werfenweng, Salzburg, Neue Energie Technik.

GENERAL FRAMEWORK

Three main issues in Austria's energy scene are favoring the increased use of photovoltaics:

The first important issue is the reduction of greenhouse gas emissions which is the main target of the environmental policy following the commitments of the Kyoto Conference. There, Austria committed to reduce 13 % of its greenhouse gas emissions from today's 7,6 tons per capita and year towards around 6,6 tons per capita and year in 2010. However, the Ratification of the Kyoto Protocol, as well as the decisions regarding the appropriate reduction measures and evaluation procedures are still in discussion within the Austrian government. Nevertheless, it is expected that photovoltaics can contribute to reach the targets in the long term.

The liberalization of the electricity market since October 1st 2001 is the second major issue regarding PV. Based on the principles of the electricity law so called "EIWOG 2" the electricity market has been 100 % liberalized. With the opening of the markets, electricity has become an article of merchandise. The whole process and the market rules are observed by a new independent regulatory body, the Electricity Control Commission.

Finally, target quotas for electricity from so called "New Renewable Energy Sources" like PV, biomass, wind power are another important part regarding the market penetration of RES. These political target quotas will be rising from 1 % in 2001 up to 4 % in 2007, in two year steps.

Today about 70 % of Austria's annual electricity consumption is generated from renewable energy sources, almost exclusively from large hydro power plants. This is the highest figure of all European Union member states and mainly due to Austria's topographic situation and the historical development of the electricity market.

Furthermore, the law states that consumers' invoices must describe the portions of primary energy sources from which the delivered electricity has been generated. Traders and suppliers are obliged to ensure that this information is in place. The first disclosure appeared

Fig. 2 - Cable-car station at the Kriegerhorn, Lech am Arlberg, 2 100 m above sea level, semitransparent modules 9,5 kWp, ATB.

at the end of October 2001. The verification system is settlement based and the rules are as follows:
Certificates of origin of primary energy are to be issued by recognized and chartered certification organizations. Statements concerning the origin, officially published in annual business reports and approved by the chartered auditor are accepted as well.
If neither of the above are available then the UCTE-mix applies.

NATIONAL PROGRAMME

There is no national programme dedicated to the promotion of PV in Austria, but several regulations are defining the framework for the promotion of RES.

Most important are the principles of the electricity law "ElWOG 2" which have gone into force via federal decrees in each of the nine regions in 2001. The regional governments had to determine the different types of promotion strategies and incentives that are used. These circumstances led to a very diverse situation with very ambitious incentives in some regions and made it difficult for investors and planners to keep an overview about all the regulations. The feed-in tariffs, for example, varied between 0,10 and 0,74 EUR/kWh, depending on the region, on the system size as well as on seasonal and day/night aspects.

To harmonize these situations, a special new law for Green Electricity called "Ökostromgesetz" was adopted by the federal government regulating issues concerning the electricity supply from RES on the national level.

The regulation, becoming effective at the beginning of 2003, will move the competencies from the regional governments to the federal government and define preferential feed-in tariffs for RES that have to be paid by the distribution network operators.
For PV, there will be one nationwide tariff of 0,60 EUR/kWh for installations up to 20 kWp and 0,47 EUR/kWh for larger systems.
The extra costs for the network operators will be compensated by an additional supplement on the customer invoices.
Furthermore, a limit of 15 MWp total installed capacity is stated in the law, up to which the high tariffs will be paid. Compared to the installed capacity of 9 MW at the end of 2002, and including the applications for new PV installations the limit is expected to be reached already in the first months of 2003.
This makes the feed-in tariff system almost ineffectively and threatens the further deployment of PV by generating uncertainty among investors and installers of PV systems.

With the "ElWOG 2", Green Electricity has become a general tradable good, and several new companies are offering their green products directly to the customers. Another increasing popular mechanism to promote the market introduction of Renewable Systems are Ecolabels. Ecolabels are voluntary Instruments based on economic-political grounds for transferring ecological values of generation processes.

Within the certification procedures certain criteria are checked through independent certification institutes. One criteria which has to be fulfilled for getting the Austrian Ecolabel "Umweltzeichen" is to verify the share of at minimum 1 % PV within the portfolio of the labeled green electricity. The positive image of solar electricity in the mind of the customers led to this jointly defined requirement.

RESEARCH, DEVELOPMENT AND DEMONSTRATION

Austrian PV research activities are mostly focussed on national and international project base. The involved research organizations and companies are participating in various National and European projects as well as in different tasks of the IEA-PVPS Programme. The RTD development and approach is widespread located and decentralized oriented. Some principal descriptions of these projects highlight the general RTD trend of photovoltaics in Austria:

- Organic Solar Cells based on thin plastic films have received increased attention due to their unique properties. These cell types are probably promising to become the cheapest solar cell in future.
  A maximum efficiency of about 2,5 % has been achieved through the bulk hetero-junction cells.
- Encapsulation of solar cells, the development of new contact pattern for crystalline cells and colored cells are investigated at the academic institutes.
- New concepts for PV-inverters and various aspects of grid-inter connection, not exclusively related to PV but more to Distributed Generation from RES in general, are the main focus of several EU financed projects, which are jointly carried out by research institutions, industry and utilities.
- New solutions for building integration of PV are investigated to reduce the costs and address the building industry by aiming to create a better understanding about chances and challenges of high integrated concepts for roofs, facades and other building elements.

IMPLEMENTATION & MARKET DEVELOPMENT

With an enormous increase of more than 45 % in 2002 installed PV power capacity reached roughly 9 MW by the end of the year. Between 1995 and 2002, the mean growth of the total capacity was more than 30 % per year. Until the end of 1996, the off-grid sector dominated the Austrian PV market. However from 1997 the majority of new systems were grid-connected according to the overall trend in the IEA PVPS reporting countries.

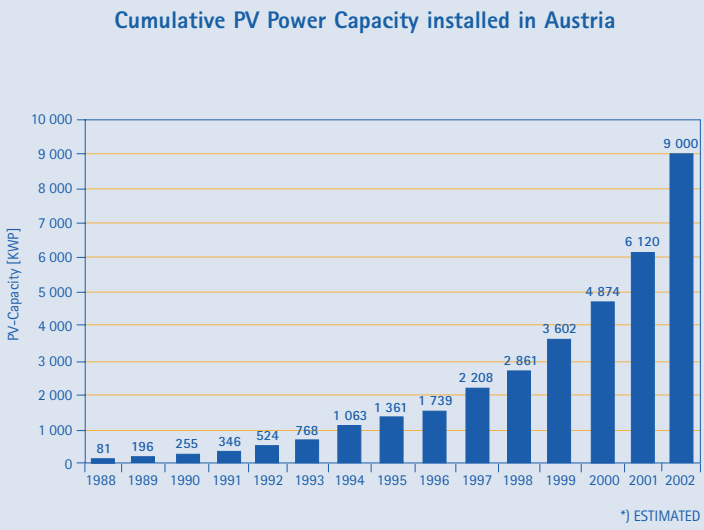


Fig. 3 - PV capacity installed in Austria between 1989 and 2002. (source: Faninger, PV market in Austria)

Fig. 4 - Refurbished PV façade at the Wels trade fair center, 17,24 kWp, stromaufwaerts GmbH.

As in most of the other countries, *Off-grid installations* were the first economic alternative for PV systems. Small autarkic systems provide electricity to technical systems or for domestic use in Alpine households or mountain huts far away from the grid; but not exclusively in remote areas. Also on urban sites, PV is an increasing option to supply infrastructure systems like parking meters or rail-greasing systems.

With improved integration into the built environment *On-grid distributed systems* are becoming more and more a common place in public's interest. More than 2/3 of the overall installed capacity are grid-connected systems in Austria.

Due to limited space available, *grid-connected centralized systems* play a minor role and so far only 400 kWp are installed.

INDUSTRY STATUS

An important newcomer entered the PV market in 2002:
PVT Austria, the first manufacturer of PV modules in Austria opened its production line for standard and semi-transparent crystalline silicon panels.

Concerning balance of system components for PV systems there are several other manufacturers involved:

FRONIUS, a power electronics company has been engaged in solar-electronics for many years and is now Europe's second largest producer of inverters for grid connected and stand alone PV systems. In 2002, they started selling their new IG series inverters. More than 90 % of the production are exported into other countries.
ISOVOLTA is manufacturing colored back sheet laminates for PV modules for almost all module manufacturers in the world.
BANNER BATTERIES is an important manufacturer of lead-acid batteries for off-grid PV applications.

A new Quality Label for PV installers will be issued by the Austrian Photovoltaic Association. Certified planners and installers are obliged to use products and components certified to the relevant standards as well as to have a quality assurance system.

FUTURE OUTLOOK

The favorable feed-in tariffs paid in some federal states and the new green-electricity law "Ökostromgesetz" regulating the feed-in tariffs for electricity from renewable energy sources on a national level already led to an enormous boom in applications for new PV installations. Due to that, the limit of 15 MW total installed capacity, up to which new PV installations are supported by the feed-in tariffs, will be already reached in the first quarter of 2003. This fact creates the paradox situation that the law will be obsolete - at least for PV - before it really has become effective. It remains to be seen, whether the PV lobby is able to persuade the Austrian government to abolish the narrow restrictions and pave the way for a widespread dissemination of PV in the country.

PV research and development will be more and more concentrated on international projects and networks, following the dynamic know-how and learning process of the world-wide PV development progress.

With the increasing number of applications and PV systems installed, a demand on training and education services will emerge. The more the industry and research organizations contribute to the application of PV the more the aspect of vocational schools and universities will automatically supported. It is urgently necessary to develop up-to-date tutorials for growing interest groups in Austria.

Financial incentives and voluntary approaches are the basis for a stronger PV market in Austria. The new regulations coming into effect in 2003 will certainly yield a substantial effect for a lasting development towards a powerful dissemination of PV in the whole country.

CANADA

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS
DR. LISA DIGNARD-BAILEY, CANMET ENERGY TECHNOLOGY CENTRE - VARENNES, NATURAL RESOURCES CANADA

GENERAL FRAMEWORK

On December 17th, 2002, Canada announced its ratification of the Kyoto Protocol to the United Nations Framework Convention on Climate Change. This was another important milestone in Canada's contribution to addressing climate change. The Canadian commitment target is to reduce its Greenhouse gases to 6 % below its 1990 level by 2008 and 2012.

The Government of Canada supported several new initiatives within the initial Climate Change Action Plan 2000[1]. Several federal departments have partnered with the Photovoltaic (PV) industry and regional stakeholders to deliver projects within the Technology Early Action Measures Program, the MicroPower-Connect initiative[2], and the expansion of the REDI program for On-Site Generation at Federal Facilities[3]. Together these projects are helping to raise the awareness of this emerging technology, as well as contributing to their improvement and cost reduction targets. Highlights of PV Industry support of Canada's climate change objectives, include:

- ATS, Spheral Solar Power Inc major investment in a novel technology that will significantly contribute to the cost reduction of solar power;
- ARISE Technologies and Cook Homes partnering to market PV solar homes to residential customers;
- Carmanah to develop improved LED lighting and solar products with partners, BC-Hydro and BCIT;
- Xantrex's launch of a customer financing program for renewable energy products; and
- ICP Global's attendance at the World Summit on Sustainable Development in Johannesburg, South Africa.

Despite the relatively low price of conventional energy, many Canadians are contributing to the growth of the PV market and industry. A sustainable market for remote and off-grid applications has developed over the last 10 years in Canada. The installed power capacity reached 10 MW in 2002, compared to 8,8 MW in 2001 (see Table 1). This is an unsubsidized market that is growing because PV technology is meeting the remote power needs of Canadian customers particularly for transport route signalling, navigational aids, remote homes, telecommunication, and remote sensing and monitoring.

TABLE 1: CUMULATIVE PV POWER CAPACITY INSTALLED IN CANADA

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
PV power (MW)	1,24	1,51	1,86	2,56	3,338	4,47	5,83	7,15	8,83	10

Data - Natural Resources Canada

Fig. 1 - Design plan for a 20 kW Photovoltaic array on façade of Goodwin Hall, Queen's University, Kingston, Ontario. (photo Strong and Associates)

NATIONAL PROGRAM

The federal Department of Natural Resources (NRCan) is responsible for energy policies and energy R&D in Canada. Within the framework of the Renewable Energy Strategy, NRCan's CANMET Energy Technology Centre-Varennes (CETC-V) is responsible for the management of the federal photovoltaic R&D and technology transfer programs. In addition, the Renewable and Electrical Energy Division (REED) is responsible for policy support and is actively supporting PV training and marketing activities to promote the use of photovoltaic and other renewable energy technologies in Canada.

The strategies of the Canadian R&D photovoltaic program are:

- To conduct R&D that will contribute to the improved performance of PV system components and applications in cold climates;
- Provide leadership and technical support that will foster the market deployment of PV technology by removing technical and non technical barriers;
- Collaborate with key partners and stakeholders to increase the awareness of the potential and value of PV;
- Provide support to globally competitive PV manufacturers that can significantly contribute to Canada's Climate Change objectives.

R&D PROGRAM

The Canadian R&D program supports the development of technologies, the evaluation of the performance of PV systems in new applications and their adaptation for use in cold climate conditions. This work is conducted in collaboration with the industry at the CANMET Energy Technology Centre-Varennes (CETC-V), a National research facility located near Montréal in the Province of Québec[5].

Current projects include:

- a comprehensive research program to evaluate the use of small PV-hybrid systems in order to optimize their performance and reduce their life-cycle cost[6];
- a research project to increase the integration of renewable energy technologies in off-grid residences in Canadian climatic condition, in partnership with the Yukon Energy Solution Centre, the Artic Energy Alliance and the Canadian Mortgage and Housing Corporation;
- evaluating the energy performance of commercial PV modules operating in Canadian climatic conditions and contributing to the development of international PV module standards;
- assessing the performance of PV products designed for building integration, in collaborations with Canadian manufacturers and system integrators;
- conducting research to improve the efficiency and performance of inverters and balance of systems components used for utility interconnected PV systems;
- championing the development of a national guideline for the interconnection of small distributed generation systems, including PV, wind, microturbines, and fuel cells, in collaboration with the Electro-Federation of Canada;
- supporting the development and adoption of performance and safety standards for use in Canada, including participation in the International Electrotechnical Commission working groups that aim to develop international standards.

Fig. 2 - In the city of Waterloo, Cook Homes, ARISE Technologies and community partners are marketing PV solar homes to residential customers. It will be the first demonstration of community-scale PV rooftop systems in a neighbourhood in Canada.

CETC-V also developed a Project Analysis Software Tool, known as RETScreen® that can be downloaded from the web free-of-charge[7]. First released in 1998 for on-grid applications, the RETScreen 2 000 model was upgraded to cover off-grid PV applications, including stand-alone, hybrid and water pumping systems. Training modules presenting case studies were completed to provide guidance to those interested in assessing the cost and benefits of PV systems in various applications.

DEMONSTRATION PROJECTS

Queens University BIPV Façade

This grid-connected 20 kW building-integrated solar photovoltaic array will be installed on the façade of Goodwin Hall, home to Queen's Departments of Mining Engineering, Electrical and Computer Engineering, and Computing and Information Science (Figure 1). This project is the result of the collaboration between the University's Integrated Learning Centre, Faculty of Applied Sciences, ATS Automation Tooling Systems in Cambridge, Ontario, Ontario Power Generation, Solar Design Associates in Massachusetts, the Photovoltaic and Hybrid Systems Program at CETC-Varennes, the Climate Change Action Fund through TEAM and Halsall and Associates Limited – a Toronto headquartered professional engineering service company. This installation will include continuous arrays above the 4th to the 7th floor windows for the length of the building's south elevation and generate about 20 megawatt-hours of electricity per year. It will result in a visible, attractive demonstration of Queen's commitment to new energy technologies and sustainability in support of the Integrated Learning Centre concept.

ARISE SOLAR Homes

ARISE Technologies Corporation, Cook Homes Limited, The City of Waterloo, Waterloo North Hydro, The University of Waterloo, the Canadian Imperial Bank of Commerce, and CETC-Varennes are partnering in a community project to advance the development and demonstration of photovoltaic (PV) solar homes in Canada (Figure 2). The project was announced during the Earth Day 2002 celebrations in Waterloo, Ontario. It will be the first demonstration of community-scale PV systems in a neighbourhood in Canada. The PV rooftop systems on 10 to 15 homes will be connected to the local electrical grid so they can send surplus electricity back to the utility. The aims of the project are to accelerate the acceptance of PV technologies for grid-connected applications in the market and to develop a framework for expanding the program to other municipalities in Canada. This project will also study the impact of solar-powered neighbourhoods from the perspective of the electrical utility, financial institutions, and municipal planning and bylaws. This community approach will be a major step in making available affordable and marketable PV solar home systems to residential customers in Canada.

City of Airdrie Environmental Educational Centre

The City of Airdrie in Alberta opened its Environmental Education Centre as a single-stop location to demonstrate solar PV, solar water heating, solar air heating, and building envelope and water efficiency. The centre's systems include a 2 kW grid-dependent solar PV system, a 30-tube evacuated tube solar water heating collector, a Solarwall air heating collector, straw bale walls, and the new dual-flush toilet.

Saskatchewan Advanced Solar Home

The Saskatchewan Advanced Solar home was retrofitted to convert the 1,9 kW solar arrays to a grid-interactive system in 2002. NRCan, the Saskatchewan Research Centre, Kelln and SaskPower partnered to test and demonstrate. The system includes a 2 kW power-conditioner marketed by ARISE Technologies. The provincial electricity company, SaskPower, supported this installation as part of their Climate Change Action Plan.

Aurum Lodge Eco-tourism Country Inn

First established in 2001, Aurum Lodge is located in an environmentally sensitive part of Alberta's Rocky Mountains. The lodge design includes a 4 kW PV array, an 11-collector solar heating system, a 400 W wind turbine, 8 kW genset, wood stove and fireplace with water jackets, and low-flush and composting toilets, placing it in the forefront of Canadian eco-tourism and hospitality industry.

IMPLEMENTATION

Canada is developing a National Implementation Strategy in order to reduce its greenhouse gas emission by 6 % from 1990 level. In 2000, the federal government committed an additional $500 million to accelerate progress towards the reduction of greenhouse gas emissions. There has also been a commitment to provide investments in technologies that will have impacts in the post 2010 period. Within this framework, several climate change measures have been initiated that should benefit the PV industry and other stakeholders:

- Technology Early Action Measure Program - This is a cost-shared program for the development of innovative technologies and their demonstration in the market place. Several PV technology proposals were approved under this program[1];
- MicroPower-Connect Initiative - This is an initiative that aims to develop and harmonize the requirements for the interconnection of emerging technologies, such as PV, wind, fuel cells, and microturbines[2];
- On-site Generation at Government Facilities - As part of its climate change action plan, the government of Canada will support the installation of approximately 15 PV systems over the next three years. Projects will include high visibility sites that demonstrate the application of building-integrated PV products[8];
- Climate Change Technology and Innovation Program - As part of this measure, the Natural Science and Engineering Research Council will manage a research fund for novel next-generation energy technologies related to greenhouse gas mitigation. This program targets early-stage and exploratory research in Canadian Universities and will enhance the knowledge base for longer-term solutions to climate change[9];
- Federation of Canadian Municipality (FCM) Green Fund - The federal government provides funding to the FCM to initiate green energy projects. By partnering with a local community champion, PV companies have an opportunity to propose PV deployment projects[10].

The restructuring of the electricity market in North America is drawing more interest in providing customers a power choice. Much of the regulation for electricity in Canada is under provincial jurisdiction. Alberta was the first Province to deregulate the electricity industry and electricity is traded on the Alberta Power Pool since January 1996. ENMAX based in Alberta has successfully created a green power market in Alberta. In the province of Ontario, Ontario Power Generation created an Evergreen Energy division to offer Green power to their customers. In 2001, Evergreen Energy installed a 4,8 kW PV power system on their rooftop, as part of their renewable energy portfolio. However, there is no provincial legislation mandating net-metering options be provided to customers in Canada. Small systems installed by residential customers can, in principal, be approved on a case-by-case basis for interconnection; however, the process is still costly and lengthy. In 2002, the Ontario government announced that it would propose a 100 000 PV rooftop program along with other measures that target the electricity market

Fig. 3 - Solar powered billboard designed by Phantom Electron Corp. to display the next phase of construction at the Toronto Airport. Solar signs and billboards continue to be very popular in many regions of Canada. (photo Phantom Electron Corp.)

in that province. SaskPower is the only provincial electricity company that has an incentive program that targets farmers who wish to purchase small PV or wind powered water-pumping systems.

INDUSTRY STATUS

The Canadian PV industry has grown steadily serving both its domestic off-grid market and the export market. There are approximately 150 organisations actively promoting PV power. Many of them are members of the Canadian Solar Industries Association or Énergie Solaire Québec[11].

ATS Automation Tooling System announced an 85 MCAD project to commercialize a next generation solar cell technology, known as Spheral Solar™. The newly created subsidiary of ATS, Spheral Solar Power Inc. will employ about 175 people at a new manufacturing plant near its head office in Cambridge, Ontario, Canada. This technology is a low-cost flexible solar energy product that can readily be adapted to a wide range of applications. Industry Canada's Technology Partnership Canada and Canada's Climate Change TEAM programs are partners in this project. ATS also owns Photowatt of France and has levered its automation expertise and high-volume manufacturing in the production of silicon solar cells and modules. ATS is a globally competitive company that now employs 3 200 people at 26 facilities worldwide.

Xantrex Technology Inc. based in Vancouver, British Columbia, Canada has acquired and formed an alliance with Statpower, Heart Interface, Cruising Equipment and Trace Engineering to create the world's leading supplier of advanced power electronics. In 2002, Xantrex launched a customer financing program for renewable energy products. This is the first renewable energy industry player to offer financing packages to residential, municipal and commercial customer. This joint initiative with Thalman Financial Inc, based in California, is a pro-active way to assist customers to move forward with the purchase through regular payment plans.

ICP Global Technologies, a leading supplier of consumer products in North America, has expanded its operations to manufacture a new line of PV panels. It now employs approximately 75 people dedicated to its solar product line. Its new manufacturing facility in Montréal, Québec was inaugurated in October 2000. ICP Global won a design and engineering award for its iSun Power Charger at the Consumer Electronics Show.

Carmanah based in Victoria, British Columbia is expanding its manufacturing efforts with a range of specialized products. A Canadian manufacturer of solar-powered LED lights estimates that it now has installed 45 000 units around the world since it expanded its business to serve the transportation sector. Carmanah is collaborating with the City of Victoria to demonstrate a new bus transit stop, the *i-STOP™*. It includes backlit schedule information, a safety light and a flashing beacon that alerts the bus driver when a customer is waiting at the stop.

A network of systems integration companies has established distribution and dealer networks that effectively serve a growing Canadian PV market. These include distributors for BP Solar (acquired Solarex), Shell Solar (acquired Siemens), Kyocera, Photowatt, and UniSolar. These modules are sold with product warranties ranging from 10 to 25 years and have certified their products to international standards.

MARKET

The Canadian PV installed capacity in 2002 was 10 Megawatt with a sustained domestic market growth that has averaged 23 % over the last nine years. In 2002, the annual PV module market grew to 1,17 Megawatt per year compared to 1,68 Megawatt in 2001. There was a surge in manufacturing and exports. Fourteen manufacturers reported sales of 57 MCAD and the creation of 251 new jobs in 2002. It is estimated that the Canadian PV industry generated revenues of 95 MCAD and employed approximately 525 people in 2002.

There are still many barriers to the development of the grid-connected market sector in Canada. In particular, residential customers find the installation and approval process costly and lengthy. Commercial and industrial customers generally have dedicated staff and expertise to deal with the various steps and are more likely to pursue projects.

FUTURE OUTLOOK

Several Canadian PV companies have invested significantly in both the development and promotion of solar PV power systems in Canada. This is reflected by strong growth in the installed base, as well as the significant private-sector investment in manufacturing.

PV power systems have demonstrated that they are a reliable source of electricity and the public perception of this technology is favourable. Nevertheless, increased knowledge of this energy choice is required to maintain the growth of its domestic market. Both the Canadian Solar Industries Association and Énergie Solaire Québec have continued their promotional and marketing activities in Canada.

More significant effort will be required to encourage the development of the grid-connected market sector in Canada. CANMET Energy Technology Centre-Varennes completed a study examining the benefits of on-site generation using photovoltaic technologies on buildings in Canada4. Several new activities have been initiated as part of an action plan that aims to build on Canadian Industry experience base and address some of the market place barriers that currently exist. New government investments in R&D for Building-Integrated PV technology, support for the development of a technical guideline for the interconnection of small power supplies, and support for demonstrations of PV on building in high-visibility sites throughout Canada will contribute to facilitating the market introduction of PV technology for grid-tied applications in the medium to long term.

Footnotes with relevant web sites:

1 *Climate change web site: www.climatechange.gc.ca*

2 *Removing barriers to interconnection: www.micropower-connect.org*

3 *Renewable Energy and Electricity Division: http://reed.nrcan.gc.ca*

4 *Photovoltaic for Building report: http://cetc-varennes.nrcan.gc.ca/eng/publication/r2001-123e.html*

5 *CETC-Varennes was formerly known as the CANMET-Energy Diversification Research Laboratory (CEDRL)*

6 *PV-Hybrid Program newsletter, HYBRID-INFO: http://cetc-varennes.nrcan.gc.ca/eng/publication/2002-109e.pdf*

7 *Free software tool: www.retscreen.net*

8 *REDI ON-SITE initiative: http://reed.nrcan.gc.ca*

9 *Funding University research: http://www.nserc.ca*

10 *Green Municipal Fund: www.fcm.ca*

11 *Directory of members and companies available from: the Canadian Solar Industry Association (www.cansia.ca) and Énergie Solaire Québec: www.esq.qc.ca*

DENMARK

PV TECHNOLOGY STATUS AND PROSPECTS

FLEMMING KRISTENSEN, ENERGIMIDT A/S, DENMARK, PETER AHM, PA ENERGY A/S, DENMARK

GENERAL FRAMEWORK

Renewable energy technologies have high priority in the national Danish energy plan, Energy 21. The goal is partly to reduce the emission of CO2 by 20 % before year 2005 and partly to diversify the energy sector now being based on fossil fuels. At present, about 12 % of the gross national energy consumption originates from renewable energy sources; wind energy provides about 12 % of the national electricity consumption. Energy 21 and its follow-up papers outline scenarios, where i. a. photovoltaics (PV) may contribute to about 7-10 % of the national electricity consumption of Denmark in year 2030. However, no specific goals for PV deployment have yet been set, but this can be expected to change in the near future, as public perception of building integrated PVs constantly increases. It is expected that the preparatory work for a national PV strategy will be completed mid 2003.

NATIONAL PROGRAMME

PVs have been included in the action plan of the Danish Energy Authority (EA) since 1992 and have received increasing attention in the consecutive three-year Solar Energy Action Plans. Since 1992, the Renewable Energy Development Programme of the EA has supported about 125 PV projects, and by the end of 2002 about 1,5 MWp have been installed in the context of demonstrations plants. A 300 roof-top's project including 750 kWp was launched early 1998 and was completed by end of 2001. A 1 000 roof-top programme was launched late 2001 as a follow up. This programme targets a mix of general cost reductions, increase in end-user payment and promotion of small roof-tops. Only a few weeks after the announcement of the programme, the SOL 1000, more than 3 000 house owners had registered their interest. However, uncertainty about the programme due to change in government and increased demand for end-user payment have introduced a delay of more than 9 months in the programme implementation. By the end of 2002, the programme reports a portfolio of some 1 300 house owners expressing firm interest in the programme. First installations are expected in May 2003.

A special support programme for PV applications in the commercial sector, funded by the CO_2 tax on electricity, was set up early 1998. The support includes a subsidy of up to 40 % for the turn-key costs. The calculation of the actual subsidy will be in favour of high yield installations. This programme has so far not been very successful, as the commercial sector seems to regard an incentive of 40 % as inadequate, and during 2002, no projects have been implemented using this support mechanism.

Net-metering for privately owned PV systems was established mid 1998 at the time, for a pilot-period of four years. Work is ongoing to make this system more permanent. In late 2002, the net-metering scheme was extended another four years until 2006. A small project has been launched to identify the best possible institutional arrangements around PV systems on multi-family buildings and housing. However, uncertainty about the net-metering scheme has delayed this project; it is now expected to be completed mid 2003.

Fig. 1 - As a first part of the Sol 1000 project an office building in Copenhagen has installed a PV-system of 23,1 kWp on the roof and the façade.

In late 1999, the parliament allocated 30 MDKK for a new three-year programme, 2000 – 2002, to promote building integrated PVs in apartment buildings and institutions. The programme includes both development of new integration methods, new components and demonstrations. A small PV cell R&D activity is included as well, targeting PEC technology. By the end of 2001 six calls for proposals have been carried out resulting in 52 proposals of which 23 have received support corresponding to about 14 MDKK. The programme has created interest for PVs in Danish building industry, but programme funding was stopped primo 2002.

Efforts to establish a unified PV programme as a replacement for the so far fragmented approach with separate, consecutive narrow-focused programmes have been started, but no immediate results are expected.

RESEARCH & DEVELOPMENT

In late 2002, the government announced a new R&D programme, which also addresses renewable energy. Over a 3-year period 110 MDKK will be allocated to renewables, however it is to early to say to which extend PVs will benefit from the new programme.

R&D on PV cell manufacturing (mono-X Si) has taken place at the Technical University of Denmark for about two decades. This R&D effort led to the establishment of the first Danish PV cell/module

Fig. 2 - As a first part of the Sol 1000 project an office building in Copenhagen has installed a PV-system of 23,1 kWp on the roof and the façade.

manufacturer in 1992. The company folded mid 1996 after a period in receivership, and is now reconstructed as a module assembling plant. R&D activities into PEC cells (Grätzel type cells) are ongoing at the Danish Institute of Technology. In 2002, this activity has been supported by the Public Service Obligation (PSO) of the Danish utilities.

At the Risoe National Laboratory, basic research into polymer based PV cells is ongoing, albeit on relative low funding.

In Mid-1995, the Photovoltaic System Laboratory (PVSyslab) was established in collaboration between Risoe National Laboratory and the Danish Institute of Technology. The main function of PVSyslab is to certify the quality of PV systems and to help industry develop better products, systems and recommended practices for design and installations. The PVSyslab, which is now integrated into the Solar Energy Centre Denmark, is active as group leader in the CENELEC & IEC TC 82 work and participates in the GAP initiative. The Solar Energy Centre Denmark has ongoing activities the field of technology cooperation with developing countries and is presently engaged in Nepal in setting up a local quality assurance scheme and laboratory.

Inverter technologies are being R&D' for both fuel cell and PV applications. Efficiencies of up to 98 % have been reported using transformer-less, highly integrated designs, and efforts to develop smaller units, about 2 kW and smaller, are ongoing.

Stimulated by the above mentioned three-year programme 2000-2002, which supports up to 40 % of R&D costs, Danish building industry has exhibited increasing interest in the integration of PV's in existing and new building components, and a few new products have emerged.

IMPLEMENTATION

The potential for large scale deployment of PVs in Denmark has been identified as building integrated systems.

However, during 2002, only a few grid-connected, building integrated PV systems were commissioned, as Denmark has been "between programmes".
The SOL 1000 programme intends to demonstrate low cost and architecturally acceptable integration of PV technology primarily on existing single family houses and to increase end-user payment, this way preparing the introduction of a more commercial market. A secondary objective has been to disseminate information and experience on PV roof-top deployment to the Danish distribution utilities.

Several projects for building integrated PV systems including commercial buildings, apartment buildings and schools have been implemented, typically in the range of 2-15 kWp.

INDUSTRY STATUS

The company Topsil, which uses a float-zone technique produces high purity Si ingots for the semiconductor industry, announced in 2002 their intention of developing a low-cost float-zone manufacturing technology. That would enable the company to offer high purity Si to the PV industry. Initial efforts indicate that +20 % efficient cells based on the float zone Si may be competitive in the near future.

PV cell production stopped in Denmark in 1996. A single Danish module manufacturer (Gaia Solar) with an annual capacity of about 1 MWp per shift has existed since 1996. A few other companies producing tailor-made modules such as window-integrated PV cells can be found.

Fig. 3 - The Float-zone crystal growth process is used by Topsil Semiconductor Materials, for their specialised low-cost PV-FZTM wafer product dedicated the very high efficiency solar cell market.

Some medium to large scale industrial corporations long established in the building industry, such as Velux Industries and Dansk Eternit, continue their R&D into how to integrate PVs in their main stream products. The products are currently under field tests in the context of demonstration projects. New companies are also exhibiting interest in this field.

There is no PV relevant battery manufacturing in Denmark at present.

A few companies develop and produce power electronics for PVs, mainly for stand-alone systems for the remote-professional market sector.

A number of companies are acting as PV system integrators, designing and supplying PV systems to the already competitive international market sector of remote stand-alone applications.

Consultant engineering companies specializing in PV application in developing countries report a slowly growing business area.

Total PV business volume is estimated to be about 10 MUSD in 2002 a reduction compared to 2001, mainly because of the Sol-300 project having finished and the SOL 1000 project having in reality only stated up ultimo 2002.

MARKET DEVELOPMENT

Market development incentives already in place are mentioned above under National Program.
Utility PSO (Public Service Obligation) support for PVs was first used in the Sol-300 project. The frame for PSO funding for PVs was about 10 MDKK in 2002.

The cumulative installed PV capacity in Denmark (including Greenland) was, by year end 2002, estimated to be about 1,5 MWp; in reality remaining unchanged when compared to 2001.

FUTURE OUTLOOK

The new government funds (110 MDKK) allocated to R&D into renewables are expected to give a boost to the PV sector, as well.

The SOL 1000 project targeting building integrated PVs mainly on single family houses, but also addressing apartment houses and institutions is expected to lead to ongoing availability of government funds for PVs. Without funding and a clear public support to PVs, the sector will quickly diminish.

However, a demonstrated constant development towards commercial sustainability for PVs is seen as critical for continued support from the government and the utilities. Danish efforts to promote PVs have so far been rather fragmented, and there is now an understanding of the need to establish a more concerted effort in order to underpin and consolidate the growing but still very weak commercial PV sector. Preparatory efforts to establish a national strategy for PVs have been started early 2003.

FINLAND

PV TECHNOLOGY STATUS AND PROSPECTS
LEENA GRANDELL, MOTIVA OY

GENERAL FRAMEWORK

In the past, main efforts in Finland regarding photovoltaics have been set on research and development. However, this changed when the Ministry of Trade and Industry launched an Action Plan for Renewable Energy Sources in 1999, in which clearly more emphasis is given for the enhancement of the domestic market development. The Action Plan is one crucial part of the National Climate Strategy, which has been formulated to achieve the goals of greenhouse gas reductions set for Finland by the Kyoto Protocol. During 2002, the Action Plan has been evaluated and revised.

The photovoltaic sector is still fairly modest in Finland, providing work to approximately less than 100 employees. The main actors consist of several companies (suppliers and consultant companies), a number of research institutes and two associations. Within the government, the Ministry of Trade and Industry has the main responsibility for enhancing renewable energy sources, including photovoltaics. Motiva, the Energy Information Centre for Energy Efficiency and Renewable Energy Sources has also an active role in the enhancement of the market. During 2001, a network called FSI, Finnish Solar Industries, was established consisting of companies and other entities. The purpose of the network is to enhance the opening of the PV markets through collaboration.

NATIONAL PROGRAMME

The Action Plan for Renewable Energy Sources sets objectives for the volume of energy generated by renewable sources in the year 2010, and in addition a prognosis on the development until 2025 is included. Even though the main emphasis of the Action Plan clearly lies on bioenergy, very ambitious goals are also set for solar energy, including photovoltaics. The objective for installed photovoltaic capacity in 2010 is 40 MWp, meaning a 20 fold increase when compared with the 1998 situation. The prognosis for 2025 is 500 MWp. Thus, the main emphasis in the coming decade is on creating the needed infrastructure (awareness, information dissemination, export, industrial activities) whereas volume effects are sought later. The impact of photovoltaics on the total environmental effects of the Action Plan is assessed to be less than 1 % in 2010.

Examples of concrete actions during the coming years include among others a comprehensive information dissemination plan, changing of building requirements to account for solar energy, or various actions to help small scale electricity producers to enter the grid.

RESEARCH AND DEVELOPMENT

Research and development work on photovoltaics is carried out by a number of institutes, mainly Helsinki University of Technology, Tampere University of Technology, University of Jyväskylä and Technical Research Centre of Finland. Also a number of companies, like Fortum Ltd and Rautaruukki Oy are active in the field. Tekes, Technology Development Centre, is the main national funding source. Public research funds are being distributed on project basis.

During 2002, a couple of research institutes and companies received funding mainly for development of new materials as well as optimisation on the system level.

Helsinki University of Technology, being the main actor in the research field, concentrated on research on ageing phenomenon of solar cells as well as new materials. Thin film cells (especially Cadmium Telluride CdTe and Gallium Diselenide CIGS) are interesting with respect to their stability in varying outdoor conditions. Accelerated ageing studies are being carried out in laboratory conditions. Dye sensitized solar cells is a new area of interest funded by Tekes. Here the aim is to concentrate on manufacturing technological aspects with the aim of understanding factors critical to the performance of the cell and development of new manufacturing methods applicable to large scale production.

INITIATIVES FROM GOVERNMENT AND UTILITIES

During 2002, investment subsidies in solar energy have been risen from the previous level of 30 % to 40 % to be comparable with other new technologies such as wind energy. Another change sought in the near future is that subsidies will be made available to private persons. Until now only communities, organisations and enterprises have been granted subsidies. During 2003, subsidies for renovation of buildings will be more focused on the energy system. This will comprise also the change of energy source towards renewables.

The Ministry of Trade and Industry is currently developing a system for guarantee of origin for electricity generated by renewable energy sources based on the European RECS project.

A new project has been launched during 2002 concentrating on the development of a solar ESCO approach suitable for the Finnish market situation. The aim of the project is to find solutions to the basic questions such as financing basis and the reliability and performance of the solar system. The project aims to a realization of at least 30 kWp photovoltaic capacity based on the SESCO approach.

INDUSTRY STATUS

The Finnish PV market is characterised through some 10 importing companies with numerous retailers. No domestic PV cell production exists but on the other hand a number of companies are active in technology development of components and on system level. Thus, several innovations of Finnish companies are on the market. One new product launched in the market in 2002 is a partly see-through PV module used as balcony glassing, which has been demonstrated at the Ekoviikki site in Helsinki.

Fig. 1 - Ekoviikki area is a unique ecological housing area in the capital Helsinki. Special emphasis has been put on several ecological issues such as energy. By the end of 2002, the largest building integrated PV system in Finland in a dwelling house (24 kWp) was installed. The modules are partly see-through type and they form part of the balcony glassing on south and west sides of the building. During summer time, the excess electricity is fed into the grid whereas in winter months the local energy company returns it back. Approximately one fourth of the electricity consumption over the year is generated by PV. (Photo Solpros Ay)

MARKET DEVELOPMENT

Three main segments continue to rule the photovoltaic markets in Finland:

- built environment
- summer cottages, recreational boats and other applications with electricity consumption concentrating on summer months
- larger applications in remote areas (>1 kWp)

The domestic markets are still dominated by small solar home systems for vacation houses, typically 50-100 Wp in size. Examples of larger applications in remote areas are telecommunication base stations, weather stations or the 20 larger stand-alone hybrid systems operated by the Finnish Coast Guard. Over the last couple of years building integrated applications have become a new important market segment, the importance of which seems to also be growing in the future.

FINNISH PV SYSTEMS 2002

	Power (kWp)
Solar home systems	2 680
Stand-alone systems	240
Grid-connected (utility)	32
Grid-connected (roof-top)	96
TOTAL	3 048

(the cumulative installed capacity)

FRANCE

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS IN FRANCE

ANDRÉ CLAVERIE
AGENCY FOR ENVIRONMENT AND ENERGY MANAGEMENT (ADEME)

GENERALFRAMEWORK OF PHOTOVOLTAIC (PV) ACTIVITIES IN FRANCE

The Agency for Environment and Energy Management (ADEME) is the French government's body in charge of the promotion of the renewable sources of energy.

In 1999, ADEME instigated a programme aimed at the development and the promotion of renewable energies sources within the framework of a 7-year contract signed with the government. This contract includes objectives in figures for installed power within the various technologies by 2006. This programme is also integrated in the objectives of the new European directive that is set at 21 %, by 2010, the share of power generated by renewable energies sources. As part of these commitments, the French overseas departments and Corsica, geographical zones where electricity is expensive to produce, are the preferred fields of implementation of the renewable energies sources.

Regarding photovoltaic solar electricity, ADEME's effort over the past years has primarily been made on the rural electrification of isolated houses located outside the grids (14 MW operational at the end of 2002). More recently, another type of system application has been integrated by ADEME in its strategy through the implementation of demonstration projects in relation with distributed photovoltaic power systems connected to the grid. Instigated by the European Commission, these projects have increased the operational power capacity for this type of application to 2 MW at the end of 2002, and they activated the ADEME's launch of a more ambitious installation programme of built-integrated PV systems connected to the grid. This new programme is accompanied by investment subsidies as well as photovoltaic electricity buy-back rates (see section on Implementation).

ADEME'S PROGRAMME

In the field of photovoltaics, ADEME's strategy (www.ademe.fr) is to encourage the rise of a high tech industry offering new energy services. ADEME relies on motivated industrial and public players who have been involved, for the most part, in the photovoltaic sector for several years.

The action programmes implemented by ADEME in view of encouraging the deployment of photovoltaics cover two types of activities:
1) a research and technological development (RTD) programme lead by the Renewable Energies Department and based at ADEME's Sophia-Antipolis centre and
2) a dissemination programme managed by the 26 regional delegations of ADEME through a partnership worked out with the regional councils for co-financing the operations.

The RTD programme was launched in 1999. ADEME, which is in charge of the French State's objectives does not own a laboratory. It works in collaboration with companies and public research teams via financing, at shared costs, and on innovation projects that come within its strategy.

Research projects cover a wide field of investigation: the purification techniques of the feedstock silicon material; the innovating processes for manufacturing photovoltaic cells and modules; studies for the improvement of the various components and the systems themselves associated with their specific high yield applications. Aimed at lowering the components manufacturing costs and the systems operating costs; the general objectives are also designed to increase their performance and their reliability by encouraging their integration into architecture.

The RTD activity is completed by accompanying studies: develop-ment of standards and technical specifications, tests and trials of components and systems, establishment of databases, training of electricians and providing information to users, etc. The total cost of photovoltaic RDT programme over the 4-year period (1999-2002) has been 70 MEUR. ADEME has contributed in the form of a 23 MEUR subsidy over this period. The additional financial share came from the industry and covered 50 % to 70 % of the total costs of the projects and from public partners that contributed 50 % to 80 % of costs.

The second aspect of ADEME's action is the dissemination programme, within which two types of photovoltaic systems are taken into consideration:

- The stand-alone off-grid PV systems feeding in electricity isolated sites, located outside the electricity grids;
- The distributed photovoltaic systems integrated into the built environment (as roof cladding or as facade), connected to the public low voltage distribution grid. These systems are also called built-integrated PV (BIPV) power systems.

Over the last 4 years (1999-2002), the public intervention budget at stake under this dissemination programme was about 36 MEUR of which 16 MEUR was for ADEME, 16 MEUR for the regional councils associated with the programme and 4 MEUR for the rural electrification fund (FACÉ).

RESEARCH AND TECHNOLOGICAL DEVELOPMENT

Companies such as Photowatt International, Total Énergie, Apex-BP Solar, Ceac/Exide, the engineering offices, the public research organizations CNRS, CEA, EDF and CSTB are the main players of ADEME's RTD programme. 2002 was the fourth and last year of the 4-year projects financing for projects which will be concluded during the second half-year of 2003 and will be subject to an in-depth assessment carried out by the PV RTD Experts Committee on which ADEME relies.

The most important projects financed in 2002 concerned:

- The implementation of the 18-month second phase of the project lead by EDF R&D on the Cu-In-Ga-Se thin film-based cells/modules in co-operation with the CNRS/LECA and

Fig.1 - 3 kW Roof Integrated Photovoltaic System. (Grenoble 38, Courtesy of Total Énergie)

Saint-Gobain Recherche. EDF devoted a financial and organizational effort to this project by bringing together on a unique site, the human resources which, until then, were scattered among several sites;

- The launch of a 4-year research project on photovoltaic cells using polymer, molecular and organic materials coordinated by CEA in collaboration with CNRS, the universities and TotalFinaElf;
- The implementation of a pilot laboratory which allows for elaborating large area photovoltaic cells based on crystalline silicon. This pilot, installed at Grenoble CEA-GENEC within a microelectronic R&D environment (CEA-LETI) will be able to study and validate, at a significant scale, the results from the innovations offered by industrial and public teams.

It should be noted that 2002 has been marked by a clear commitment of CEA in photovoltaics. This resulted not only in the provision of additional personnel to the GENEC Laboratory (PV components and systems) of Cadarache and its involvement in the PV organic compound cells project but also in an investment shared with ADEME in the equipment of the GENEC pilot laboratory of Grenoble, as mentioned above.
CNRS, for its part, has reorganized its policy vis-à-vis photovoltaics. A group of experts made up of specialists from CNRS, the industry and society has been given the responsibility to think about the new orientations of the "photovoltaic cells of the future" programme. A programme of actions will be unveiled in 2003.

A technical seminar, organized on 19 and 20 November 2002 by ADEME in conjunction with CNRS at ADEME Centre at Sophia-Antipolis, has brought together one hundred specialists working on the themes of material and processes for photovoltaic cells. The quality of the presentations and the results, which were emphasized by ADEME's PV RTD Expert Committee, together with the number of participants have shown the new impetus given to this field (seminar proceedings in French are available upon request).

Regarding further questions on the integration of photovoltaics into the built environment, four projects concerning new BIPV products (roof tiles, canopies and curtains walls, etc.) have been selected. Two of these are in the invitation to tender launched by ADEME in 2002, within "Preparing the construction industry for 2010" programme. Regarding accompanying studies carried out under the RTD programme, in 2002, the development and the publication of two technical documents should be mentioned:

- Technical specifications for integration of photovoltaic systems into the built environment. This publication has been prepared by CEA-GENEC and ADEME in cooperation with the industry.
- Technical documents for the approval of the integration of PV modules into the built environment. This document has been developed by CSTB (the French Construction Industry's Scientific and Technical Centre) in partnership with ADEME. CSTB has launched the first procedures for the technical assessment of the PV modules. The assessment campaign, in view of issuing the Technical Approvals (ATec CSTB), will start in 2003.

These documents have been presented on the occasion of two meetings, which brought together over one hundred and twenty people: professionals from the photovoltaic industry, companies from the construction industry and architects (Montpellier, February 2002 and Sophia-Antipolis, October 2002). The objective of these meetings was to launch the ADEME's BIPV power system programme and to discuss with the stakeholders about its implementation means.

Within this partnership environment, ADEME has signed agreements with public organizations CEA, CNRS, CSTB and EDF in order to allow the implementation of a consistent national policy of actions.
Still on consistent action, it should be said that within the European Union, ADEME is participating in a network of experts within the framework of a project called PV-EC-NET, which aim is to harmonize the national photovoltaic RTD policies (www.pv-ec.net). A report of findings will be handed in during the second half-year of 2003.

Regarding the collaboration with third countries, ADEME and its partners are stakeholders in projects receiving funds from the European Commission (DG RESEARCH and DG TREN) as well as in study projects at shared costs such as those under the Photo-voltaic Power Systems programme of the International Energy Agency (IEA). In this programme, ADEME contributes to Tasks 1 and 9 and has entrusted specific duties to Armines (Task 2), CEA-GENEC (Task 3) and IED (task 9) while PHK Consultants was entrusted with running Task 3. In 2002, several new technical reports on the stand-alone photovoltaic systems have been published (see www.iea-pvps.org).
ADEME, CEA-GENEC and EDF-R&D are active in the International Electrotechnical Commission (IEC, www.iec.ch) Technical Committee TC 82 working groups and of the TC82, TC21 and TC88 technical committees joint coordination group in order to develop the future IEC 62257 International Standard on the technical specifications of decentralized rural electrification using renewable energies sources.

IMPLEMENTATION

The implementation elements of the ADEME's PV RTD programme have been described in the section Research and Technological Development.
For the implementation of the dissemination programme, ADEME will rely on partners such as the regional councils, with which contracts for commitments to the promotion and funding of renewable energies have been signed.
The main public financing sources allowing the installation of off-grid photovoltaic systems are primarily the Rural Electrification Fund (FACE) and the tax deduction measures attached to the investments made in the French overseas departments and territories.
In addition, supplementary financial support is provided by the regional councils, ADEME, the European Commission and EDF ("urban regime", non-rural). The grant given by the FACE fund is equal to 70 % of the installed system's cost (further support may be granted as a supplement, but at least 5 % of the cost must still be incurred by the user). With 90 kW of projects funded and a total amount of 1,62 MEUR in works, the number of projects submitted to the FACE fund selection committee for the isolated sites in 2002 remains modest. This slowdown in the activity since about two years can be explained by a saturation of the potential market of off-grid isolated sites, notably across mainland France. Conversely, the level of installations benefiting from tax deductions under the Tax Exemption Act for investments made in the French overseas departments remains stable: about 1 MW installed per year.

The ISIS (www.base-isis.com) proprietary database has put together technical, financial and sociological data on the stand-alone off-grid photovoltaic systems funded with public funds. The database became operational in 2002 with 600 installations registered (3 000 are planned by the end of 2003).

In the case of the distributed grid-connected photovoltaic systems, about 500 kW have been installed over the year 2002. In order to implement the new BIPV power systems dissemination programme, ADEME relies on preferential buy-back rates of electricity and an investment subsidy scheme. According to the type of beneficiaries and the type of partnership signed with the various regional councils, the investment subsidy covers from 40 % to 80 % of costs.
The maximum eligible cost is of 9 kEUR per installed kilowatt.

Photovoltaic electricity buy-back rates, set by the 13 March 2002 decree, are 15,25 eurocents a kWh in mainland France and 30,50 eurocents a kWh in the French overseas departments and Corsica. The contracts for purchasing electricity energy generated by the photovoltaic installations will come into force in 2003. In 2002, grid-connected photovoltaic systems operated on the basis of a buy-back rate equivalent to the cost paid by the private user, i.e. about 9 eurocents a kilowatt-hour.

Contracts for connection of the distributed photovoltaic power systems to the public low voltage distribution grid have been submitted to the CRE (Electricity Regulation Commission) for advice and should be published in 2003. The PV industry, engineering office Transénergie, the Hespul association and the Professional Federation of Renewable Energies (SER) have been very active in the development of texts relating to these contracts.

Électricité de France (EDF), the French electricity utility carries out several projects: a) research works supported by ADEME on the Cu-In-Ga-Se thin film-based polycrystalline obtained through electrodeposition in collaboration with Saint-Gobain Recherche and CNRS; b) studies carried out on the storage and management systems as well as the tools and materials for rural electrification and, c) rural electrification in the developing countries with the "ACCESS" programme. An annual budget of about 9 MEUR has been earmarked by EDF for all of these activities.

INDUSTRY STATUS

For most of the companies operating in the photovoltaics industry (Photowatt International, Free Energy Europe, Total Énergie, Apex Bp Solar, Sunwatt, Naps France, etc.) their business continues to increase in turnover (over 20 % of increase in average) as well as in new jobs (+ 16 %).

Photowatt International Company has achieved an annual production rate of 20 MW of photovoltaic cells (13 MW in 2001). The cells size has increased from 10 cm x 10 cm to 12,5 cm x 12,5 cm for the thinnest wafer on the market with an average conversion efficiency improved by one percentage point. The various stages in the manufacturing processes require the techniques developed as part of the research projects supported by ADEME (directional solidification of the multicrystalline ingots, wire-sawing in thin wafers, screen-printing of the metal contacts, nitridation and plasma enhanced hydrogenation, etc.). Some of these innovations resulting from the RTD "PV-16" (1999-2003) project supported by ADEME, have recently been integrated into the production tool and others will be included as they come and according to their validation (objectives: 150 µm thin wafer, cell conversion efficiency at 16 %, direct production cost of module at 1,17 EUR a watt, etc.).

The Free Energy Europe Company manufactures around 600 kW of amorphous silicon modules which stabilized power ranges from 4 W, 6 W and 12 W. The company has put several types of small stand-alone photovoltaic systems on the market, designed for rural electrification. In 2002, new modules with 19 W of power, using tandem junctions have been developed and they will be submitted to a series of tests to meet the requirements of the IEC 61646 Approval Standard. They will be launched onto the market in 2003.
Total Énergie and Apex Bp Solar companies hold international influence and are specialized in components for engineering, development and the installation of ready-made systems. They are deeply involved in ADEME's dissemination policy through their subsidiaries in the French overseas departments. These two companies are stakeholders in the RTD projects supported by ADEME. The main objective is to cut, by 30 %, the costs of components (inverters, energy management and packaging, electronics, pumps, etc.) and the operating costs of the photovoltaic systems. In 2002, Total Énergie Company has decided to install a new plant in Toulouse, for manufacturing photovoltaic modules. For its part, Apex BP Solar has extended its commercial network in French Polynesia and in Africa.
The recently built Emix Company, has laid the foundation stone for the plant near Limoges, which will manufacture ingots of multicrystalline silicon by continuous pulling technique through an electromagnetic cold crucible. In 2002, companies such as Pechiney and Apollon Solar have enhanced their reflection on the issues of low cost feedstock silicon but they did not come to the decision of implementing a production plan. In 2002 still, companies such as Imerys-Toiture, Clipsol, Kawneer and Solarte got involved, with the support of ADEME, in studies on the development of PV components integrated into the built environment.

MARKET DEVELOPMENT

The global turnover achieved by the main companies of the photovoltaic electricity industry is around 142 million euros in 2002 (20 % increase).

During the year 2002, the installed capacity of photovoltaic systems in France and receiving public grants has been about 1,6 MW which brings the total operational capacity to 16 MW of which 2 MW is from grid-connected systems. In 2003, ADEME has planned the installation of 1,8 MW of grid-connected BIPV systems and 1,2 MW of off-grid PV systems. The Professional Federation of Renewable Energies SER (www.ser-fra.com) would like to have ADEME increasing its investment subsidy budget for the BIPV systems programme.

FUTURE OUTLOOK

Four years ago, ADEME launched an action programme aimed at supporting the development of photovoltaics by taking advantage of the new political and regulating measures decided by the Government (National Energy Efficiency Plan, the implementation of the European directive and PV electricity buy-back rates).

The outcome of ADEME's programme has been the enhancement of the R&TD activity associated with the confirmation of the companies and the public organizations' participation, and notably in 2002, CEA, CNRS and EDF decisions to commit themselves to ambitious projects. In the year 2003, ADEME will make an assessment of the 4-year research programme (1999-2002) and will launch new research and development operations encouraging new players.

The dissemination programme of the distributed grid-connected built-integrated PV systems launched in 2002, made provision for the installation, by 2006, of 20 MW of systems. This programme will start in 2003 with an installed capacity of 1,8 MW. It is also planned, in 2003, to participate in the installation of 1,2 MW of stand-alone off-grid PV systems, i.e. in total for these two types of applications 3 MW. This is an important increase in the activity when compared to the last two years.
The texts of the photovoltaic electricity purchase contracts and those of the public grid connection contracts worked out in the year 2002 will be fully operational in 2003 and photovoltaic companies have well-filled order books to participate in ADEME's BIPV systems dissemination programme.

Footnote:

[1] *Mainland France, Corsica and French overseas departments (exclusive of the overseas Territories)*

GERMANY

PV TECHNOLOGY - STATUS AND PROSPECTS
CHRISTOPH HÜNNEKES, PROJEKTTRÄGER JÜLICH (PTJ),
FORSCHUNGSZENTRUM JÜLICH GMBH

Fig. 2 - EFG Cell Production Line of RWE Schott Solar's SmartSolarFab™. (Photo RWE Schott Solar GmbH, Alzenau)

GENERAL FRAMEWORK

The reduction of emissions of greenhouse gases is an important target of many environmental policies in Germany. It is expected that photovoltaic (PV) may contribute to this target in the long term.

Analysis performed for the Federal Ministry of Environment (BMU) [1] came to the conclusion that there is a technical potential for all renewable energies in Germany of 450 TWh electricity annually and that PV may be responsible for approximately 19 % of this. Therefore, research, development and demonstration as well as market introduction of PV are supported from several sides, especially the Federal Government, the Federal States, local autho-rities and utilities.

NATIONAL PROGRAMME

Since autumn 2002, the Federal Ministry of Environment (BMU) is responsible for the renewable energies within the Federal Government. Research and Development (R&D) is conducted under the **4th Programme on Energy Research and Energy Technology**. Important parts of this programme, namely the development of techniques for an efficient use of energy and renewable energies are managed by the Project Management Organisation PTJ.

In 2002, the federal support for R&D on PV amounted to about 23,6 MEUR shared by 129 projects in total. The distribution of the budget to the various sectors of R&D shows that funding is concentrated on the long-term options and activities to create a technological basis for small and medium enterprises (see Fig. 1).

Funding for R&D 2002 by BMWA (23,6 Mio. EUR in total)

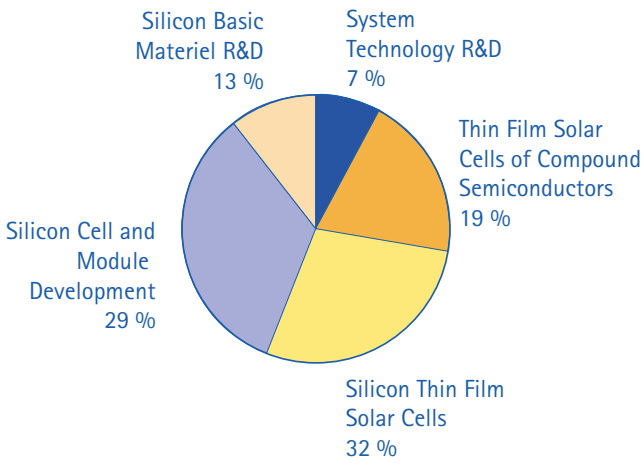


Fig. 1 - Governmental Funding of R&D in 2002

In January 1999, the so called **"100 000 Rooftops Solar Electricity Programme"** came into force. It is expected that with support of this programme approx. 300 MW will be installed until the end of 2003. In addition to this programme, the **Renewable Energy Sources Act (EEG)** works are guaranteeing a feed in tariff of currently 0,48 EUR/kWh for PV (initially the EEG started with 99 DPf / kWh – 0,51 EUR/kWh).

R,D&D

With a time horizon of ten years a so-called **"Way Paving Programme Photovoltaic 2005"** has been formulated in the 4th Energy R, D&D Programme with three main goals:

- Cost-reduction for PV-cells and modules by decreasing production costs and by increasing cell and module efficiencies.
- Cost-reduction, technical optimisation and removing other obstacles that prevent the use of PV in different types of buildings.
- PV for decentralised, grid-independent electricity supply.

In the following, selected topics of important R&D-activities in Germany are described.

Crystalline Silicon (Basic Material R&D - Cell and Module Development)

Crystalline silicon is still the most important material for manufacturing solar cells. Today, emphasis is placed on efficient manufacturing techniques. In 2002, new R&D activities were focused on:

- Co-operate R&D project ASIS - **A**lternative **S**ilicon materials for **S**olar Cells;
- Development of a progressive technology for EFG Silicon ribbons and solar cells (see Fig. 2);
- Expert circle SOLPRO - Innovative and economic production processes for Silicon based PV modules (see www.solpro.de);
- development of innovative solar cell concepts like rear contact cells.

One important aim is to strengthen technologically oriented small and medium sized companies and by this, to create a productive supply industry.

Thin Film Technologies

Thin Film Technologies have the potential to combine low material- and energy-consumption with simple process technologies resulting in a cost-effective large area production. Today, several materials are used and a lot of cell concepts with different maturity exist:

TECHNOLOGY	NEW R&D ACTIVITIES WITH FEDERAL SUPPORT
Currently amorphous Silicon (a-Si) has the highest technological maturity. In Putzbrunn RWE Schott Solar GmbH is running a production line.	• co-operate R&D project for the development of textured TCO layers, • a-Si / µ-Si Tandem Cells
Thin Film Solar Cells on basis of CuInSe2 (CIS) have been developed in Germany for years. Currently Würth Solar GmbH&Co. KG is operating a first pilot production line.	• development of efficient deposition techniques
Antec Solar, engaged in the production of Cadmium Telluride (CdTe) cells, is looking forward to finalise contracts with a new investor.	• basic research on materials and layer interfaces
A very promising technique seems to be the crystalline Si thin film cell.	• joint R&D project to develop efficient deposition techniques on large substrates, development of ceramic substrates

System Technology

Increasing numbers of decentralised power systems connected to the public grid like small and medium sized PV systems make it necessary to analyse their influence on the stability of the grid. Features like communication, power management and safety become more important. R&D projects like the SIDENA - project (see www.sidena.de) address these questions.
Beside this, the evaluation of PV-systems is a topic of interest. Corresponding activities are partly carried out under Task 2 of the IEA-PVPS programme.

Demonstration

Today, the EEG together with the "100 000 Rooftops Solar Electricity Programme" is the driving force for the development of the German PV market. Consequently, demonstration projects play a minor role within the current R, D&D-programme.

IMPLEMENTATION

In recent years, Germany has executed important programmes in the field of PV which have triggered remarkable results in market development and technology progress. Complementary to the R, D&D- programme the following measures in the area of market introduction have been established:

- The "Electricity Feed Law" introduced in 1991 was substituted by the **"Renewable Energy Sources Act (EEG)"** in April 2000. The new law rules the input and favourable payment of electricity from renewable energies by the utilities. For PV systems built in 2002, a feed in tariff of 0,48 EUR/kWh will be paid.

- In January 1999, the Federal Government started the **"100 000 Rooftops Solar Electricity Programme"**. Until end of 2002 almost 54 000 applications were received and a total capacity of 200 MWp was granted (see Fig. 3). The programme is a soft loan programme (current rate of interest 1,9 % per year) and will last until 2003. Applications can be filed by small and medium enterprises as well as by individuals. A budget of approx. 460 MEUR was offered for the whole period of this programme.

- Moreover, other applications of renewable energies (solar-thermal, geothermal, biomass etc.) are supported by soft loans or subsidies. The PV initiative **"Sun at School"** is part of this programme.

- Some of the **Federal States** (Länder) have defined their own programmes, mainly to support the application of renewable energy and energy conservation.

- The **Federal German Environmental Foundation** (DBU) supports development and demonstration in the field of renewable energy sources and energy conservation.

- A number of **utilities** have launched initiatives to build PV-demonstration and pilot systems or to provide advice and information. In a growing number of cases, financial support for the rational use of energy and for renewable energies is provided. **Cost-effective payments** for every kWh of energy fed into the public grid from PV and other renewable energy systems is offered by some utilities belonging to cities and communities.

INDUSTRY STATUS

During recent years, an industrial infrastructure has been created with the main focus on crystalline Silicon technologies. Like almost everywhere, the PV market still strongly depends on governmental support.
For 2000, the BMU estimates a total turnover of 340 MEUR for PV in Germany. Roughly 4 000 full time labour positions are connected to this business [1].

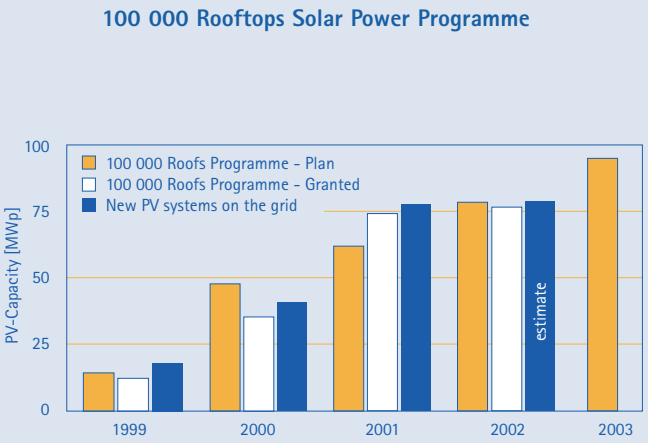


Fig. 3 - Grid connected PV power supported by the Federal "100 000 Rooftops Solar Power Programme"

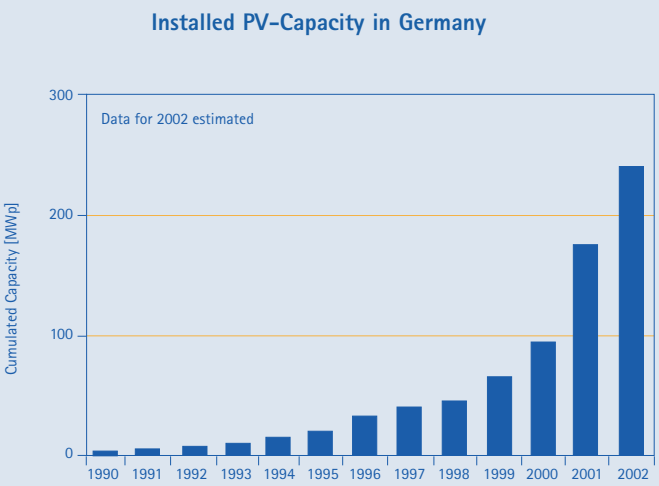


Fig. 4 - Cumulated grid connected PV power in Germany

MARKET DEVELOPMENT INCENTIVES

The programmes described above have accelerated the installation of PV-systems in Germany significantly (Fig. 4). Following a first estimate there could be roughly 260 MWp on the grid at the end of 2002.

FUTURE OUTLOOK

While the EEG was extended to a maximum PV capacity of 1 000 MW in summer 2002 the "100 000 Rooftops Solar Electricity Programme" was designed to run until the end of 2003. Follow-up initiatives are under discussion but currently, it is not clear which kind of incentive will be adopted.

LITERATURE

[1] Umweltpolitik - Erneuerbare Energien in Zahlen, BMU 2002 (see www.bmu.de)

ISRAEL

PV TECHNOLOGY STATUS AND PROSPECTS: AN UPDATE
DR. H. AVRAHAM ARBIB, DIRECTOR, DIVISION OF R&D,
MINISTRY OF NATIONAL INFRASTRUCTURES

GENERAL

Photovoltaic activity in Israel is concentrated mainly in academic research, with limited industrial involvement. The ubiquity of the electricity grid makes most applications non-cost-effective, except in unique situations.

About 470 kWp have been installed so far; 32 kWp were installed in 2001. Nearly all the applications are off-grid remote electrification systems. Most installations were made on an economic basis, the PV system being the most economically viable alternative (because of its distance from the electric grid).

The Israel Electric Corporation (IEC) is required to purchase electricity from private producers, according to rules set by the Ministry of National Infrastructures. There are no promotion initiatives or subsidies for PV systems. However, there are indications that public perception of renewable energy is becoming increasingly positive. As a result, both the Government and the IEC are studying net-metering schemes and revising regulations to enable power buy-back.

A resolution adopted by the Government in November 2002 mandates that at least 2 % of total electric energy be generated from renewable sources by 2007, rising to 5 % by 2016. The decision might positively influence also the local PV market.

There are no special regulations relating to PV systems, although the IEC has general guidelines relating to the quality of the electricity it purchases.

INDUSTRY INVOLVEMENT

A few firms are active in the PV field, and they deal mainly with system integration. Most companies are small, and are not exclusively dedicated to PV. Some of the local production of systems is exported.

Presently there is no local production of PV cells nor inverters. Israel has the required technological infrastructure enabling it to produce all the components needed for integration in PV systems. However, due to economical considerations, components such as modules are imported. In spite of this, some unique Israeli PV systems have high added value related to the balance of system (in particular, control systems), and therefore, they have international market potential.

RESEARCH AND DEVELOPMENT

More than fifty research teams are involved in photovoltaic R&D, most of them from academe, spread over most research areas (with no concentration of effort on particular subjects). Many of these teams cooperate with leading teams worldwide (both in academe and in industry).

Among the current R&D projects, a number are highly innovative and worth noting:

- A novel thin-film solar cell from carbon, in its new form of buckminsterfullerene(C_{60}), is being investigated at the National Solar Energy Center in Sde Boker.

- Scientists at the Weizmann Institute of Science have tackled the problem of the questionable stability of CdTe/CdS thin film solar cells, and are confident that they have solved the problem. The issue was and is a vexing one as these are the first truly thin film polycrystalline cells for which plants of several MW production capacity have been built.

- An innovative industrially-oriented design and fabrication technology for high-efficiency crystalline silicon solar cells with a selective back-surface field structure was developed by a team at the Jerusalem College of Technology, in cooperation with the PV Group of ENEA at Casaccia, Rome. An improved method for the determination of cell recombination parameters was also developed as a tool for the control of fabrication processing effects.

- Performance of various photovoltaic modules under desert conditions is being monitored at the National Solar Energy Center in Sde Boker.

DEMONSTRATION AND APPLICATION

A number of projects are underway, and the following are particularly worth mentioning:

- At Kibbutz Samar in the Arava Valley (Negev Desert), the first 4,5 kWp of a planned 200 kWp project have been built. The system claims the lowest ever balance of system (BOS) for a grid-connected project. Computer simulations of system performance were run by the Ben Gurion National Solar Energy Center, based on ten years of hourly recorded data gathered five kilometers from the site.

- Tel Aviv University is planning a 45 kW grid-connected system on the facade of a new building.

- Traffic and toll billing on the new Cross-Israel Highway are monitored by Traffic Probe Readers (TPRs) powered by PV panels. TV cameras read the cars' license plate numbers and the system reports the information to the control center for toll billing to the driver. 51 TPRs will be installed eventually. The system is the first of its kind in the world, and consists of a 220 Wp solar panel and a 400 Ah battery bank that can provide four days of autonomy. It was designed and built by Millennium Electric Ltd.

- The Israel Electric Corporation (IEC) is investing 1 MUSD in a 30-home grid-connected demonstration project in the Negev. Each home will have a 3 kWp PV array, and the system will include inverters, meters and data-collection units. Through this project, called the "Solar Village," the IEC will investigate the operating regime, the impact on the local grid, the types of interconnections, the selection of suitable meters, etc.

Fig. 1 - Traffic probe readers powered by PV panels on the new Cross-Israel Highway (Millennium Electric).

EDUCATIONAL ACTIVITIES

In the Nitzana village in the Negev desert, an educational project is underway, called "Science Following the Sun". The project brings to hundreds of school children the message of solar energy, including photovoltaics. Within its framework, the IEC is planning to erect a reverse-osmosis desalination unit powered by a PV array. In addition, the IEC will turn four single-family homes into grid-connected solar homes, each with a 2 kWp PV array. These installations will be a test bench toward the "Solar Village" project.

GOVERNMENT ACTIONS

As mentioned above, it is expected that the recent Government resolution establishing a minimum quota for electricity from renewables will influence favorably the PV market. In addition, a number of actions are being taken to encourage the PV activity. Among them:

- Keeping the R&D excellence centers alive through selective Government support of projects. The R&D expenditures in photovoltaics of the Ministry of National Infrastructures were 125 000 USD in 2002; however, additional funding is available in this area from other research foundations.

- Supporting grid-connected demonstration projects by up to 30 % of investment.

ITALY

PV TECHNOLOGY STATUS AND PERSPECTIVES
S. CASTELLO, ENEA
S. GUASTELLA, CESI

GENERAL FRAMEWORK

Italy has been widely involved in a photovoltaic program, ranging from research on materials and devices, development and experimentation on both grid-connected and stand-alone plants as well as technology diffusion through public incentives. ENEA (the Italian Agency for New Technology, Energy and Environment), CESI (Institute for Research and Certification of Electric Components and Systems), the Ministry of Environment and all the Italian Regions, ENEL Green Power (ENEL Group) and some Italian PV industries have been the most active operators.

From the market point of view, the total cumulative PV power installed in Italy, at the end of the year 2002, was about 22 MWp. Rural electrification, off-grid domestic applications, on-grid centralized systems and on-grid distributed systems constitute the most important sectors of the Italian market, which has showed during this year, a behaviour strongly dependent on financial support coming from the Italian roof-top Program.

In particular, after a year and a half from its starting phase, this Program is well ongoing. The first Sub-program, managed by the Ministry of Environment and funded by about 10 MEUR, is almost completed while the second Sub-program, funded by about 30 MEUR, has confirmed a strong involvement of all Italian Regions and an amazing amount of submitted projects. Following the real success recorded by the two Sub-programs additional funds of about 24 MEUR have been made available by the Ministry of Environment to finance all the first Sub-program demands (5,4 MW) while additional resources, funded by the Ministry of Environment and Regions, foresee a commitment of about 45 MEUR. In this scenario, ENEA provide the technical support to the Ministry of Environment in the definition, management, data monitoring and reporting of the two Sub-programs.

As a consequence of the electrical market liberalization, in 2000, CESI has acquired from ENEL its R&D activities in generation, transmission, distribution, end-use of electricity, environment and renewable energies. CESI is now carrying out studies and experimental activities, in the sector of photovoltaic systems, on behalf of Italian Ministry of Productive Activities (formerly Ministry of Industry). In 2002, ENEL Green Power Spa, the ENEL's company for business on renewable energy market, confirmed its position as the world's largest company dedicated exclusively to renewable energy.

NATIONAL PROGRAMME

In 2002, an impressive amount of submitted applications in the framework of the Italian roof-top Program occurred, demonstrating the relevant success of the initiative. The involvement of Local Authorities, the wide interest of PV operators, the stronger and stronger popular acceptance for the photovoltaic technology as well as the citizens awareness toward environmental concerns have surely contributed to reach this success. In particular, the first Sub-program, managed by the Ministry of Environment and funded by about 10 MEUR, is almost completed: most of the 146 plants (corresponding to an installed capacity of 1,75 MW) admitted to contributions have been already installed. Moreover, because of this real success, in July 2002, additional funds amounting to about 24 MEUR have been made available by the Ministry of Environment to finance (with a share of 50 %) applications coming from those Regions, that have provide the rest of funds. Therefore, other 314 applications already positively evaluated have been admitted to contribution. Concerning the second Sub-program, composed by many local Programs completely managed by the Italian Regions, within March 2002, all the Italian Regions (with the exception of Sicily) have issued their regional announcements. Two of them, Tuscany and Valle d'Aosta, have adopted "open announcements" up to resources running out while the Autonomous Province of Trento has chosen annual annoncements. At that time, a great amount of applications had been submitted, amounting to about 5 700, well beyond its objective to realize a total capacity around 5,5 MW, corresponding to 1 800 projects.

Fig. 1 - Italian Roof-top Program: photovoltaic modules mounted on shading elements at Turin.

At the end of 2002, the second Sub-program was well ongoing; most regions have already evaluated the projects submitted and have started the installation of the first plants while other regions are still evaluating their own shares of applications submitted. Following the great success recorded by the two Sub-programs, additional resources, funded by the Ministry of Environment and Regions, foresee a commitment of about 45 MEUR In this contest, priority will be given to fully integrated roof-top applications while a decrease in the economic incentive and in the maximum cost allowed is foreseen. Moreover, in this phase the feeding law is under evaluation and an installed power of about 10,6 MW is expected. On the whole, with this sub-program, the Ministry of Environment incentives will activate an investment amount of about 150 MEUR to install a total capacity of around 21 MW.

Finally in the last year, on a total of 60 projects submitted in the framework of the PV in high architectural valence building initiative, four of them, corresponding to a total power of 200 kW, have been admitted to contribution.

Fig. 2 - Italian Roof-top Program: 20 kW on Pisa University.

R&D AND DEMONSTRATION

Most of these activities are carried out directly by ENEA at their own laboratories; some others have been conducted by CESI on laboratories and on field, while some specific topics are studied in cooperation of ENEA with the PV industries.

Activities on material and devices are focused on a-Si/c-Si heterojunction, developed in ENEA Portici Laboratories for future industrial applications. Moreover, to improve the efficiency and stability of devices, both single-junction and tandem structures are investigated. At the ENEA Casaccia Laboratories, crystalline silicon devices based on laser assisted processes, on advanced screen-printing technologies and on buried contact cells have been currently realized with efficiency greater than 17 % and 16 % respectively.

Moreover, in the field of a-Si/c-Si heterojunction, cooperation between Eurosolare, ENEA and some other European operators, is currently carried out in the framework of the "MOPHET" Program promoted by the European Community. Activities on poli-Si thin film cells on foreign substrates are also carried out, in the framework of the V FP "Subaro".

In the second half of 2001, the PhoCUS (Photovoltaic Concentrators to Utility Scale) Project was started by ENEA in order to investigate photovoltaic concentration technology and to assess their technical and economical feasibility. The first phase of the project is aimed at developing and optimizing the most appropriate technologies for the solar cell, the optical devices and the solar tracker.
At CESI laboratories, research has been carried out on high efficiency GaInP2/GaAs/Ge triple junction photovoltaic cells. This research on the fabrication of photovoltaic cells for spatial applications, is aimed at the development of GaAs-based cells whose cost could justifies their terrestrial application.

In the field of systems and components, activities on small grid-connected plants, as prototypes of roof mounted systems are carried out by ENEA in Manfredonia test facility and in Portici Center. Performances of these plants are analyzed in terms of energy output, energy losses, power quality, operation and maintenance procedures. Analysis and tests on medium and large power plants have been carried out by ENEA on Delphos 600 kWp and Casaccia 100 kWp grid-connected plant.

Furthermore, the performance evaluation of photovoltaic components and plants has been carried out by CESI on several PV plants owned by the ENEL Group (throughout the Italian territory), in order to assess long term behavior of PV technology in different climatic conditions and in different electric configurations.

Also, in the field of plant experimentation, system and components performance are routinely evaluated by monitoring the most important parameters of the 18 pilot plants installed from 1999 to 2001 in the framework of the preliminary actions of the roof-top Program. Detailed performance analysis has proved that the values of their indications of performance are in good accordance with the expected figures for such kinds of applications.
On the side of components, the experimental support has been mainly focussed on international market analysis and product acquisition in order to carry out specific measurement and aging tests on BIPV modules and to perform characterization and qualification tests on inverters and interface devices.

INDUSTRY STATUS

The Italian PV industry consists of two major module manufacturers, some inverters manufacturing firms and several industrial operator in the field of design, construction and commercialisation of PV systems.

The major PV module manufacturer is Eurosolare with a staff of about 70 people. Its manufacturing facilities have a production capability of 3 MWp/year per shift. Both single-crystal and polycrystalline silicon cells are currently produced. The Eurosolare polycrystalline module manufacturing process is completely integrated starting from the ingot fabrication while single crystal modules use wafers bought on the international market. Eurosolare production includes also specially designed modules for roof tops and facades.

The second Italian module manufacturer is Helios Technology. Its manufacturing facilities have a production capability of 2,5 MWp/year. Helios Technology module manufacturing process comprehends the fabrication of cells and modules from monocrystalline silicon wafers.

In the field of PV systems, it is worth mentioning that both Eurosolare and Helios Technology activities include the commercialisation, design and turn key supply of PV system. Other industrial operators in this field are A.N.I.T., Gechelin Group, SEI, Artistica and all the companies included in the Italian PV Firms Group (GIFI).

MARKET DEVELOPMENT

The total PV power installed in Italy in 2002 was expected to be about 22 MWp. In particular, the results that rural electrification (about 6,3 MWp), off-grid domestic applications (about 5,3 MWp) on-grid centralised systems (about 6,7 MWp) and on-grid distributed (about 3,7 MWp) constitute the most important sectors of the Italian market.

In the last year the national PV market has been showing behaviour strongly dependent on subsidised projects. In particular, the sector of PV plants for power generation has been strongly boosted by the financial support coming from the Italian Ministry of Environment through the Roof-Top Program.

JAPAN

PV TECHNOLOGY STATUS AND PROSPECTS
ICHIRO HASHIMOTO, NEDO

Fig. 1 - 506 kW PV system installed to the roof of Nishi-Harima Governmental Office Building of the Hyogo Prefecture .

GENERAL FRAMEWORK

The promotion and deployment of photovoltaic (PV) system has been implemented through the foresight for new energy in "The Total Primary Energy Supply Outlook" prepared by the Advisory Committee for Energy. Japan's target for PV system introduction by FY2010 was revised to 4 820 MW from 5 000 MW in 2001. The Ministry of Economy, Trade and Industry has been actively driving forward the promotion measures and policy for research and development for PV systems to achieve the introduction target. "The New Energy Law" established in 1997 also stipulates that national and local governments, energy consumers, energy suppliers and energy equipment manufacturers should take responsibility to introduce and expand this new energy. "The Renewable Portfolio Standard Law," newly established in 2002, also requires energy suppliers to use a certain percentage of renewable energy.

In addition, the "Law Concerning Promotion Measures to Arrest Global Warming" and "Law for Green Purchase" were enacted.

NATIONAL PROGRAMME

The Government has implemented R&D, demonstration tests, promotion policies, and law enactment towards the achievement of the targeted introduction capacity of 4 820 MW of PV systems by FY2010. In the field of R&D, technical development for cost reduction of PV systems and technology development for PV promotion and innovative next generation technology has also been realized. Regarding demonstration tests, the following have been continued: a cost reduction demonstration test by standardization of PV systems for industrial use aiming at the introduction and promotion of PV systems for private facilities; a demonstration test for new type of PV systems. As for promotion policy, the Residential PV System Dissemination Programme has been strongly moved forward. In addition, the Government has implemented supporting programmes for the introduction of new energy to local governments and private entrepreneurs.

The budgets for FY2002 of major National PV Programmes are as follows:

1. Photovoltaic power generation technology research and development (Including Technology development to deploy PV system): 7 300 MJPY
2. Residential PV system Dissemination Programme: 23 200 MJPY
3. Field Test Programme for industrial use: 4 500 MJPY
4. Demonstrative development of centralized grid-connected PV system: 100 MJPY
5. Financial support for entrepreneurs introducing new energy: 23 620 MJPY
6. Introduction and promotion of new energy at regional level: 12 700 MJPY
7. Support for local efforts to develop the vision of new energy use and energy-saving: 1 230 MJPY
8. Support for local activities for new energy: 140 MJPY
9. Support for local activities to introduce new energy: 880 MJPY
10. Support for regional global warming prevention: 470 MJPY

The budgets for items 5, 6, 7, 8, 9 and 10 include ones for PV and other new energies.

R&D, D

The New Sunshine Project established in FY1993 to promote a comprehensive, long-term R&D is now finished, and the new technological programme, the "5-Year Plan for Photovoltaic Power Generation Technology Research and Development (FY2001-FY2005)" which was initiated in FY2001, is based on the results obtained thus far. The programme aims at: early establishing PV technology for the realization of approximately the same generation cost as the electricity rate for household; developing common basic technology necessary for full-scale deployment of PV applications; and developing essential technologies PV cells and PV systems based on the new concept. The development objectives of the programme are classified into the fields as stated above. The programmes in progress are as follows; the short- and medium-term target is (i) the development of advanced PV cells (thin-film silicon PV cell, thin-film CIS PV cell, InGaP/InGaAs/Ge PV cell and highly efficient polycrys-talline PV cell), (ii) the development of technology focused on PV promotion (large area amorphous silicon wafer, thin-film polycrystalline silicon wafer and polycrystalline silicon wafer), and (iii) development of common basic technology necessary for full-scale deployment of PV applications (performance evaluation of PV cell and PV systems, recycle and reuse technologies of PV system). The long-term target is research and development of innovative next generation technology for PV systems (Cat-CVD process, nano-structure silicon PV cell, dye-sensitized PV cell, spherical crystalline silicon PV cell).

DEMONSTRATION

The main demonstration programmes, implemented by the Ministry of Economy, Trade and Industry (METI) in FY2002 are "PV Field Test for Industrial Use" and the "Demonstrative Development of centralized Grid-Connected PV System", newly started in FY2002.

PV Field Test for Industrial Use

This programme started in FY1998 and this year enters the 5th year of the programme. The aims are; (i) to install new types of PV system including building integrated PV systems and

Fig. 2 - 150 kW PV system installed to the roof and façade of the municipal office of Chiyoda-Cho of the Hiroshima Prefecture.

standardized PV systems with 10 kW power unit in various applications for the industrial sector; (ii) to analyze the data collected under a long-term operation and to get a head on introduction and expansion of PV systems in the industrial sector and (iii) to realize price down by standardization. Private companies, local public organizations and other organizations are eligible for subsidy. Half of PV installation cost is subsidized. 315 PV systems, a total of 8 410 kW were installed between FY1998 to FY2000. In FY2001, 218 PV systems, totaling 4 890 kW have been installed. In FY2002, 218 PV systems, totaling 5 280 kW were accepted. Under the programme, PV systems were mainly installed to schools, welfare facilities, factories, medical facilities, office buildings, and private facilities. The typical capacity of the installed PV systems was between 10 and 30 kWp.

In addition, PV Field Tests for Public Facilities implemented since FY1992 successfully achieved the expected target and were completed in FY1997. Acquisition and canalization of the operation data continued since FY1998 and were completed in March of 2002.

Demonstrative Development of Centralized Grid-Connected PV System

This new programme was started in FY2002, in order to conduct demonstrative testing of large-scale introduction of grid-connected PV systems equipped with storage batteries. It aims at establishing grid connection technology for a centralized grid-connected PV system intensively installed to one area. The site for the demonstrative test was selected in FY2002 and PV systems with 3kW capacity will be introduced to 200 residential houses in one area from FY2003.

IMPLEMENTATION

The Ministry of Economy, Trade and Industry

The main implementation programmes that were carried out in FY2002 were the "Residential PV System Dissemination Programme", the "Introduction and Promotion of New Energy at the Regional Level" and "Financial Support for Entrepreneurs Introducing New Energy".

Residential PV System Dissemination Programme

The "Residential PV System Monitor Programme" initiated in FY1994 was renamed "Residential PV System Dissemination Programme" in FY1997, and aims to develop initial residential PV system market. The programme continues to be actively promoted. In 2002, the number of PV systems installed under these programmes exceeded 80 000 systems.

The "Residential PV System Dissemination Programme" aims at reducing the expenses of PV system installers and creating an initial PV market through subsidizing the installation cost for residential PV systems. The subsidy is given in three categories, (i) to an individual who is going to install PV system to his own house, (ii) to ready-built house suppliers of housing development complexes and (iii) to local public organizations who are going to introduce PV system to public buildings. PV systems with reverse flow connected to low voltage lines are subsidised. In FY2001, subsidy was provided at 120 000 JPY/kW, but in FY2002, the subsidy was decreased to 100 000 JPY/kW.
The residential PV systems have been installed to 52 352 houses, totaling 189 MW from FY1994 to FY2000. In FY2001, 29 389 houses, total 114,7 MW were accepted, and as of December 27, 2002, 29 880 houses were accepted.

The Introduction and Promotion of New Energy at the Regional Level

This project aims at accelerating new energy introduction by supporting the regional projects that local governments develop the new energy introduction. Subsidy is provided to local public organizations who are going to introduce and promote PV, wind power, solar heat, differential temperature energy, natural gas co-generation, fuel cells, wastes generation, use of waste heat, production of

Fig.3 - 20 kW tank cover-integrated PV system for a water treatment plant of Yokohama-City of the Kanagawa Prefecture.

wastes fuel, clean energy cars and energy saving measurements. A PV system is subsidized for a 150 kW output and over. Half of the system installation cost is subsidized. 81 systems, in total, were subsidized from FY1998 to FY2000. 37 systems of these were PV systems. The total capacity installed was 3 965 kW. In FY2001, 37 systems in total were qualified and 15 systems out of them were PV systems. Total capacity installed was 3 074 kW. In FY2002, 57 systems in total were qualified and 21 systems out of them were PV systems. Total capacity installed was 2 391 kW. The programme allows local governments to understand the benefit of the introduction of renewable energy and to introduce PV systems selectively to school buildings and public facilities over several fiscal years.

Financial Support for Entrepreneurs Introducing New Energy

This programme aims at accelerating the new energy introduction by supporting the industrial entrepreneurs who set about introducing new energy, such as PV, wind power, solar heat, differential temperature energy, natural gas co-generation, fuel cells, wastes generation, use of waste heat, produc-tion of wastes fuel. The private entrepreneurs who set up new energy businesses are eligible for guaranteed debt or subsidy. A third of the system installation cost is subsidized and guaranteed debt is 90 % of a debt. The capacity of an eligible PV system is 100 kW and over. 76 systems in total were qualified from FY1998 to FY2000 and 2 systems out of them were PV systems with 216 kW in total. In FY2001, 34 systems in total were qualified and one system was a PV system with 140 kW. In FY2002, 25 systems in total were qualified and one system was a PV system with 25 kW.

Additionally, support has been given to the projects in order that local governments develop their vision for the introduction of new energy at the local level and to NGOs' supporting activities to introduce new energy at the local level.

The Ministry of Land, Infrastructure and Transport

Under the "Guideline for Planning Environmentally-Friendly Government Facilities (Green Government Office Building)", construction of green government office buildings with PV system have been promoted. The ministry started introducing PV systems to government office buildings from FY2001. Introduction of PV systems 410 kW, in total, will be completed on 13 government office buildings by the end of FY2002.

The Ministry of Posts and Telecommunications

The Ministry continues its "Environmentally-Friendly Facilities Provision Project" for the purpose of environmental protection in the community and are promoting the introduction of PV systems to post offices.

The Ministry of Education, Culture, Sports, Science and Technology

The Ministry continues its "Eco-school Promotion Pilot Model Project" initiated in partnership with METI in FY1997 and is promoting the introduction of PV systems to elementary and junior high schools in Japan. 157 schools over Japan were designated as pilot model schools by FY2001, and 114 schools installed PV systems with 10 kW and over. In FY2002, 87 schools were designated as pilot model schools and PV systems are to be installed to 47 schools among them. In addition, the Ministry initiated the introduction of PV systems to national universities and other national schools and installed 275 PV systems with 10 to 50 kW to 133 schools throughout Japan by the end of FY2001. Total capacity installed was 8 000 kW.

The Ministry of Environment

The Ministry is promoting project of CO2 emission reduction measures by use of natural energy under the "Basic Guideline for Promotion Measures to Arrest Global Warming" settled in FY1986. In addition, "Law for Green Purchase" came into force in April 2001. Commodities procured by Government have to be replaced by environmental-friendly products. Since PV systems are specified as special procurement products, the introduction of PV systems to governmental facilities is under discussion. There are indications that these actions are expanding to local governments.

The Local Governments and Municipals

Movements to grapple positively with environmental issues are spreading among the local governments and municipals. Some prefectures began to set their own target for the introduction of the amount of new energy following the national target for PV system introduction (4 820 MW). More and more local municipals began to develop the new energy introduction vision and to plan the introduction of PV systems. Some local governments and municipals also provide their own additional subsidy to public financing and their number is increasing year by year. Promotional supports to PV systems are enhanced at the local government and municipal levels. As of September 2002, local governments who provided the subsidy for residential PV system totaled 229.

Utilities

Electric power companies continue the introduction of PV systems to their own facilities, and the net metering system with buy-back contracts for surplus PV electricity at the same rate as selling. As of

Fig.4 - Skylight PV system (20 kW) installed in Kansai Gaidai University in the Osaka Prefecture.

the end of March in 2002, the capacity installed to their facilities was 4 548 kW and the power bought by buy-back contract totaled 124 139 MWh.

Electric power companies in Japan established a "Green Power Fund" in October 2000 aiming at introducing and promoting PV systems and wind power systems. Electric power companies bill additional charge as a contribution of 500 JPY/share/month to their supporters among their customers, and contribute the same endowment as the amount of their supporters' contribution. The fund is used for the installation of PV systems and wind power systems. In 2001, 39 public facilities throughout Japan, including schools were subsidized through the Fund. The total capacity installed was 829 kW. In 2002,85 public facilities were designated and the installation of PV systems 1 370,6 kW in total, are underway.

Financing Institutes

Some financing institutions, including banks, provide preferential financing at a low interest rate with the introduction of residential PV systems for private use.

INDUSTRY STATUS

For several years, the PV industry has been rapidly growing through policies for research and development, measures for promotions and the development of the environment for dissemination by METI and other ministries and agencies. Especially the market for residential PV system has been remarkably growing and playing a role of pulling the PV market in Japan. The annual production of PV cells in Japan increased from 50 MW level in 1998 to a 100 MW level in 2000, and it exceeded 200 MW in 2002. Thus, the range of industries supporting photovoltaic power generation is expanding beyond PV cells and PV systems manufacturers to other industries such as suppliers of feedstock for PV cells, manufacturers of production equipment, manufacturers of PV components and power systems, housing constructors and other manufacturers producing products equipped with PV cells.

In response to these trends, the Japan Photovoltaic Energy Association (JPEA) has announced the promotional scenario, "Self-sustainable PV Industry Vision: the Genesis of PV Industry for Energy and Environment". It indicates future perspectives and a roadmap of PV promotional means for the next 30 years up to 2030, and has declared that the PV industry would establish a self-sustainable market and evolve to be one of the cornerstones of Japan's industry. The Vision visualizes that PV market scale will reach 473 billion Yen by 2010, 1 250 billion Yen by 2020 and 2 250 billion Yen by 2030.

Main PV cell manufacturers are Sharp, Kyocera, Mitsubishi Electric, Sanyo Electric, Canon, Kaneka, Matsushita Ecology Systems (former Matsushita Seiko), Mitsubishi Heavy Industry, Showa Shell Sekiyu and MSK. Furthermore, Kobe Steel and Kawasaki Heavy Industries entered into the PV market in cooperation with overseas manufacturers. To correspond to recent increase of worldwide demand for PV cells and PV modules, manufacturers in Japan have been positively expanding their production capacity. Sharp expanded their annual production capacity from 94 MW to 200 MW in 2002 and announced that it would produce PV modules in a plant with 10 MW of annual production capacity in the USA. Kyocera is planning to manufacture PV modules in China. Sanyo Electric is planning to expand its annual production capacity to 100 MW by 2005 and announced a plan to manufacture PV modules, 10 MW/Year in Mexico. Mitsubishi Electric also expanded their annual production capacity from 25 MW to 45 MW and is planning to construct a new plant. Mitsubishi Heavy Industry constructed a plant of amorphous silicon PV cell with 10 MW of annual production capacity and started its operation in 2002, following Kaneka.

As for wafer manufacturers for PV cells, SUMCO Solar expanded their production capacity of poly-crystalline silicon wafer by electromagnetic casting process, as well as M Setek, which expanded production of monocrystalline silicon wafers.

Kawasaki Steel started to produce polycrystalline Si ingot for PV cells with a 40 MW of annual production capacity. Tokuyama is constructing a pilot plant for solar grade silicon.

Furthermore, major housing manufacturers released new models with adapted building-integrated PV systems one after another since they commercialized "the houses equipped with PV system as a standard specification" in 1999. Especially, Sekisui Chemical focuses on the sales of the houses equipped with PV systems as a standard specification. They successfully received orders for 17 500 houses in 2002. In addition to the above-mentioned manufacturers, building material manufacturers produce roofing materials, outer wall materials and sheet glass and commercialize building materials integrated with PV cells. Moreover, some builders start to construct buildings with integrated PV cell as "environmental co-existence" buildings. As previously mentioned, industries from different fields are commercializing products with PV cell, and therefore the range of PV industry is expanding.

TABLE 1 SHOWS THE CUMULATIVE INSTALLED PV POWER IN 4 SUB-MARKETS.

sub-market application	1998 kW	1999 kW	2000 kW	2001 kW
off-grid domestic	450	500	550	600
off-grid non-domestic	52 300	56 200	63 000	68 960
on-grid distributed	77 750	149 000	263 700	379 770
on-grid centralized	2 900	2 900	2 900	2 900
TOTAL	133 400	208 600	330 220	452 230

MARKET DEVELOPMENT

The possibility and application area of PV cells and PV systems have been expanding through financial support corresponding to the market scale of PV systems and policies for research and development of PV systems initiated by METI. The initial market development for PV systems has increasingly made progress, in the market sector of private houses, public facilities, industrial facilities, traffic facilities, railroad facilities and commercial buildings. Especially in the housing sector, marketing to new and existing houses is satisfactorily progressing. The market scale of 3-5 kW residential PV systems is expanding to annual sales of 30 000 to 40 000 systems. Leading housing manufacturers are creating new markets for PV systems by developing all-electrified houses equipped with PV systems, and developing housing areas with 50 to 100 houses equipped with PV systems and housing complexes electrified with PV system. Also in the sectors of public facilities, Industrial facilities, commercial facilities and commercial buildings, standardization of PV systems of 10-500 kW scale and the development of novel type PV systems is promoted. The market size for these sectors is estimated to be 500 to 1 000 systems annually. To correspond to the demand of the above-mentioned sectors, PV cell manufacturers and building material makers commercialize highly efficient modules, thin type modules, lightweight modules, triangle modules, trapezoid modules, lighting type modules, colored modules, flexible modules, roofing integrated modules, wall material integrated modules, and bifacial generation modules which meet user's needs to improve design and function. Furthermore, there is a widespread trend that local governments enhance the installation of PV systems to schools, governmental offices, welfare facilities, hospitals, and community centers. Private enterprises are also promoting the application of PV systems to rooftops and roofs of their head office buildings, business offices, factories and warehouses. Some private enterprises are planning to introduce PV systematically to restraints, railway stations, service stations, etc.

Additionally, off-grid non-domestic PV systems without governmental support are actively utilized as commercial power supply sources for telecommunications, traffic signs, telemetering, ventilating fans, and lighting.

FUTURE OUTLOOK

With backing for the promotion and deployment of PV systems, publicity activities, promotion measures to arrest global warning, green purchase activities implemented by the Government's policy, individuals, government offices, local governments and private entrepreneurs have promoted a better understanding of introduction of PV systems. With the growth of the PV market, PV cell manufacturers make an effort to expand their production capacity and to reduce PV system cost. The roofing industry, building material industry, housing industry, construction industry and power source equipment industry are stimulated to enter into the PV market.
These sectors are expected to play an essential role in promoting PV systems as a go-between to the PV industry and end users. Therefore, the PV market, especially for residents, public facilities, commercial buildings and industrial facilities, will be deploying more and more, and is expected to grow to a self-sustaining market in the near future.

Finally, METI decided to continue the Residential PV System Dissemination Programme and plans to establish a new budget for the PV Field Test for New Technologies for the FY2003 budget bill, in place of the PV Field Test for Industrial Use. Thus industries, the government and academics will continue to support the promotion of PV systems. Moreover, the Renewable Portfolio Standard Law will be enforced from April 2003. It is expected to further accelerate the introduction of new energies.

KOREA

PV TECHNOLOGY STATUS AND PROSPECTS
JINSOO SONG, KOREA INSTITUTE OF ENERGY RESEARCH (KIER)

GENERAL FRAMEWORK

The Korean government has definitely settled "The 2nd General National Energy Plan" in December 2002, which is a 10 year long-term plan for the years 2002 - 2011. This will provide directions to decision-makers as they establish policies and strategies to promote the energy industry. Worldwide globalization and the rapidly emerging East-Asian energy market are causing dramatic environmental changes in world energy market. Regarding the great need of positive proposal to cope with this phenomenon, the objective of the 2nd General National Energy Plan is to pursue the sustainable development of domestic energy market. The method adopted to achieve this objective is the progressive transfer of the government managed system of Korea's energy market into a privately managed one. Korea's renewable energy market is presently succeeding a 1,12 % dissemination rate of total energy consumption. The rate is expected to rise to 5 % until 2011, as this objective is accomplished. With the promise of continuous economic development in Korea, an action plan aimed at establishing environmentally friendly energy systems has been developed. Since the core has led the renewable energy market to focus on PV power development, and as a result, renewable energy is considered to be PV power.
The growth of renewable energy market is highly dependent on practical support for PV technical development and its dissemination rate. By this definition, the "Solar Land 2010" program has been specifically declared.

NATIONAL PROGRAMME

To enlarge the use of PV power, it is necessary to find a solution to the high expense of PV power system installations. The "Solar Land 2010" program is fundamentally aiming at utilizing cost-effective PV power systems to be economically competitive against commercialized electronic power systems. The advanced technology, large-scale production, and high-level distribution of PV will be the prominent factors in attaining this goal. Considering these three factors, the Korean government has selected the projects described below:

- Installation of 3 kW PV systems to 30 000 residential houses until the year 2010;
- Achievement of cost-reduction through commercialization of thin-film solar cells;
- Achievement of performance and reliability improvement of the related products through implementation of PV Certification and Test & Evaluation Center;
- Construction of 4 demonstration villages equipped with PV facilities;
- Building solar cities in 2 areas; complying with the IEA program;
- Subsidizing both 20 % of total installation cost and difference of electricity price between PV(716.40 KRW/kWh) and conventional method(48,80 KRW/kWh);
- Enhancement of financial support for producers and users by providing long-term loans, tax deduction, and incentives;
- Enhancement of both IEA technical cooperation and research co-work with other countries;

TABLE 1-NATIONAL BUDGET FOR PV R&D AND DISSEMINATION FROM 2002 TO 2008 (BILLION KRW*)

	2002	2003	2004	2008	Total
R&D	5,0	9,0	13,0	72,0	99,0
Dissemination	7,1	12,8	18,0	120,0	157,9
Total	12,1	21,8	31,0	192,0	256,9

KRW: Korean Won (1 USD is equivalent to about 1,200 KRW

Table 1 shows that the cost of both technology development (R&D) and dissemination of PV systems will need 256.9 billion KRW in total for the years 2002 – 2008; 99,0 billion KRW for the former and 157,9 for the later, respectively. The PV companies participating in the program have planned to pay about 100,0 billion KRW for the expense of their own technology development in addition to governmental financial aids.

R&D,D

The projects of the "Solar Land 2010", related to technical development, are focused on achieving high efficiency and price effectiveness of thin-film solar cells and grid connected PV systems. With Korea Institute of Energy Research (KIER) as a central figure, those projects have been carried out in cooperation with other industries, universities, and research centers.

The major research projects presently undertaken are the following:

- Mass production and cost-reduction of crystalline silicon solar cells;
- Increase of cell size and efficiency of CIS and poly-Si thin-film solar cells;
- Standardization and cost-reduction of inverter and storage batteries;
- Optimization of grid-connected PV system and PV-Wind hybrid system;

Beside the projects listed above, there are three representative supportive activities for technical development to be introduced here. The one is standardization activity to comply Korean Industrial Standards(KS) to the IEC which represents the international standard. As an international collaborative project, the field test of PV power systems, implemented in developing countries such as Vietnam and Mongolia, is another. The activity both to strengthen the IEA/PVPS program and to found a "Renewable Energy Forum in North-East Asia" is the third.

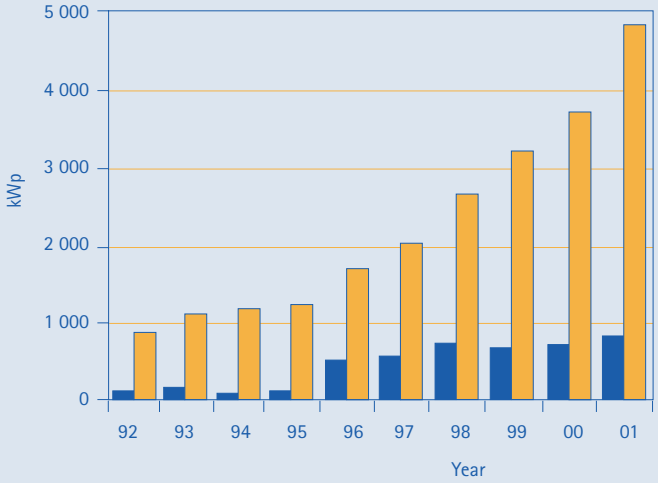


Fig. 1 - Annual Installed and Cumulative PV Capacity in Korea

IMPLEMENTATION

The electrification rate of Korea is reaching 99 %, of which Korea's PV market has been limited to islands or mountainous areas where there are geographical obstacles in obtaining commercialized electricity. Therefore, the amount of PV applications has been more inclined to government enterprises than private ones. Playing as a significant figure in the decision making process of PV industry, the Korean government has exacerbated the tendency of that the changes of annual rate of PV power system installation is to be subordinate to government PV dissemination policy. However, the government policies in a supportive manner toward PV industry, as shown in Table 2, have resulted in an upward-trend of the annual rate of PV power system installation. The achievement of 792 kW PV power energy distribution in 2001, demonstrates a 49 % increase in comparison with the previous year. For the rate of PV power system installation per application area, electrification for isolated islands and BIPV applications ranked as the highest number installations as with 259 kW. Street lamps for highways and resort areas consumed 204 kW, ranking the second; traffic signals and power sources for communications followed. Since late 2001, the capacity of PV installation has been accumulated to reach 4 943 kWp. In 2010, when the Solar Land 2010 program will have come to the end, it is anticipated that the capacity will reach 120 MWP.

INDUSTRY STATUS

The limited domestic market and low level of price competitiveness have curtailed the growth of Korea's PV industry. To overcome these negative conditions, the Korean government has practiced supportive policies including positive financial aids. This governmental support created investment from the non-government sectors and encouraged a number of new companies to enter the PV power industry. The main PV cell manufacturers are Neskosolar and Photon Semicon Energy equipped with IMW production facility and two more up-and-coming companies are in the preparation process for the large scale production of PV cell. In the case of PV module manufacturing, large enterprises, like Samsung Energy and LG, have been leading figures, but small and medium-sided enterprises, such as, Solar Tech, Soleitech, and Haesung, are actively participating in this business. They assemble home-manufactured solar cells and imported solar cells to make solar modules that will be exported to other countries. In addition, there are relevant manufacturers growing in number, for example, DongMyung Electronic and Hex Power, the inverter manufacturer, and Global Hitech, the lead-acid battery manufacturer, etc. The rise of domestic and international market demand will progressively contribute to the growth of these kinds of companies.

Fig. 2 - 15 kWp Curtainwall PV systems at KIER Research Building.

TABLE 2-PV INSTALLATIONS FOR VARIOUS APPLICATIONS IN 2001 (KWP)

	Installation Capacity
Electrification	259
Communication	62.8
Street lamps	203.9
Emergency telephone	-
Water recycling	46
Road, aviation signaling	80
Others	139.8
Total	791.5

FUTURE OUTLOOK

As mentioned above, progressive improvement in PV technology that will succeed the preferred level of manufacturing capacity plays the key role in developing PV industry equally with the issue of cost-reduction to promote the enlarged use of PV power. The Korean national PV program has established a so called, "Cost Target," as shown in Figure 4 in order to achieve competitive pricing for PV products. It has a plan to price down the module to 1,9 USD/Wp which had been 7,0 USD/Wp and to reduce the cost of Balance-of-Systems, such as inverter and storage battery, down to one third of the present cost state. Prior to this, reduction in the price of solar cells will be achieved. The reduced price will be 1,7USD/Wp until the year 2010, compared to 3,5 USD/Wp, present cost.

In the event of this cost target completion, the price of PV power system is anticipated to be dropped to 5 000 000KRW per kW from 15 000000KRW per kW. Furthermore, this price drop of PV power systems will provoke the reduction in unit cost of production, which is expected to be 270KRW/kWh.

Fig. 3 - 107 kWp BIPV Systems at Cavity Expo Pavilion.

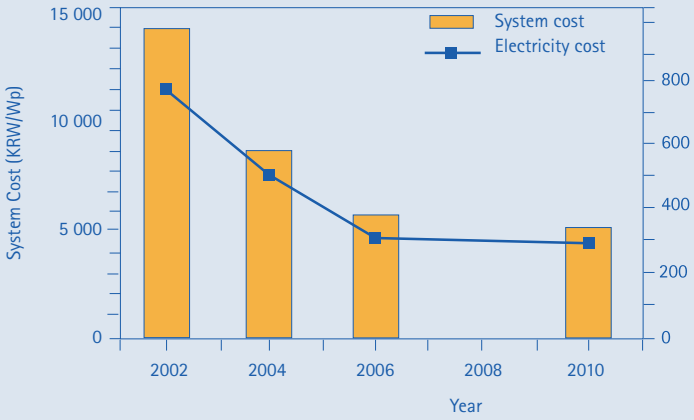


Fig. 4 – Cost Target of PV Systems and Solar Electricity

MEXICO

PV TECHNOLOGY STATUS AND PROSPECTS IN MEXICO
JAIME AGREDANO, JORGE M. HUACUZ
ELECTRICAL RESEARCH INSTITUTE (IIE)

GENERAL FRAMEWORK

Good sunshine availability throughout the year makes the use of PV systems an attractive option for remote power supply as well as grid-connected applications in Mexico. Solar home systems, small water pumps and a variety of professional applications, mostly for rural electrification and telecommunications, have been installed for more than a decade in this country. More recently, a few small pilot grid-connected systems have also been installed.

NATIONAL PROGRAMME

Still no national PV program has been instrumented by the central government. Nevertheless, almost 600 kW of SHS were installed during 2002, mainly through poverty alleviation programs operated by municipal authorities.

RESEARCH AND DEVELOPMENT

Grid-connected PV R&D activities continued during 2002. Five pilot systems installed for peak power sharing in northwest Mexico are being monitored to determine system's performance. A new 1 kWp system was installed in 2002 and its operation being monitored in a joint project between the Mexican Electrical Research Institute (IIE), the local municipality and a commercial company, in the northern state of Nuevo Leon. This system provides a portion of the load for air conditioning in a kiosk retrofitted to house a number of desktop computers which provide Internet services to the youngsters in town (see photograph). The company plans to replicate this concept, being called "cyber-kiosk" in other localities throughout the country.

PV-wind hybrids research continued during 2002. Strategies for system control were tested in connection with productive processes to foster the use of this technology in rural areas.

In yet another pilot, a PV rural electrification project carried out in a mountain village in the southern state of Oaxaca, the concept of Regional Center for Energy-Based Services (RECEBS) is being tested. The idea here is to create a model that could be replicated in other regions of the country, in which a community complying with a number of given criteria, is provided with basic services such as clean water, health center, school, telecommunications with satellite links, etc., for its population and that of the neighboring smaller communities.

Cyber-Kiosk in San Pedro, Nuevo Leon, Mexico

Satellital Education System Powered by PV in a Rural Community.

IMPLEMENTATION

The federal government is in the process of launching a new effort to increase the coverage of rural electrification with renewable energy. The emphasis is still on poverty alleviation, and the programs will be operated and managed by municipal and state authorities. This time the effort will be focused on native rural communities to provide them with services under the scheme of RECEBS mentioned above, while at the same time, promoting the use of renewable energy technology for productive activities.

INDUSTRY STATUS

Mexican industry is fit to manufacture almost all BOS components for small off-grid PV installations, but small market volumes keep this a low profile activity. Power inverters in the range of a few kilowatts and up, for both grid-connected and off-grid applications, are being imported, as well as some battery banks for professional installations. Late last year Sanyo Electronics announced the construction of a new assembling facility for PV modules as part of its industrial complex in the Mexican city of Tijuana, just across the border from California. The production capacity of this facility will be 10 MW, and all the PV modules produced there will be shipped for the US market.

MARKET DEVELOPMENT

The Mexican PV market for 2002 was close to 1200 kW, which represents an increment of about 14 % with respect to the previous year. The market segmentation was as follows: rural electrification was again the main application, with an installed capacity of 594 kW in 2002; telecommunications, 237 kW; off-shore oil platforms, 237 kW; water pumping and cathodic protection 120 kW. Cumulative PV installations in Mexico by the end of 2002 amounted to 16,159 kWp. The Mexican PV industry forecasts that the 2003 market will double with respect to the previous year.

FUTURE OUTLOOK

In the Mexican National Energy Programme 2001 – 2006, the Federal Government has declared renewable energy of national interest. Policy actions are being instrumented to encourage private sector participation in new renewable energy projects, and to expand the scope of previous programs such as PV rural electrification.

THE NETHERLANDS

PV TECHNOLOGY STATUS AND PROSPECTS
JAN-WILLEM JEHEE AND MICHIEL VAN SCHALKWIJK (ECOFYS)

GENERAL FRAMEWORK

2002 was politically very turbulent for the Netherlands. A new right wing government announced large budget cuts on several subsidy schemes applicable for renewable energies in 2003. Specifically two tax measures, EIA and VAMIL, were affected, leading to hesitation in renewable energies investments; in particular by utility companies. In addition, green power was taxed, which could lead to a decreased interest from electricity consumers due to higher prices. Denmark-like effects were feared.

The new government fell already in autumn 2002. At the end of 2002, the clouds seemed to be disappearing rapidly for renewable energy in general. The most important tax measure EIA was restored for renewable energy investments and most utilities leave their green power prices unchanged, resulting in a continuous demand for green power. A support scheme for renewable energy production was installed, which is called MEP. Only for photovoltaics it may not have so much effect, since the bonus per produced kWh is limited to 6,8 EUR cents, similar to the bonus for off shore wind production. That means that it is very unlikely that this regulation will increase investments in solar by utilities.

For the private consumer market the Energy Premium Regulation still is the most important tool.
In 2002, the responsibility for the co-ordination and promotion of the regulation was transferred from the Ministry of Economic Affairs to the Ministry of Housing. It was also decided to transform the regulation from a fiscal measure into a generic subsidy. With system prices for private consumers fluctuating around the 7,- EUR / Wp, the EPR subsidy of 3,50 EUR is an effective incentive. In 2002, this subsidy was raised with a 25 % bonus to 4,375 EUR / Wp after a positive Energy Performance Assessment (EPA). Although the EPA bonus will be changed to 10 % in 2003, the subsidy given by the EPR will remain equal.

In 2002 the EPR proved very successful for the DIY market for small systems. Many thousands of customers used the opportunity to buy a small (< 600 Wp) PV system.
Where the energy premium regulation was a good incentive for the private consumer, the project developers were still unable to use this subsidy scheme. As a consequence, project developers had difficulties financing their PV projects, which made it more difficult for PV to be implemented on newly built houses. Only developers with very short building times have been willing to rely on the EPR.

Although a negative impact of the liberalisation of the energy market was feared, it had a positive influence in the Netherlands. The competing utilities already introduced an extra subsidy for PV. In order to receive this subsidy, customers have to be a client of the utility. For PV, these subsidies are around 1,- EUR/ Wp. Also, some smaller utilities and energy traders are offering feed-in tariffs for PV, ranging from 0,18 EUR- 0,25 EUR per kWh. Another effect of the liberalisation is that utilities are competing on the green energy market by stating the origin of their electricity: Essent, for example, makes a statement of the fact that their green electricity is produced in the Netherlands. The same way, Nuon put extra focus on their solar component in their 'Natuurstroom'.
This already resulted in the construction of the largest solar roof of the world, which was on display at the Floriade 2002. The solar roof consists of 19.000 PV panels with a total power adding up to 2,3 MWp. Since the Floriade had a couple of million visitors, this was an enormous promotion of solar in The Netherlands.

Fig. 1 - PV integrated on roofs in Purmerend.

NATIONAL PROGRAMME

Last year, the Renewable Energy Programme (BSE-DEN), carried out by Novem, consisted of two calls, one in August and one in December. At the moment of writing this report only the results of the August call were known, and they turned out to be disappointing for PV. Only a few PV research projects were able to compete with mainly wind and biomass projects. Due to the Dutch target of 10 % renewable energy in 2020, biomass and wind energy projects took priority over PV. For highly innovative PV research projects, subsidies were available from the New Energy Research (NEO) subsidy scheme that was opened in April 2002. This will only be a small inducement for PV research, since this subsidy scheme has a relatively small budget for a large range of energy research.

RESEARCH AND DEVELOPMENT

Solar cell research in the Netherlands is still mainly concentrated on improving multi crystalline and amorphous silicon production, but the work on CIS by Scheuten Solar is gaining in importance. As the

Fig.2 - Solar roofs in Langedijk, a part of the "City of the Sun".

Fig. 3 - PV roofs on in Etter-Leur. Each house is supplied with a 2,7 kWp system.

BSE DEN programme appears to be a more difficult option for solar energy research, the R&D in the Netherlands is mainly relying on European support programmes.
In addition, many Dutch PV parties are co-operating in the preparation of an important national research project in a framework for improving technology infrastructure in The Netherlands. When successful, this could outline the R&D work for all important solar involved parties for the next 4 years, starting in 2004.

The short-term changes in the governmental policy for photovoltaics have certainly influenced the short lead time research projects, like the development of inverters and PV building products. Existing products were improved, for instance to fit the demands of the German market, existing projects continued, but no new initiatives were started for these products.

In spite of this, an interesting improvement for PV was developed. The companies OKE-services, ECN, NKF electronics and Oskomera Solar Power Solutions together used the NEO programme to develop a PV mounting construction called "PV-wirefree". This mounting construction also serves as a current conductor, thus bringing back the wiring to a minimum. Secondly, whereas normally all PV panels are connected in series, this system connects the panels in a parallel circuit. Apart from the advantages on the level of safety (low voltage PV system), this mounting construction is estimated to reduce the costs of the installation by 50 %. It is expected to be brought to the market in 2003 or 2004.

INDUSTRY STATUS

At the end of 2002, Shell Solar announced the closing of their factory in Helmond, which is due in April 2003. Streamlining the production after the Siemens and Shell merger last year, together with world wide production overcapacity were mentioned as the main reasons. The closing of the factory in Helmond effectively ends the production of solar panels in the Netherlands.
Both Mastervolt and NKF launched new types of inverters on the Dutch market.

The most important newcomer in 2002 was Philips Solar, who started selling their complete PV system in July 2002. With the participation of Philips, industrial interest in solar was given new momentum. It is expected that other important parties will come to the Netherlands in due time.

With a decreasing co-ordinating role of Novem/Ministry of Economic Affairs the urge was felt to get organised better as an economic entity. This resulted in the restart of the PV industry association under the umbrella of Holland Solar. In 2003, this will evolve into the most important solar platform in The Netherlands.

DEMONSTRATION PROJECTS, IMPLEMENTATION AND MARKET DEVELOPMENT

As stated before, NUON displayed the world largest roof integrated PV system at the Floriade 2002 exhibition near Amsterdam Airport, totalling 2,3 MWp of semitransparent photovoltaic panels. The City of the Sun, a project where 5 MWp in total is planned in a new urban area between the municipalities Heerhugowaard, Alkmaar and Langedijk, encountered problems caused by the uncertainty of the budget cuts of the government. Because the financing of the "City of the Sun" was a.o. based on both the Dutch EPR and a subsidy of the European Union, the announced budget cuts of the government directly endangered the project. The European Union demanded financial guarantees in order to subsidise the project "The City of the Sun." This caused a great deal of commotion, finally resulting in a guarantee fund of 1 600 000,- EUR raised by the province of Noord-Holland, the municipality of Heerhugowaard and the utility Nuon. This guarantee fund could compensate for the worst case scenario if PV would not be subsidised by the EPR. Fortunately, this will not be necessary in 2003. At the end of 2002, there was approximately 1,5 MWp installed.

In Apeldoorn, Housing Corporation St. Joseph installed 1 MWp of Lafarge systems in the countries biggest solar renovation project. The project clearly shows the potential of the EPR for housing corporations. It is expected that this example convinces more corporations in the next few years.

Fig. 4 - The 1 MWp solar renovation project of Housing Corporation St. Joseph, Apeldoorn.

Many other attractive and innovative demonstration projects were completed in 2002. They can be seen on two websites: www.pvdatabase.com (of IEA PVPS Task7) and www.pvinfo.nl (in Dutch – by Novem).

Although at the moment no exact numbers of the installed power in 2002 are known, a few things can be said. First of all, just as in 2001, a few large projects (as mentioned above) make a large contribution to the total installed power. On the other hand, since subsidies in the Netherlands are most profitable for the consumer market, small PV systems (< 600 Wp) have a large impact. The market for small PV systems was boosted even more by dedicated campaigns of municipalities, some of them offering extra subsidies. The most important parties in the consumer market are currently BeldeZon, Philips Solar and Stroomwerk, where smaller parties like Oskomera Solar Power Solutions and Buro Wilders still attract a vast number of clients.

Informative links to lists of system suppliers are:

http://www.pde.nl/de/pv/adreslijst_netgekop.html
(grid-connected PV);
http://www.pde.nl/de/pv/adreslijst_autonoom.html
(autonomous PV).

FUTURE OUTLOOK

The market for PV in 2003 will continue to develop a focus on the consumer market. With the worldwide overcapacity of PV, a further drop in prices can be expected (in 2002, the prices dropped about 6 %) which makes PV power even more attractive considering the same subsidy level by the EPR.

Bringing the EPR under the responsibility of the Ministry of Housing offers new possibilities for making arrangements in the regulation for property developers. In 2003 these will be under consideration, which might lead to a solution for 2004. More importantly, making the Ministry of Housing responsible for the implementation of renewable energy options in houses could lead to a very consistent approach in making the housing stock more energy efficient. As an example, this department took the decision that from 2003 onwards no construction permits will be needed for smaller PV and solar thermal systems.

The lower price of PV, together with subsidies at the same level and easier procedures, will assist the consumer market in continuing growth. Moreover, the fact that the EPR has been successful for three years in a row will increase confidence in the regulation itself. This in turn may lead to new developments (e.g. financing schemes) that use the EPR efficiently for larger systems as well. It is therefore expected that systems of 1-3 kWp will increase in number.

For consumers, the main value of PV is seen "behind the electricity meter", since private households pay the highest energy tariffs. Developing the consumer market will specifically ask attention for quality control, education and training and improvement of the supply chain. It is expected that activities in these fields will expand during 2003. It is expected that municipalities will continue to become more involved with campaigns for the use of solar energy.

The subsidy given by utilities is expected to end in October 2003. On the other hand, the introduction of the MEP combined with the liberalisation of the energy market could generate interesting possibilities for the larger PV systems. Adding the green image of solar power to this, PV becomes an increasingly feasible option for commercial organisations.

The Renewable Energy programme 2003 will open in the second quarter of 2003. However, when looking at the results of 2002, it is not expected that many PV research projects will benefit from the subsidy scheme.

In conclusion, it can be expected that the PV market will be maturing in 2003, with the establishment of a professional branch organisation and the growth of business-to-consumer sales.

NORWAY

PV TECHNOLOGY STATUS AND PROSPECTS

KNUT-ERIK MADSEN, ECO ENERGI

GENERAL FRAMEWORK

The political willingness to support PV in general, is still limited. PV enthusiasts had hoped that "green certificates" would send new signals to the PV-market. The Government is still waiting to decide implementation of a certificate market.

The new organisation called ENOVA is responsible for financing and demonstrating how renewables can take part in the energy picture in Norway. ENOVA does not set PV (the sun) as an important energy source and the financial support is still negligible.

"PV Nord" is an EU project. Its objective is to demonstrate and evaluate PVIB (PV In Buildings) in northern countries (Norway, Sweden, Denmark, Finland) So far 8 projects in total are launched. At least one reference project will be built in Norway (possibly 2-3). The first building picked out is a psychiatric hospital in Vest Agder (Southern part of Norway) The PV installation is typically 5 kW. The project started in 2002 and will continue until 2004. Results will be ready for harvesting in 2003. The Norwegian consulting company, KanEnergi (www.kanenergi.no), is responsible for the work on financing and ownership. Reference: www.pvnord.org

NATIONAL PROGRAMME

The programme NYTEK financed by the Norwegian Research Council came to an end 2001. The programme was renewed for another 5-year period, but Photovoltaics in this programme has to compete with other renewables like bio energy, wind, waves, hydrogen, solar thermal and others. The new programme is called EMBA (Energy – Environment-Buildings and Construction) (www.emba.no). The total funds for PV-related R&D projects were approximately 8 MNOK. Most of the R&D projects are focused on the silicon chain from feedstock to solar cells.

The programme called "From Sand to Solar Cells" is coming to term but will be prolonged by a new programme co-financed by industry and the Research Council, hopefully involving more players.

RESEARCH AND DEVELOPMENT

There are three main R&D groups in Norway:

- **NTNU** (Norwegian University of Science and Technology) **Trondheim:** 3 PhD studies. Focusing on silicon feedstock, refining and crystallisation. Supporting Scan Wafer and Elkem Building Integrated PV (BIPV) supporting Norwegian Research Council, EU, Hydro, British Petroleum and SollEnergy;
- **Agder College:** 2 PhD on silicon in co-operation with Oslo University supporting Elkem;
- **IFE** (Institute of Energy Technology): pilot line for sales cells recently acquired and installed. Supporting industry (Scan Cell and others) 3 PhD students working on solar cell processing.

An annual R&D workshop was held Aug. 27-28 in Trondheim (NTNU). Reports are available at: http://www.chembio.ntnu.no/users/hagen/solceller/Seminar2002/

IFE is involved in a project called:" Market Potential Analysis for the Introduction of Hydrogen Energy Systems in Stand Alone Power Systems".

The project is working to establish realistic market development projections for hydrogen and fuel cell technologies in small to medium sized remote power applications.

A large number of stand alone power systems (SAPS) are installed throughout Europe. These systems provide power to technical installations and communities in areas which are not connected to the regional or national power grid. An increasing number of SAPSs include renewable energy technologies, i.e. solar or wind power, most often in combination with diesel generators and/or batteries for backup power, but the majority of larger SAPS are still based on fossil fuel power generation. Replacing diesel generators and batteries in SAPS by fuel cells running on locally produced hydrogen would diminish fossil fuel dependence, improve environmental standards, and possibly reduce operation and maintenance costs. The fuel cell technology is developing fast and the SAPS market is believed to be a market segment where this new technology can be competitive in the near future.

The project will first of all establish a broad understanding of the technical and economical market potential for hydrogen SAPS based on local renewable energy sources. This will be a base for industry and governments for promoting new technologies in the existing SAPS market. Secondly, one will identify and quantify the technological and practical issues relevant for the HSAPS market and draw the attention of related industry towards solving problems related to component integration and the needs of the user market. Thirdly, the project will identify the legal, regulatory and administrative hurdles for the HSAPS market development and draw the attention of authorities towards amending such problems. Finally, the project will propose a demo-project plan for H-SAPS installations based on the scientific results obtained during the project. References are available at: http://hsaps.ife.no/

IMPLEMENTATION

Prototype Solar Façade – The Norwegian University of Science and Technology, Trondheim, Norway

A prototype solar façade system has been constructed on an existing building at the Norwegian University of Science and Technology in Trondheim, Norway. This type of façade produces both electricity and heat and is suitable for existing and new buildings. This 5 MNOK project with SINTEF and NTNU was started in 1997 to develop novel use of BP Solar technology in a building application. The 455 m^2 double façade has a 16 kW integrated PV system for heat and electricity.

The system is based on a combination of a double skin façade and building integrated PV façade cladding, where the PV cells are integrated in the outer glass skin. The cells are laminated in glass, and placed in façade sections that are not in front of the ordinary windows. The performance characteristics of the two combined façade concepts are complementary; the systems help each other if controlled properly.

The prototype façade has been financed mainly by BP Norway and developed in cooperation with BP Solar. It has been monitored for a year with satisfactory results. The PV system generated 6 600 kWh this year, and the heating demand for the building behind the new façade was reduced by 7-8 %. The offices on the top floor of the building experienced summer periods of overheating, but a revision of the control strategy for the double façade cavity venting is expected to reduce this problem.
References are available at: annegrete.hestnes@ark.ntnu.no

Demonstration of PV cells on Kvernhuset Junior High School in Fredrikstad, Norway

Kvernhuset Junior High School, completed in January 2003, places special emphasis on using the building as an active element in learning. The school is divided into 3 thematic sections; a "green" section that demonstrates ecological issues such as growth; trees, plants and recycling of materials, a "blue" section that demonstrates the water cycle; use of water, and so on, and a "yellow" section that

Fig. 1 - Sketch of Kvernhuset Junior High School.

demonstrates the sun and solar energy. The PV system is placed on the south façade of the yellow section, see illustration.

The PV system consists of 6 glass modules from Saint-Gobain Glass Solar with crystalline cells from Kyocera. Each module has a peak power of 120 Wp. The glass modules consist of a 6 mm glass, 2 mm cell gap, another 6 mm glass, a 12 mm argon filled space and a 10 mm low-e coated glass.

The PV system will be used by the students when learning about solar energy. The system will be connected to a monitoring system as well as PC-based calculation programs, which the students will use in their work.

Fig. 2 - Kvernhuset Junior High School Façade, Fredrikstad, Norway.

INDUSTRY AND COMPETENCE

Scan Wafer is building plant NR. 3 in south of Norway (Porsgrunn), with a 60-70 MW capacity. The plan goes according to schedule. Commissioning and up-start are planned for the second quarter of 2003.

Scan Cell has started production of solar cells based on multicrystalline silicon wafers in November 2002. Location: Narvik. Capacity 6-8 MW for the first line.

Silicon carbide (SiC), abrasive used for wire-sawing wafers is mass-produced at 3 plants in Norway (Orkla Exolon, Saint-Gobain Ceramics at Lillesand and Arendal).

Elkem is making progress on its silicon feedstock. (for more information, contact Elkem ASA Solar).

Renewable Energy Corporation AS has finalised a joint venture agreement with Komatsu (Japan) and ASiMI (a US Komatsu's subsidiary) to produce and develop silicon feedstock to the solar cells industry. See the press release at: www.komatsu.com or www.asimi.com or www.rec-pv.com

Fig. 3 - Scancell Façade, Narvik, Norway.

TARGET AUDIENCE AND COMMUNICATION STRATEGY

A National Team of 5 experts has been established: Knut-Eric, Madsen, IEA PVPS ExCo, Norway (ECO Energi), Bruno Ceccaroli (Renewable Energy Corporation), Arve Holt (Institute of Energy Technology), Fritjof Salvesen (KanEnergi as) and Erik Sauar (Renewable Energy Corporation).

The National Target Audience is comprised of:

- Utility Companies
- System Retailers
- Industry
- R&D Sector
- Engineering and Consultant Companies
- NGO, Political Sectors

The first Annual Seminar was held on 31 January 2002 and was attended by approximately 30 participants (on invitation only). Mr. Stefan Nowak, IEA PVPS Chairman, opened the workshop with a presentation on the IEA PVPS programme.

The National Team will follow up on the recommendations presented by the National Target Audience.

Fig. 4 - Kvernhuset Junior High School, façade from the inside.

PORTUGAL

PV TECHNOLOGY STATUS AND PROSPECTS

PEDRO SASSETTI PAES, LABELEC – EDP GROUP

Fig. 1 - Rural electrification (individual system) in Gouveia.

GENERAL FRAMEWORK

The Portuguese energy system is characterised by:

- a strong dependency on imported fossil fuels (about 85 % of the primary energy consumption), and consequently a high energy bill,
- the highest GDP energy intensity among the European Union (EU) member countries, reflecting the low efficiency of the energy system.

In 2001, the government launched a new energy policy instrument - the E4 Programme (Energy Efficiency and Endogenous Energies), consisting of a set of multiple, diversified measures aimed at promoting a consistent, integrated approach to energy supply and demand. By promoting energy efficiency and the use of endogenous energy sources, the programme seeks to upgrade the competitiveness of the Portuguese economy and to modernise the country's social fabric, while simultaneously preserving the environment by reducing gas emissions, especially the CO2 responsible for climatic change.

Aiming at simultaneously assuring the security of supply, reducing the energy bill and preserving the environment, the E4 strategy relies upon three main lines of action:

- Diversifying the access to energy sources available in the market and increasing the security of services provided by energy suppliers;
- Promoting the improvement of energy efficiency, thereby contributing to reduce GDP energy intensity and the external energy bill, on the one hand, and responding to climate change. On the other hand, laying special emphasis on the opportunities and means of optimising demand-side efficiency;
- Promoting the use of endogenous energy sources, namely hydro, wind, biomass, solar (both thermal and photovoltaics) and waves, establishing a highly dynamic compromise between technical and economic viability and environmental constraints.

While in the past 5 years the main priorities were focused on the introduction of natural gas (aiming at progressively substituting oil and coal in the energy balance) and liberalisation of the energy market (by opening this former state-owned sector to competition and private investment), the emphasis for the next 8-10 years will be put on energy efficiency (supply and demand sides) and exploitation of endogenous (renewable) energy.

NATIONAL PROGRAMME

The E4 Programme established goals concerning the exploitation of renewable energy sources (RES) for power (and thermal) generation, which are consistent with the recently approved EU Directive (2001/77/CE) on renewable electricity, under which Portugal has to aim to deliver 39 % (including large hydro) of its gross electricity consumption by 2010.

The goals for 2010 are:

- 4 400 MW new installed power from renewables (doubling the current capacity), of which: wind – 3 000 MW; small and large hydro – 1 000 MW; others, including biomass & waste and wave power - 350 MW; PV - 50 MW).
- 500 MW additional CHP (currently 1 200 MW).
- Solar thermal: 1 million m2 (currently 200 000 m^2), based on a sustainable annual market of 150 000 m^2 (currently ~7 000 m^2).

A set of initiatives (legislation, incentive schemes) have been introduced in 2001/2002, aiming at stimulating the market (private investors), not only for RES electricity, but also for CHP, solar thermal use and building energy efficiency, namely:

- Decree-Law defining the conditions regulating the awarding and management of grid interconnection points for Independent Power Producers;
- Decree-Law establishing a range of favourable feed-in tariffs for RES electricity;
- Decree-Law revising the technical and tariff conditions regulating the CHP generation;
- National programme for supporting wide diffusion of solar water heating;
- National programme on building energy efficiency;
- Adapting or broadening the scope of financial incentives for energy efficiency and use of endogenous energies in the framework of the POE Programme (Operational Programme for Economical Development).

RESEARCH, DEVELOPMENT AND DEMONSTRATION

PV R&D activities are carried out by Universities and National Laboratories (e.g., INETI – National Institute for Engineering and Industry Technology) and mainly address amorphous and thin film crystalline silicon technologies.

Applied research, demonstration and dissemination also involve Universities and Public Research Laboratories (INETI), as well as Energy Agencies (ADENE and regional agencies), utilities and asso-

ciations such as SPES (National Solar Energy Society) and APISOLAR (manufacturer and installer association). Demonstration systems concern mainly remote electrification and professional system applications (TV and telephone repeaters, parking meters, water pumping), as well as some of the few grid-connected systems.

IMPLEMENTATION

Among the government initiatives introduced in the framework of the E4 Programme, the new (revised) legislation promoting renewable electricity deserves special emphasis: the tariff rates are now differentiated by technology, allowing not only to maintain development of well-established technologies (wind, mini-hydro) but also to support introduction of new ones, with high potential in the medium run, such as PV and wave power. For PV, the new buy-back rates of 0,28 EUR/kWh (systems over 5 kWp) and 0,50 EUR/kWp (systems under 5 kWp), make PV investments considerably more attractive than the former tariff (0,06 EUR/kWh).

Financial incentives for renewables and energy efficiency applications are available under the POE programme (2000-2006) – III EC Framework Programme. Grants are provided on the basis of energy and environmental value of the projects, typically ranging from 20 % to 40 % of the total eligible costs, with a maximum of 150 kEUR per application. The total indicative budget for renewables and co-generation projects is 350 MEUR for the whole period.

Indirect market development incentives for renewables are also available: reduction of VAT rate from 17 % to 12 % on renewable equipment, custom duties exemption and income tax reductions.

This new legal and incentive framework has already contributed to an increased interest in PV applications, of which 2 initiatives deserve a special emphasis:

- The first building (facade) integrated, grid-connected PV system (12 kWp) has been designed by INETI and will be installed and demonstrated at the campus of INETI with the support of the POE programme;
- The world largest PV power plant project (64 MWp), currently under preparation.

Non government institutions and private companies are also involved in PV implementation:

- The national Agency for Energy (ADENE) is developing a considerable effort in promoting PV installations, especially in isolated, non grid-connected rural communities;
- The largest Portuguese electrical utility (EDP) participated in a number of PV projects, as part of its R&D activities on New Energy Technologies, including demonstration projects supported by the EU, either in stand-alone and on-grid distributed systems;
- The BP "Sunflower Project", started in 1998 and consisting in the integration of PV modules on BP gas station canopies. So far, about 250 kWp have been installed.

INDUSTRY STATUS

Shell Solar has a factory in Portugal (Évora), manufacturing mono and multi-crystalline PV modules (cell assembling), mainly for exports. In 2002, Shell Solar manufactured more than 80 thousand modules, with a total output of 10,8 MW.

There are two solar type and stationary battery manufacturers (SPAT, AUTOSIL).

A dozen companies are supplying and installing PV modules and BOS components imported from the EU, USA and Japan. A few of these companies produce power electronics for stand-alone PV applications (small charge regulators, ballasts, etc.).

MARKET DEVELOPMENT

According to the most recent survey, the total installed PV capacity by the end of 2002 was about 1 500 kWp, of which 82 % are stand-alone applications and 18 % are grid-connected applications. The effect of the new framework is still not visible in the market development: apart from the significant growth occurred in 1999, thanks to the BP Sunflower programme, the market seems to stabilise at around 150-200 kWp installed power per year, mainly in stand-alone applications.

INSTALLED POWER IN PORTUGAL

Year	Stand-alone (kWp)	Grid-connected (kWp)	Total annual power power (kWp)	Cumulative power (kWp)
Up to 1995	324	12	336	336
1996	88		88	424
1997	98	5	103	527
1998	100	21	121	648
1999	132	146	278	926
2000	217	33	250	1 176
2001	115	51	166	1 342
2002	167		167	1 509
Total by end 2002	1 241	268		1 509
%	82,2 %	17,8 %		

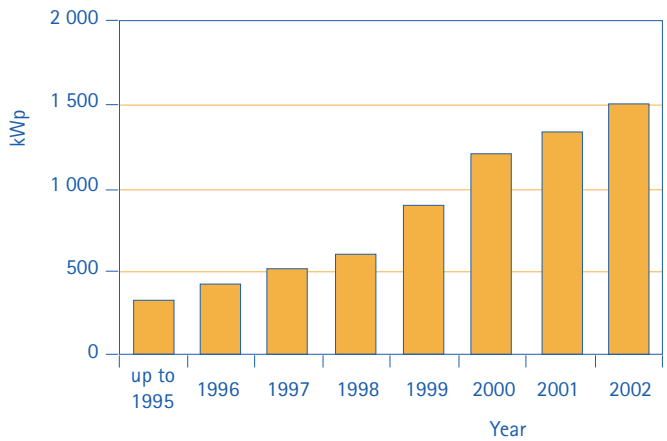
Fig. 2 - Centralised hybrid system (PV+diesel) for village supply. (Ourique)

FUTURE OUTLOOK

The Portuguese strategy for the promotion of renewables, introduced by the E4 Programme, created a favourable legal framework and incentive schemes which will likely contribute to meet the targets agreed under the EU Directive on the promotion of electricity from RES in the internal electricity market. Wind will form the bulk of the new installed power (3 000 MW) over the next 8 years, while PV's contribution is set to increase from the current level of about 1,5 MW to 50 MW by 2010.

This target will be reached earlier if the 64 MW power plant, under development, will be realised. However, a few critical barriers still remain for the widespread of PV in the built environment: PV price, equipment and installers' certification, low voltage grid interconnection legislation, building codes for PV integration.

Cumulative PV Power



SWEDEN

PV TECHNOLOGY STATUS AND PROSPECTS
MARIA MALMKVIST, SWEDISH ENERGY AGENCY
CRISTIAN ANDERSSON, ELFORSK- SWEDISH ELECTRICAL UTILITIES' R&D COMPANY

GENERAL FRAMEWORK

The Swedish Energy Agency is the national authority on issues regarding the supply and use of energy. Its main task is to implement the energy policy programme approved by the Swedish Parliament in the spring of 1997. The aim of the programme is to establish an ecologically as well as economically sustainable energy system. One part of this is to promote the use of renewable energy sources such as hydropower, wind power and PV.

Elforsk – the Swedish Electrical Utilities' R&D Company is owned by Swedenergy – the Swedish trade association for production, distribution and sale of electrical power and Svenska Kraftnät (the Swedish national grid). Elforsk is to conduct efficient R&D of importance to generation, transmission, distribution and utilisation of electricity.

The Swedish electricity supply system mainly consists of nuclear and hydropower. Wind power is still a small, but growing, part of the energy system. Energy from PV is negligible. There are a few grid connected PV systems but the main volume is the domestic-off-grid sector, typically recreational applications like remote cabins, campers, caravans and boats.

Today there are no market initiatives or regularly subsidies directly promoting PV in Sweden but during 2003, Sweden will launch a system for promotion of renewable energy through tradable electricity certificates. The system includes all renewable energy sources like biomass, hydro, wind and PV. The short term prices for the certificates are however probably too low to have an impact on the PV market in Sweden at current PV system prices. The Agency hence provides funding for cost-shared Research, Development & Demonstration projects as outlined below.

NATIONAL PROGRAMME

In 1996 the Swedish Energy Agency together with the Swedish Foundation for Strategic Environmental Research, MISTRA, decided to start a new and merged programme for R&D on PV. The programme is called Ångström Solar Center (ÅSC) and is located at Uppsala University. The first phase had a total financing of 70 000 000 SEK, approximately 700 000 USD and lasted until the end of year 2000. The second phase started in the beginning of year 2001 and will last until the end of year 2004 with a total financing of 80 000 000 SEK, approximately 800 000 USD.

The overall goal of the Ångström Solar Center programme is to contribute to a sustainable energy system in the future, preferably contributing to the economic competitiveness of Sweden.

The approach is to start from an existing strong scientific platform and evolve progressively toward applications by scale-up, prototype manufacturing, and eventually, commercialisation in three sub-programs:

- Thin Film Solar Cells
- Smart Windows
- Nanostructured Solar Cells

Fig. 1 - Sickla kaj by NCC AB (Architect: White Arkitekter). Winning contribution to the environmental competition announced by the City of Stockholm. NCC AB will install a total of 420 square meters of PV in their Hammarby Sjöstad projects (Photo White Arkitekter, 2001).

Furthermore the Swedish national co-financed programme on PV systems and applications, managed by Elforsk, has conducted its second three-year period (2000-2002). It primarily involves the energy and building industry. Architects represent new partners. This programme was evaluated during the autumn of 2002 and another three-year period is under preparation.

This programme is complementary and to some extent linked to the Ångström Solar Center R&D programme. The main task is to perform development, objective analysis and information dissemination concerning technical issues, costs and applications of PV systems.

RESEARCH

The Ångström Solar Center R&D programme embraces three project areas as mentioned earlier. The main challenge for Phase II is to progress further along the line toward applications by scale-up, prototype manufacturing and spin-off toward commercialisation. The Thin Film Solar Cells project is technologically the one closest to industrial realisation.

The technical achievements from CIGS thin film solar cell research in Sweden include cell conversion efficiencies up to 17 %, at the time making the breakthrough towards truly high performance thin film solar cells. In the year of 2000 a sub module consisting of nine cells in series and having 16,6 % efficiency was fabricated. This is the present world record for a solar cell module of any thin film material. This has resulted from R&D efforts where the focus has been on CIGS film fabrication by co-evaporation. A large area deposition concept, suitable for mass fabrication, has been invented and patented. The aim is that the CIGS technology should be brought to a state where performance and manufacturability make it ready for large-scale commercialisation. Utilising processes and materials that minimize the impact on the environment shall achieve performance

Fig. 2 - Grid-connected 3,24 kW roof-munted sc-Si system for educational purposes at Borlänge University, Borlänge, Sweden. (Photo Carl Michael Johannesson, 2001)

and cost goals. Thus, in research for a next generation technology, elimination of cadmium and minimization of usage of indium are main tasks.

The nanostructured solar cell research concerns the development of dye-sensitized electrochemical cells fabricated with a continous process with very low costs. Efficiencies are still low with respect to CIGS and the competitiveness for this technology is currently in the niche product area. Basic research is aimed at increasing the efficiency.

Smart windows have large potential for energy savings and enhancement of the comfort in commercial buildings. The focus in the research program is on electrochromic coatings on flexible foils. This type of smart windows can be retrofitted in existing windows as well as being used in new fabrication. This increases the market potential. Currently, commercialisation is made in a niche application.

DEVELOPMENT

The national programme on PV systems and applications is focused on system integration. It has in somewhat switched from energy perspective towards PV in buildings perspective. Architects represent new partners, but it still primarily involves energy and building industries.

The vision is that the market for PV will expand from stand-alone applications to power production through grid-connected building integrated and other decentralised PV systems. This expansion, however, depends on PV systems and applications knowledge among the future industrial partners in the PV area. To fulfil the vision and contribute to the reduction of the critical PV system costs, the programme goal is to enhance knowledge about PV as an energy source as well as a building component, identify possible applications of PV and raise the commercial awareness concerning PV systems.

The programme includes coverage of the rapid international development concerning PV systems in general and for grid-connected building integrated PV systems in particular. The programme does provide a basis for international exchange, such as the participation in IEA PVPS.

The programme performs evaluations of procurement, installation and start-ups for Swedish PV installations. It is also defines and implements a monitoring process for existing and future grid connected Swedish PV-installations.

Efforts concerning PV niche applications are focused on cathodic corrosion protection of power pylons and remote controlled switchgear in electricity distribution systems.

A promising concept for increasing the amount of irradiation and thus lowering the cost of PV systems is the use of reflectors. Development of reflector and hybrid-concepts for PV-systems are important efforts within the program. In addition, interesting synergies with Ångström Solar Center CIGS-modules has been identified and implemented through tests with prototype modules.

The interest from the Swedish building industry is focused on building integrated PV systems. Program activities include development of tools for carrying out PV projects in the built environment – material for architects, constructors and other actors to guide them through the process.

DEMONSTRATION

A number of niche applications have been demonstrated. Demonstration of grid-connected PV systems is at present limited to a few smaller systems.
The awareness of PV in buildings has started to rise through these demonstrations. In the near future we are to see further developed demonstrations of PV in buildings. One example is the results of

Fig. 3 - The thin film solar cell research at Ångström Solar Center of Uppsala University has resulted in minimodules with world record efficiencies. (Photo Teddy Thörnlund, 2002)

an environmental competition concerning Hammarby Sjöstad, Stockholm's largest residential building project. The winning contributions by NCC AB and JM Byggnads AB (see Fig. 1) and contributions from Familjebostäder and SBC will be realised and comprise PV-solutions.

Sweden is also taking an active part in two large EU-projects, PV Nord (Paving the way for Building Integrated PV in Northern Europe) and USHER (Urban Solar Hydrogen Economy Realisation Project). Both of these projects comprise demonstrations of large building integrated PV-installations. Sweden is also a part of the EU-network PV-EC-NET.

IMPLEMENTATION

The Swedish policies, which indirectly could promote the use of PV power systems, are taxes and fees related to energy production and environmental protection and a system for promotion of renewable energy through tradable electricity certificates that will be launched during 2003. The current levels of these taxes and fees and the short term prices for the certificates are however probably too low to have an impact on the PV market in Sweden at current PV system prices. Instead, in the current pre-commercial state of PV, new installations of significant size would most likely be considered as a demonstration system and receive support from governmental funds. With this funding, the public support can be up to 50 % of the innovative part of a demonstration project.

The fact that Sweden has a free electricity market with very low electricity prices, compared to electricity produced with PV, is a high barrier.

Since PV is a long term sustainable renewable energy technology the general view on PV in Sweden is positive and the interest from the industry has increased. The solid and steady progress, which has occurred during the recent years, has been noted and hopefully it will develop over the coming years. However PV will probably not be utilised for large-scale electricity power generation within the next 5-10 years.

INDUSTRY STATUS

The PV industry in Sweden consists primarily of three companies, Gällivare Photovoltaic AB, ArcticSolar AB and Naps Sweden AB. Gällivare Photovoltaic AB and ArcticSolar AB are producers of photovoltaic modules. They are all situated north of the Arctic Circle in Lappland.

The companies purchase solar cells, both monocrystalline and multicrystalline cells, on the world market and produce modules. The process steps include cell testing, soldering, lamination, attachment of junction box, framing and module testing. Together they offer a wide range of products of standard modules. The companies can also manufacture customer-designed modules and laminates for building integration and other special applications.

Naps Sweden AB is designing, marketing and selling products and systems based on PV modules. System controllers and the majority of solar modules are of their own design. Naps Systems has experience in consumer applications, industrial applications, rural electrification and on-grid distributed systems. Naps Systems Oy, a company in the Fortum Group owns the company.

MARKET DEVELOPMENT

The total installed power during year 2001 was 226 kWp, which is approximately the same as in 2000. The main volume of the Swedish PV market is in the domestic-of-grid sector. More than 70 % of the installations during 2001 were in this category. By the end of 2001, the total cumulative installed capacity in Sweden was about 3 MWp. Seven grid-connected systems were installed during 2001. Several projects are planned for the coming years, i.e. approximately 80 kWp grid-connected installations are planned in Hammarby Sjöstad.

The main part of the system components is imported and the dominant fraction, around 95 %, of the Swedish module production is exported.

FUTURE OUTLOOK

The high quality research and development that is carried out at Ångström Solar Center will continue. The ÅSC programme is highly relevant for the Swedish Energy Agency since it deals with important issues for a future sustainable energy system and potential commercial ventures beneficial to Sweden.

In the near future, we are probably going to see new initiatives bringing PV closer to the commercial on-grid electricity market. These initiatives could be realised in co-operation between traditional and partly new but essential actors, such as architects and building companies, which can make a contribution to market development driven by factors other than energy prices.

This, together with enhanced user oriented knowledge, through the national co-financed programme on PV systems and applications will form the basis for future initiatives in Sweden.

SWITZERLAND

PV TECHNOLOGY STATUS AND PROSPECTS
STEFAN NOWAK, NET NOWAK ENERGY & TECHNOLOGY LTD.,
ON BEHALF OF THE SWISS FEDERAL OFFICE OF ENERGY (SFOE)

GENERAL FRAMEWORK

The general policy framework is set by the new Swiss energy programme, SwissEnergy (www.swiss-energy.ch). SwissEnergy is a Swiss federal government programme for the promotion of renewable energy and more efficient use of energy. It involves the collaboration of the cantons and of a great many local authorities as well as the private sector, and various environmentalist and consumer groups. SwissEnergy is the follow-up to the Energy 2000 Action Programme and like it will have a duration of 10 years.

The objectives that have been set for the new SwissEnergy programme are derived from the Swiss federal constitution, the federal energy law and the CO_2 law, and also reflect Switzerland's commitments under the international convention on climate warming. Specifically, these objectives are as follows:

- The consumption of fossil fuels in Switzerland and the corresponding CO_2 emissions must be reduced by 10 per cent between 2000 and 2010.
- The growth of electricity demand must not exceed 5 per cent.
- Hydropower's share of final electricity consumption must not be reduced despite deregulation of the Swiss electricity market.
- The contribution made by other forms of renewable energy must increase to 0,5 Terawatthours (TWh) or 1 per cent of total electricity production, and in the case of heating energy to 3 TWh or 3 per cent of the total.

Other important SwissEnergy objectives that are less easy to measure include the development of a greater awareness of the energy dimension among the general public as a prerequisite for the optimum implementation of voluntary measures; ever closer co-operation among all partners; a spirit of innovation in all fields and an overall strengthening of the Swiss economy at the end of the day.

Following a negative public vote in 2002, the Swiss electricity market will not yet be liberalised as originally foreseen by the legislator. This electricity law would have favoured renewable electricity with free transmission for 10 years and immediate full market liberalisation. It remains to be seen how this situation will evolve under the given circumstances of the liberalised European electricity market. For the time being, renewable electricity is promoted by the stringent labels "naturemade basic®" and "naturemade star®" for green power products (www.naturemade.ch), which include portfolio approaches of different technologies. For the "nature made star®" label, 2,5 % of the total energy delivered in a service area has to be from new renewable energies (photovoltaics, wind, biomass). Using these labels, green electricity is now also promoted as part of the SwissEnergy programme.

The framework for the RTD activities is given by the Swiss energy research concept, a 4 year plan presently valid for the period 2000 - 2003, developed by the Swiss energy research commission (CORE) and the Swiss Federal Office of Energy.

Fig. 1 - Dock Midfield: 283 kWp multifunctional system at the airport of Zurich.

NATIONAL PROGRAMME

Switzerland has a dedicated national photovoltaic RTD programme which involves a broad range of stakeholders in a strongly coordinated approach (www.photovoltaic.ch). This national photovoltaic programme focuses on R&D,D in a system and market oriented approach, from basic research, over applied research, product development, pilot and demonstration projects all the way to market stimulation. To increase the quality of new systems, a number of software tools for improved project design and recommendations for project implementation are available. Further accompanying measures which help to support and promote market deployment include the customer-oriented promotion in the campaign "solar electricity from the utility". Finally, the programme emphasizes information and communication in order to raise the awareness for opportunities involving photovoltaics. Direct promotion of the market through incentive schemes has become the responsibility of the cantons on a voluntary basis. This has lead to regional

Fig. 2 - Sunny Woods: 6 kWp amorphous silicon system in an energy optimised multifamily house in Zurich.

differences whereby the governments of the cantons define their priorities between promotion of energy efficiency and/or renewable energies. Support for photovoltaics through direct subsidy schemes is limited to a few cantons presently.

On the technical level, thin film solar cells and building integration remain the foremost topics of priority. Through the bias of Task 9 of the IEA PVPS Programme, the subject of technology co-operation with developing countries has received increased interest and new, stronger strategies are being developed which will increase Switzerland's efforts in this area.

RESEARCH, DEVELOPMENT AND DEMONSTRATION

The Swiss Photovoltaic RTD Programme is based on a 4 year RTD concept, presently covering the period from 2000 – 2003. Overall, 80 projects, supported by various national and regional government agencies, the research community and the private sector are conducted in the different areas of the photovoltaic energy system. Market orientation, cost reduction, industrial viability and transfer as well as increased efficiency and reliability are the main objectives of the technical R&D.

For solar cells, the main focus remains on thin film solar cells with projects in a wide variety of materials (amorphous and micro-crystalline silicon, silicon-germanium, compound semiconductors, dye-sensitised cells). Transfer to industry of these RTD activities has continuously increased over the past years. At the end of 2002, the board of the equipment manufacturer Unaxis has taken the decision to considerably invest into a new thin film solar cell activity which builds on the strong synergies with the company's expertise for production equipment of flat panel displays. This new venture of Unaxis with the Institute of Microtechnology at the University of Neuchâtel intends to develop a leading position in the industrial production equipment of thin film "micromorphous" silicon solar cells.

A strong emphasis is placed on the application of building integration, both for new solutions involving thin film solar cells as well as for new mounting systems and structures for sloped roofs and facades.

With the ongoing market development, quality assurance of products and systems, as well as standardisation are becoming topics of high priority. Three centres of competence have been established which evaluate products such as PV modules, inverters and components for building integration. Long term experience with the operation of photovoltaic power systems is carefully tracked for a number of grid-connected systems, ranging between 10 and more than 20 years of operation. In 2002, a new activity looking into the energy rating of photovoltaic modules has started.

International co-operation continues to form a strong pillar of the R&D activities with about 20 projects running in the RTD-programmes of the European Union. International projects are also carried out as part of programmes such as the European Union Altener Programme or the European Space Agency. The co-operation within the IEA PVPS programme has remained a further strategic activity for which target-group specific dissemination is crucial.

IMPLEMENTATION

The majority of the market implementation of PV systems continues to be driven by the campaign for "solar electricity from the utility". By the end of 2002, more than 130 utilities (1996: 7) provided solar electricity to their customers. Different financial models are being used according to the preferences of the utilities. About 50 % of the Swiss population meanwhile have access to solar electricity and more than 30 000 customers annually subscribe to about 5 GWh of this new energy service. Through the past 5 years, this concept has enabled more than 6 MWp of PV systems installed with a high awareness effect among the public. The campaign has proved to be a successful approach, involving different stakeholders, provided a strong and consistent marketing is undertaken. Benefits were iden-

Fig. 3 - Parking de l'Etoile: 143 kWp on the roof of a parking house in Geneva.

tified also by the utilities in introducing new customer relationships. Since the introduction of the naturemade® labels for renewable electricity (see above), utilities have started introducing different product brands, some with a mix of different renewable energy sources and others with technology specific products, e.g. the product "Premium Solar" by the utiltiy of the city of Zurich. The willingness to pay the comparatively high prices for solar electricity is typically around 5 % of the customers in the best cases and requires a strong and consistent marketing approach.

The trade of renewable electricity through a certificate system, e.g. RECS (www.recs.org), is starting to be implemented using the naturemade® labels and individual product brands, e.g. "Pure-Power Graubünden" by Rätia Energie. Many of these developments are to be seen as bottom-up initiatives which favour market and customer oriented approaches. Solar electricity can be part of the renewable energy mix, namely through naturemade star® labeled products.

INDUSTRY STATUS

Swiss industrial PV products cover mainly system components such as inverters, both for grid-connected and stand-alone applications, components for electrical connection, mounting systems for building integration and custom designed PV modules. On the PV industry supply side, different products count among the world leaders, e.g. for wire-sawing machines and measuring equipment for PV module manufacturers. In the past years, assembled PV modules based on crystalline silicon technology were introduced into the market to form aesthetically attractive products for building integration. Whilst the main market driver, the campaign "solar electricity from the utility", has favoured least cost solutions on flat roofs, industrial development shows a trend to higher integration and innovation, partly with thin film technologies.

More recently, industrial activities have started in the field of process equipment (see above, Unaxis solar) and small scale products based on thin-film technology (Flexcell). This development reflects the existing technological know-how within the research community, combined with an increasing awareness of new market opportunities by the industry.

Based on the long term experience and the large number of installed systems, considerable know-how is available amongst engineering companies for the design, construction and operation of a large variety of different applications, ranging from small scale, stand alone systems for non-domestic, professional applications and remote locations, over small domestic grid-connected systems to medium and large size grid-connected systems in various types of advanced building integration.

Besides an increased interest from the manufacturing industry, the finance sector continues to promote financial services directed towards renewable energy. Increased investments have occurred in the renewable energy sector, including photovoltaics, and dedicated funds are operated by important finance organisations. This trend clearly demonstrates the growing perception of the renewable energy sector as a field of increasing business opportunities.

TABLE 1: SWISS PHOTOVOLTAIC ENERGY STATISTICS FROM 1989 – 2001

Year	Number of New Systems	Total Number of Systems	Installed Capacity [MWp DC]	Energy Production [MWh]	Specific Energy-Production [kWh / kWp]
1989	60	60	0,3		
1990	110	170	0,8	400	
1991	210	380	1,8	1 100	
1992	110	490	3,1	1 800	800
1993	110	600	4,0	3 000	810
1994	80	680	4,8	3 500	800
1995	60	740	5,4	4 000	815
1996	80	820	6,2	4 700	825
1997	130	950	7,4	6 000	880
1998	150	1 100	9,2	7 100	860
1999	125	1 225	11,0	7 700	770
2000	100	1 325	13,0	10 000	810
2001	125	1 450	15,0	11 000	800

(grid-connected systems)

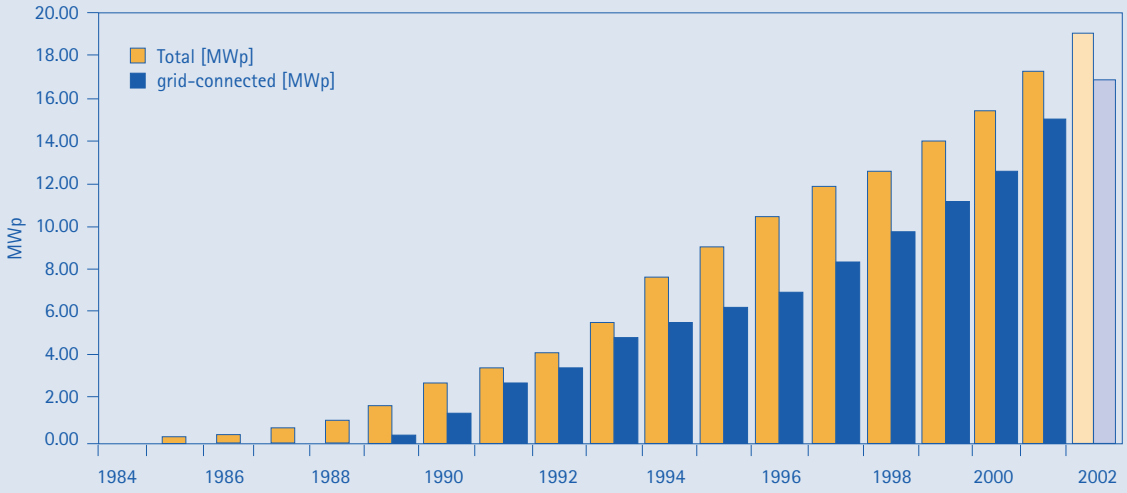


Fig. 4 – Evolution of the installed photovoltaic capacity in Switzerland between 1984 and 2002 (total and grid-connected, estimated values for 2002)

MARKET DEVELOPMENT

The market development has been mainly driven by the federal campaign "solar electricity from the utility", supported by promotional programmes and actions in some cantons as well as pilot & demonstration projects within the national programme. The annual market volume for grid-connected systems is estimated to about 1,7 MWp, which would be lower than in previous years. The total installed capacity thus rises to about 19 MWp (Figure 4), corresponding to about 2,7 Wp/capita. The PV energy statistics has been established tracking the energy produced by grid-connected PV systems and their statistical distribution since 1992 (Table 1).

FUTURE OUTLOOK

Regarding photovoltaic technology in Switzerland, the broad support of the national PV programme can be expected to continue with an ever-increased focus on industrial developments, new products for niche markets and ongoing international involvement. For solar cells and modules, the effort to bring Swiss technology to the market place will continue. Efforts in the technology development will concentrate on market oriented approaches and continuous quality assurance.

PV market implementation will continue to be limited to indirect promotion measures within the federal energy programme, the activities of regional authorities and the initiatives by the utilities. The strategy to promote international co-operation on all levels will continue, related to activities in the 6th framework programme of the European Union, the IEA PVPS programme and increasingly in technology co-operation projects.

UNITED KINGDOM

GARY SHANAHAN, RENEWABLE ENERGY DEVELOPMENT AND DEPLOYMENT TEAM,
DEPARTMENT OF TRADE AND INDUSTRY

GENERAL FRAMEWORK

In the UK, the Department of Trade and Industry (DTI) is the lead Department dealing with energy issues. Other Departments with significant interests are the Department of the Environment, Food and Rural Affairs (DEFRA), the Office of the Deputy Prime Minister (ODPM), the Cabinet Office and the Treasury.

The increasing importance of renewable energy sources to the UK in terms of meeting emission reduction targets, contributing to diversity and security of supply and developing internationally competitive industries has been recognised and has led to a number of significant policy initiatives.

The Government has imposed an Obligation on electricity suppliers (the Renewables Obligation) which requires them to deliver a specified proportion of their supplies from electricity generated from specified sources of renewable energy, or to buy Renewables Obligation Certificates or to make a buyout payment. This will enable the UK to make progress towards its target of generating 10 % of its electricity from renewable energy sources covered by the Obligation by 2010. This forms the main element of the Government's strategy for renewables deployment but it has been supplemented by a number of other initiatives described below.

In November 2001, the Performance and Innovation Unit (part of the Cabinet Office) published its report detailing how an additional 100 MGBP of funding for renewables - previously announced by the Prime Minister - should be spent. The Performance and Innovation Unit has also been conducted a review of Energy Policy which was published in February 2002. The review addressed issues such as the scope for increased targets for renewables in the post 2010 period and the Government has responded to the recommendations made in the Report in an Energy White Paper published in February 2003.

NATIONAL PROGRAMME

For photovoltaics, the UK's National Programme consists of the following elements:

- Research and development, under the DTI Renewable Energy Programme and the Engineering and Physical Sciences Research Council (EPSRC) programme;
- Field tests and demonstrations, under DTI programmes;
- Participation in international programmes (EC and IEA);

The overall goal is to develop the capabilities of industry and to encourage sustainable growth in the market by removing barriers to the deployment of PV.

A Photovoltaic Government – Industry Group, set up at the request of the then Minister for Energy, Helen Liddell, made a series of recommendations to Government in its final report, dated 26 March 2001. These included the need for a market stimulation programme for housing and non-residential PV systems, simplified connection arrangements, planning guidance on PV, and setting up a national training and accreditation scheme for installers and service personnel. These and the other recommendations of the group have being taken forward by the Department of Trade and Industry and others.

Fig. 1 - Steelstown Energy Programme, Northern Ireland. 51 kWp BP Solar laminates, installed under DTI Domestic Field Trial.

RESEARCH, DEVELOPMENT AND DEMONSTRATION

The existing DTI Renewable Energy R&D Programme has been strengthened through the preparation of "Technology Route Maps" for each technology in consultation with industry. This has resulted in an improvement in the quality of proposals received as response to the periodic competitive calls for proposals. Funding of the PV element of the programme is running at about 3 MGBP per annum.

The current priorities for work supported under the R&D Programme are as follows:

- The identification, development and evaluation of novel materials and/or cell structures which offer significant improvements to current PV performance and costs;
- Innovative approaches to existing cell or module technologies with the goal of improving performance and/or reducing costs;
- Identification, development and evaluation of new production methods and processes which offer significant potential for cost reduction;
- innovative approaches to balance of systems technologies such as power conditioning equipment, metering, wiring and installation systems with a view to significant improvements to the cost or performance.

The DTI is working with a number of industrial partners to pursue these objectives. Work includes development of amorphous silicon, high efficiency thin film silicon and organic cells.

Fig. 2 - The Alexander Stadium, where the World Indoor Athletics Championships were held in March 2003. 100 kWp Kaneka thin film modules, installed by Solar Century.

Fig. 3 - First Major PV Demonstration Programme installation in Dover using Atlantis Sunslates.

The Field Trial of Domestic PV Systems referred to in the previous IEA PVPS Annual Report is underway. The budget of 1,4 MGBP is supporting 9 projects with 166 dwellings totalling 220 kWp.
A second phase of the trial was announced in October 2001 with a budget of 4 MGBP. This will allow for PV to be installed on 379 dwellings on 23 sites with a total capacity of over 600 kWp.
A similar field trial for larger systems (non-residential) for public sector buildings was launched in November 2001 with a budget of 3 MGBP – the budget was subsequently increased to 4,2 MGBP in view of the significant number of high-quality applications, with 18 projects for installations above 20kWp (covering areas of more than 200m2) awarded grants. Both the Domestic and Non-Domestic Field Trials are now closed to new applications.

APPLICATIONS

A Major PV Demonstration Programme was launched by the Secretary of State for Trade and Industry in March 2002. This is the first phase of a potential 10 year programme which aims to rival the deployment programmes of Germany and Japan. Funding of GBP 20 million has been allocated for the first phase (3 years). The programme will provide capital grants for the installation of domestic and non-domestic PV systems in the public and private sectors.
The programme aims to support some 1 500 small scale application (less than 5kWp), 140 grouped domestic installations (comprising 1 500 roofs in total) and 140 non-domestic buildings. The total capacity installed under the programme should be approximately 9MW. The programme has also put in place an installer accreditation scheme to ensure the quality of installations which are receiving grant funding. The quality of installers will also be underpinned by the establishment of training schemes for PV installers

The process for obtaining network connection for small PV systems has been simplified and improved. Network connection guidelines (G77/G83) have been put in place following consultation involving the PV industry and utilities.

Planning Policy Guidance annex specifically for photovoltaics applications was published in April 2002.

INDUSTRY STATUS

The UK's only indigenous producer of photovoltaic panels (ICP Solar, formerly known as Intersolar) has trebled its capacity to 3 MW using private capital. ICP is continuing Intersolar's major R&D programme covering both manufacturing process and product development with assistance from the Department of Trade and Industry. Crystalox has expanded its capacity to maintain its position as one of the world's major suppliers of silicon ingots.

MARKET DEVELOPMENT

By the 31 December 2001, the totalled installed PV capacity in the UK was 2 746 kW, of which 2 231 kW (81 %) was on-grid distributed. This represents a 42 % increase over the previous year. Anecdotal evidence suggests that at least a further 1 MW was installed during 2002, but this is subject to confirmation. Solar Century, a solar solutions company has been very successful in building new business although BP Solar remain responsible for the lion's share of installations, largely on BP's own buildings and service stations.

FUTURE OUTLOOK

The Major PV Demonstration Programme will provide a significant boost to PV in the UK. Installer accreditation and training, and grid-connection issues will become more important as the level of installed capacity begins to ramp up significantly. There has been a significant increase in the level of interest in the UK PV market from manufacturers across the world since the programme was announced.
Significant cost reductions together with steady improvements in the quality, reliability and service of systems will be vital to underpin the sustained growth of the sector.

THE UNITED STATES OF AMERICA

PV TECHNOLOGY STATUS AND PROSPECTS
WARD BOWER, SANDIA NATIONAL LABORATORIES, ALBUQUERQUE, NEW MEXICO, 87185-0753*

GENERAL FRAMEWORK

The U.S. Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy directed the U.S. PV Program through its Office of Solar Energy Technologies in the U.S. through September 2002. Beginning in October 2001, the U.S. DOE reorganized its renewable energy work into a new National Solar Program with the Photovoltaic topic being a subprogram. The U.S. DOE was the leading funding source for PV research and development in 2002 and it offered the resources of the national laboratories to assist in the PV industry's applied research and development (R&D) activities. The Office of Energy Efficiency and Renewable Energy led the national laboratories to develop comprehensive operating plans based on strategic, multiyear plans that respond to the broad policies for energy R&D determined by the executive and legislative branches of the federal government. The National Center for Photovoltaics (NCPV) worked with the PV industry through various cost-shared programs to develop and improve component designs, device manufacturability and systems. Education, technical transfer, technical assistance and competitive contracts were used extensively to accomplish the work in 2002. PV-related activities funded by the DOE were appropriated to PV cell and module development, manufacturing, balance-of-system and system technologies. The U.S. Department of Energy web site (http://www.eren.doe.gov/pv) provides up-to-date information on and links to all aspects of the PV activities in the U.S.

The "Industry Roadmap," refined in December 2000 unified the vision and long-term (2000-2020) strategies and goals for the PV industry. The vision goals are geared toward the electrical/energy consumer competitive and environmentally friendly energy products and services from a thriving U.S.-based solar electric power industry. The "DOE PV Program 5-Year Plan (2000-2004)" that was written in concert with the "Industry Roadmap" helps to guide the national PV activities. In addition, the U.S. DOE Million Solar Roofs Initiative promoted the reduction in greenhouse gas and other emissions. The initiative sponsors State and local partnerships, financial tools, consumer awareness, and support with codes, standards, and certification programs.

The National Center for Photovoltaics (NCPV), an alliance of organizations, continued to serve as the focal point for the nation's capabilities in PV. The R&D goals and strategies are formulated each year by a governing board in concert with the "Industry Roadmap" and through the NCPV "Annual Operating Plan."

PV technologies for thin-film devices continued a partnership program in 2002. The Thin-Film Partnership Program collaborated with manufacturers on technology issues that were common to all manufacturing processes and non-proprietary.

NATIONAL PROGRAM

The U.S. Department of Energy is the principle source of funding for PV research and development. Research is focused on increasing domestic capacity by lowering the cost of delivered electricity and improving the efficiency of PV modules and systems. Fundamental research at universities helps to develop non-conventional, breakthrough technologies. Laboratory and university researchers will work with industry on high-volume, low-cost manufacturing, such as increasing deposition rates to grow thin-film layers, improving materials utilization, reducing cost, improving reliability and using in-line monitoring to increase yield and performance. Specific goals by 2006 are to:

- Reduce the direct manufacturing cost of PV modules by 30 percent from the current average cost of $ 2,50/W to $ 1,75/W;
- Identify and begin prototype development of leap-frog technologies that have the potential for dramatic cost reduction;
- Establish greater than 20-year lifetime for PV systems by improving the reliability of balance-of-system components and reduce recurring costs by 40 percent;
- Work with the PV industry to facilitate achievement of its roadmap goals of 1 GW cumulative U.S. sales (Export and Domestic) by 2006.

The national PV activities are directed through the U.S. Department of Energy (DOE) with headquarters in Washington, DC, and by research centers at the National Renewable Energy Laboratory (NREL) and Sandia National Laboratories (Sandia). Overreaching goals of the U.S. PV activities are to accelerate the development of PV as a national and global energy option and to ensure technology and global market leadership for the nation. The dissemination of information pertaining to PV technologies is handled through printed reports, web sites, and conferences. The National Solar Program shared the costs in areas of fundamental research, technology development and advanced materials and devices. The authorized funding was categorized into three major areas for FY 2002 for PV.

Fundamental Research	33 % of the budget
Technology Development	41 % of the budget
Advanced Materials and Devices	26 % of the budget

The total FY2002 federal budget for the Photovoltaic component of the National Solar Program totaled $ 66,1 million dollars. Substantial funding for PV-related projects also came through State and local governments, partnerships, PV industry cost sharing, and utilities.

The NCPV relies on the core expertise of NREL and Sandia to create, develop, and deploy PV and related technologies. Other national PV resources that the NCPV draws on are Brookhaven National Laboratory, two Regional Experiment Stations (the Florida Solar Energy Center and the Southwest Technology Development Institute),

**Sandia National Laboratories is a multi-program laboratory operate by Sandia Corporation, a Lockheed-Martin subsidiary, for the U.S. Department of Energy, contract #DE-AC04-94AL85000*

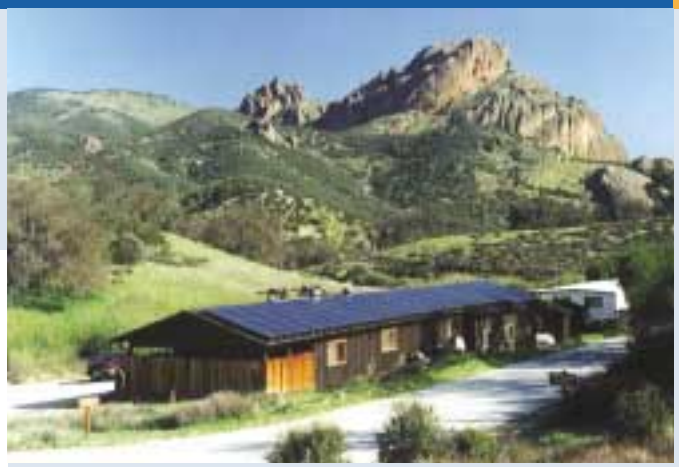


Fig.1 - Pinnacles National Monument: This 10 kW PV Power System provides power for the ranger station, visitor center well pump and other loads. (Photo Courtesy of NREL)

and U.S. DOE Centers of Excellence at the Georgia Institute of Technology and the University of Delaware (Institute of Energy Conversion). In addition, more than 90 university, industry and utility research partnerships across the country are linked together to function in a unified way. The NCPV awards most of its federal funds through competitive procurements to industry, universities, and other research centers.

RESEARCH, DEVELOPMENT AND DEMONSTRATION

The national PV effort included fundamental, advanced materials, device, and manufacturing R&D. Critical PV program contributions were provided through national laboratory support to the industry through basic research, device characterization, and environment, safety and health activities. A web-based virtual laboratory allowed collaborators from universities and industry to access real-time data on test results related to their projects.

Research on Thin-film Photovoltaics

Thin-film devices and materials development were a major part of the PV program and were administered through the NCPV and the Thin-film Partnership Program. Thin-film devices include amorphous silicon (a-Si), copper indium diselenide (CIS), copper indium gallium diselenide (CIGS), cadmium telluride (CdTe), thin-film silicon and others. The Thin-film Partnership Program continued awarding contracts for the next round of research. Responding to sustained research efforts, the efficiency of thin-film devices is rising. Six companies marketed thin-film ranging from a few watts to nearly 100 watts.

Research has moved efficiencies of a-Si devices toward the national goal of 13 % efficiency. United Solar Systems increased a-Si production to more than 8 MW in 2002. BP Solar operated its 10 MW/year plant with enhanced throughput that produces tandem-junction until November 2002.

PV devices using CdTe can be manufactured using potentially lowcost techniques such as spraying, electro deposition, and high-rate evaporation. Achieving high laboratory efficiencies using these lowcost techniques is an important objective of the National PV Program. To date, more than ten techniques have been used to grow CdTe. First Solar, LLC has continued to advance its ultrahigh-rate vapor transport deposition through collaboration with the NCPV.

A major goal for CIS research is to transfer years of government-sponsored research to industry for pilot-scale manufacturing and to produce commercial modules. NREL scientists have achieved replicable CIGS cells with efficiencies greater than 21,1% under 14-sun concentration. Industry explored new deposition systems for large-area CIS devices.

Shell Solar and Global Solar sold commercial products using CIS alloys in 2002. Shell Solar produced 5- to 40-W PV modules made of CIS alloys. Global Solar produced flexible modules for a variety of field applications.

Research and Development of the Balance-of-System

Research within the industry and the national laboratories continued to explore improved solid-state switching methodologies for inverters, new control firmware and software, new balance-of-system hardware designs, and entire PV systems that are cost effective. Inverter development included higher reliability, universal/modular inverters and conformance with anti-islanding and code requirements. A market for new grid-tied installations using battery storage remained steady. Sandia maintains a program to evaluate and improve batteries and charge controllers for PV applications. Issues pertaining to environment, safety and health remained an essential aspect of working with the balance-of-system industry and were included in all work sponsored by the National Solar Program.

Research on High Performance and Concentrating PV

The National Solar Program contains a 10 year program goal to double the efficiency of multi-junction thin-film modules. There is also a goal to demonstrate a high-efficiency III-V cell in a pre-commercial concentrator module. To help achieve this objective, the High Performance PV Initiative was continued in 2002. The NCPV and Spectrolab are collaborating toward a goal of a 40 % cell under concentrated sunlight. Workshops and concentrator forums were held during 2002 as work continues on several fronts to develop materials that will perform well at very high concentrations of sunlight.

Plug and Play Research and Development

A new concept called the AC PV Building Block was detailed and patents were applied for. This concept is expected to fill an important market niche for code compliant, retrofit and building-integrated applications.

Demonstration Programs

No major national demonstration programs were active during 2002. Several programs were sponsored by various sectors of state governments and utilities, most notably California. Deregulation of the electric utilities and localized energy shortages have spurred several state programs that require installation of PV energy systems along with new R&D efforts aimed at fielded PV systems.

Fig. 2 - Solar Decathlon: The U.S. Department of Energy organized the Solar Decathlon international competition to challenge student teams to capture, convert, store and use enough solar energy to power today's modern lifestyle. Fourteen teams competed.
(Photo Courtesy of Richard King, US DOE)

MANUFACTURING AND IMPLEMENTATION

Industry Roadmap

Success of the PV component of the National Solar Program depends on the direction, resources, best scientific and technological approaches, use of the best technologies and continued efforts of the best and brightest among industry, federal laboratory and university partners. The NCPV worked in concert with the industry to lay the groundwork for a "Systems Driven Approach" to guide new PV work that meets the goals of the industry roadmap and that will be funded by the U.S. DOE.

Photovoltaic Manufacturing

In 2002, the U.S. PV industry marketed about $ 1,2 billion of the world's estimated $ 3,2 billion of PV products. To maintain technology leadership and market share, improvements in product must move from laboratories to the world marketplace. Against this backdrop of a growing market, the PV Manufacturing R&D Project continued it support through, "Photovoltaic Manufacturing R&D—In-line Diagnostics and Intelligent Processing in Manufacturing Scale-Up."This solicitation encourages teams to share the cost of high-risk research to develop intelligent processing for larger scale manufacturing that will be the foundation for achieving the goals set out in the U.S. Photovoltaic Industry Roadmap. Great progress has been made in reducing the cost of PV systems and improving the performance and reliability of commercial products under the manufacturing research and development program. Work under previous subcontracts awarded under PV Manufacturing Technology (PVMaT) solicitations were completed in 2001, just as new contracts were awarded.

Systems

A systems engineering program that included a balance-of-system program was accelerated this year with Sandia leading efforts to fund evolutionary changes to power processing hardware that would result in improved reliability and performance. Improved reliability of inverters and required switchgear was also funded with Phase I of the high reliability inverter initiative begun in 2002. The initiative continues working with industry to improve "Total Quality Management" programs in the manufacturing and assembly areas. Sandia also urged industry to participate in "Highly Accelerated Life Tests (HALT™)" and "Highly Accelerated Stress Screens (HASS™)" to improve quality and reliability of hardware. The test facilities at Sandia and NREL continue to contribute significantly to all of the reliability-improving programs.

Sandia and NREL conduct module performance and durability studies for manufacturers based on data from several test sites. For new modules or for those that have operated in the field for years, researchers collect data on electrical performance, extent of delamination, integrity of solder joints, and properties of encapsulants. Tests include outdoor electrical performance, dark current/voltage (I-V), infrared (IR) imaging, ultraviolet (UV) inspection, solder-joint metallurgy, and ultrasonic characterization, as well as destructive testing for specific failure modes.

An inverter test facility at Sandia provides for characterization, benchmarking, surge testing and accelerated life testing. A new 30 kW hybrid test bed for inverters, designed for grid-connected or stand-alone PV systems was in operation as the Distributed Energy Test Laboratory (DETL). It includes a complete mini-grid control unit and a 75 kVA micro turbine; a 90 kVA diesel; and load banks that are resistive, inductive, and capacitive in nature. The product of an agreement with the Salt River Project and Sandia, this DETL can be used to study the effects of any distributed generation system (including PV and PV hybrid systems) on electrical utility operation.

NREL maintains the Outdoor Test Facility (OTF) to test performance and reliability of solar cells, modules, and small (1–5 kW) systems. The OTF also calibrates primary reference cells for use in-house, by other national laboratories, by industry, and by universities. Researchers at the OTF measure performance in actual outdoor tests and using solar simulators indoors. Indoors at the OTF, modules are tested for failure and performance in conditions of high voltage, high heat, high humidity, flexing, static loading, and simulated hail strikes. Outdoors, the test beds at the OTF measure long-term performance and stability. Two test beds perform stress tests of modules under accelerated conditions of high voltage and high sunlight concentration.

Sandia support increased at least five-fold the participation by systems and balance-of-system industry at the 23rd IEEE PV Specialist Conference. For the first time in a decade, the conference topics include six dedicated systems sessions with overflow participation. Topics for the sessions included increasing reliability, improving performance, reducing life-cycle costs, removing barriers, certification of practitioners and hardware, and expanding markets.

Although manufacturers are now offering 10- to 20-year warranties on PV modules, PV systems that operate reliably for 25 years are a

major goal of the PV system activities. To reach that goal, the program is supporting research and analysis using field data and models to identify areas for further technical development. Sandia's "PV System Reliability Plan," drafted in consultation with industry, is guiding hardware and system development. The plan recommends continuation of several activities such as developing a reliability database to improve understanding of the performance of real systems; examining PV systems and components after extended operation in the field to identify sources of performance degradation or failures that could be prevented by changes in manufacturing; modeling system performance to identify fault-tolerant designs, sensitivity to component failure, and cost-effective component replacement strategies; and working with industry and users to resolve technical or institutional barriers to system reliability.

MARKET DEVELOPMENT

The National Solar Program provided continuing support for state-supported PV applications using assistance through the Interstate Renewable Energy Council (IREC). Much of this work continued to provide PV applications and education for parks and public spaces through the "Photovoltaics for Utilities (PV4U)" program.

The approach to removing barriers to PV for utilities is a network of State working groups that promote PV. Working with the States and supporting the North American Board of Certified Energy Practitioners for "A Voluntary National Certification Program for Practitioners" remained a focal point for the IREC program in 2002 featuring workshops and special sessions at conferences.

There is a huge potential market for installing solar electric systems as an alternative to upgrading aging power lines to existing rural loads in the U.S. If 5 % of all applications in the rural electric cooperative system were replaced with PV, the market would equal 50 MW. Barriers to this large potential market for PV systems are being addressed when NCPV personnel provide analysis and technical assistance to organizations such as the U.S. Department of Agriculture's (USDA) Rural Utility Service, the U.S. Department of Defense, the U.S. Agency for International Development, the Florida Solar Buildings Program, the U.S. Bureau of Reclamation, Mexico's Agricultural Secretariat, the Salt River Project, and the Navajo Tribal Utility Authority (NTUA).

IMPLEMENTATION

As more installations of PV systems occur, the electrical and personnel safety of the systems are undergoing more thorough examinations by designers, installers, inspectors and users. Vital utility and industry issues, such as codes and standards, are continuing activities in the National Solar Program. The program supported work to provide a consensus of industry input into the National Electrical Code® (NEC®), listing and certification standards, and numerous standards activities in both the domestic and the international arena. An "Industry Forum" proposed 24 changes in

Fig. 3 - This 1,18 MW photovoltaic installation on the Santa Rita jail is located in Dublin, CA. It reduces peak power consumption by 30 % and produces over 1.4 million kWhr per year. (Photo Courtesy of PowerLight Corporation)

Article 690 of the NEC for the upcoming 2005 Code and submitted them in October.

The IEEE929-2000 standard spearheaded by Sandia was published in 2000, and now serves to help remove barriers to interconnection of PV systems to the utility grid. The NCPV headed up other IEEE PV standards activities and also actively participated in the International Electrotechnical Commission activities for PV-related international standards. The new IEEE 1547 "Standard for Interconnecting Distributed Resources With Electric Power Systems" received 90 % affirmatives and may soon become a standard after resolution of the negative ballots. Underwriters Laboratories amended the UL1741 "Standard for Static Inverters and Charge Controllers for Use in Photovoltaic Power Systems" and is now considering expansion of the standard to include inverters for all distributed generation.

PowerMark Corporation continued as a non-profit certification body. PowerMark previously recognized the Arizona State University PV Testing Laboratory (PTL) and approved them for performing module certification tests based on the accreditation certificate they received from the American Association of Laboratory Accreditation. Module models have been qualified to IEEE1262 /IEC61215 or IEEE1262/IEC61646 standards since the work began in 1996. The PTL continues to test module types to the UL1703 PV module standard to determine their suitability for listing and has a reciprocity arrangement with European testing organizations. The PTL also announced plans to perform preliminary "Systems Certification Tests" within the next year.

A "National Voluntary Certification Program" for PV installers is being developed with the support of the U.S. DOE PV Program. Most of the critical documentation, logistics and legal work had progressed towards completion of the preparatory stage of the program next year. State funding was also begun in 2002 with cost sharing by New York.

INDUSTRY STATUS

The quantity of PV modules produced in the United States in 2001 reached 100 MW and continued to grow at more than 20 % in 2002. Photovoltaic installations in the U.S. grew to more than 50 MW.

Fig. 4 and 5 - Naval Base in San Diego, California. This 924 kWp PV system provides long-term covered parking for over 400 vehicles while providing enough electricity to power more then 900 homes. (Photo Courtesy of PowerLight Corporation)

The United States PV applications in 2002 involved virtually all market sectors with the exception of the central power application. The majority of the growth was in the grid-connected sector and was spurred by the national Million Solar Roofs program, the California $ 3,50/W "buy-down, the SMUD $ 3,00/W effective buy-down (to allow <$ 3,50/W costs to the consumer), the Los Angeles Depart-ment of Water & Power renewable energy program and other state subsidies in Illinois, New York, and North Carolina.

The U.S. now installs more than 15 MW per year of grid-connected systems. Approximately 7 MW of small, 2- to 4-kW roof-mounted systems are installed on private residences. The systems use all types of PV modules and are sometimes connected to a multiple mode inverter that permits the PV system to first serve the building's load and then to send excess power to the utility grid. When the grid power is not available, the inverter may be designed to switch to "standby" and power the local load from energy stored in a battery bank.

There are several inverter manufacturers serving the U.S. market. They all have complementary markets for inverters, and some export a large percentage of their product. Much of the U.S. inverter industry has been consolidated under Xantrex of Canada. Xantrex acquired Trace Engineering, Trace Technologies, Heart Interface, and Statpower. Trace Engineering was the largest manufacturer of inverters for stand-alone and utility-interactive systems. Other producers include Advanced Energy Systems Inc., Heliotrope General, and Vanner Weldon. In 2001 SMA (Germany) opened a sales office (SMA America) in the U.S. and now sells its UL-listed grid-connected residential inverters for U.S. applications.

MARKET DEVELOPMENT

International work included continuation of the Mexico Renewable Energy Program that is sponsored by the U.S. Agency for International Development (USAID) and supported by the U.S. Depart-ment of Energy to institutionalize the use of renewable energy technologies. This program had been honored as one of the most successful renewable energy programs for USAID and now serves as a model for increasing the use of renewables in other parts of the world. These projects were implemented in partnership with local Mexican organizations in each geographical or political area to purchase, finance, install and maintain the sustainable systems. This program is resulting in wide-scale system replication, through increased awareness of the benefits of renewable energy technologies, and improved private sector capacities to serve the market.

The NCPV support, such as training and technical assistance in Bolivia, Brazil, China, Ghana, Guatemala, Honduras, India, Indonesia, Kenya, Mexico, Morocco, Nigeria, Pakistan, the Philippines, Russia, South Africa, and Venezuela, has helped U.S. companies continued to make inroads into the international market.

FUTURE OUTLOOK

The U.S. Department of Energy, in partnership with its national laboratories, will continue with strong PV initiatives through the National Solar Program. The "Industry Roadmap" and an updated "DOE PV Program 5-year Plan" will guide the work using a "Systems Driven Approach" to determine priorities based on market needs. The market development and expansion will include all of the components, interconnects, and materials needed for the PV industry. PV materials, manufacturing processes, balance-of-system hardware, fire and personnel safety, codes, standards, hardware certification and practitioner certification will remain vital elements in the program.

The U.S. DOE Million Solar Roofs Initiative promotes the use of PV and solar thermal to reduce the energy demands of buildings. It enables businesses and communities to install solar systems on one million rooftops across the U.S. The U.S. DOE leads this initiative by working with partners in the building industry, local governments, state agencies, the solar industry, electric service providers, and non-governmental organizations to remove market barriers and strengthen grassroots demand for solar technologies. The "MSRI Action Plan" serves as a guide for the initiative and includes assistance to MSR "State and Local Partnerships" through regional DOE offices, enhancement of financial tools available for solar energy, increased consumer awareness, strengthened ties to other Federal Agencies, encouraged adoption of uniform interconnection standards and codes, support for R&D and testing programs, establishment of certification programs, and encouragement to builders and developers to include solar energy systems.

ANNEXE A

IEA – PVPS EXECUTIVE COMMITTEE

AUSTRALIA

Mr. Harry SCHAAP, Deputy Chairman
Assistant Director, Environment and Sustainable Energy
Electricity Supply Association of Australia
G.P.O. Box 1823Q
AUS - Melbourne VIC 3001
Tel.: 61-396 70 10 14
Fax: 61-396 70 10 69
Email: schaap@esaa.com.au

AUSTRIA

Mr. Hubert FECHNER
arsenal research
Business Unit, Renewable Energy
Faradaygasse 3 - Obj. 210
AUT – 1030 Vienna
Tel.: 43-505 50 62 99
Fax: 43-505 50 63 90
Email: hubert.fechner@arsenal.ac.at

Mr. Heinrich WILK - Alternate
Energie AG
Böhmerwaldstrasse 3
AUT - 4020 Linz
Tel.: 43-732 90 00 35 14
Fax: 43-732 90 00 33 09
Email: heinrich.wilk@energieag.at

CANADA

Mrs. Lisa DIGNARD-BAILEY
CANMET-Energy Technology Center
Natural Resources Canada
1615, Montée Lionel-Boulet
CAN - Varennes, Québec, J3X 1S6
Tel.: 1-450 65 25 161
Fax: 1-450 65 25 177
Email: lisa.dignard@nrcan.gc.ca

Mr. Josef AYOUB - Alternate
CANMET-Energy Technology Center
Natural Resources Canada
1615, Montée Lionel-Boulet
CAN - Varennes, Québec, J3X 1S6
Tel: 1-450 65 21 981
Fax: 1-450 65 25 177
Email: jayoub@nrcan.gc.ca

DENMARK

Mr. Flemming KRISTENSEN
EnergiMidt Entreprise A/S
Soendergade, 27
DK - 8740 Braedstrup
Tel.: 45-70 15 15 60
Fax: 45-76 58 11 11
Email: fvk@energimidt.dk

Mr. Peter AHM - Alternate
Director, PA Energy A/S
Snovdrupvej 16
DK - 8340 Malling
Tel.: 45-86 93 33 33
Fax: 45-86 93 36 05
Email: ahm@paenergy.dk

EUROPEAN UNION

Mr. Rolf OESTRÖM
EC, DG Research Directorate J, Unit 3
European Commission
MO75, 04/04
B - 1049 Brussels
Tel.: 32-2 296 20 85
Fax: 32-2 296 42 88
Email: rolf.ostrom@cec.eu.int

Mr. Roberto GAMBI
Directorate General for Energy and Transport
DG TREN D.2, DM24 03/110
Rue de la Loi, 200
B - 1049 Brussels
Tel.: 32-2 299 81 75
Fax: 32-2 296 62 61
Email: roberto.gambi@cec.eu.int

FINLAND

Mr. Peter LUND
Helsinki University of Technology
P.O. Box 2200
FIN – 02015 Hut (Espoo)
Tel.: 35-8 945 13 19 7
Fax: 35-8 945 13 19 5
Email: peter.lund@hut.fi

Mr. Jerri LAINE - Alternate
TEKES
P.O. Box 69
FIN – 00101 Helsinki
Tel.: 35-8 105 21 58 74
Fax: 35-8 969 49 19 6
Email: jerri.laine@tekes.fi

FRANCE

Mr. André CLAVERIE
Renewable Energies Division ADEME
500, Route des Lucioles
FRA - 06560 Sophia Antipolis
Tel.: 33(0)4 93 95 79 13
Fax: 33(0)4 93 95 79 87
Email: andre.claverie@ademe.fr

GERMANY

Mr. Christoph HUENNEKES
Forschungszentrum Jülich
Projektträger Jülich - ERG
DEU - 52425 Jülich
Tel.: 49-2 461 61 22 27
Fax: 49-2 461 61 28 40
Email: ch.huennekes@fz-juelich.de

Mr. Norbert STUMP - Alternate
Forschungszentrum Jülich
Projektträger Jülich - ERG
DEU - 52425 Jülich
Tel.: 49-2 461 61 47 44
Fax: 49-2 461 61 28 40
Email: beo41.beo@fz-juelich.de

ISRAEL

Mr. Avraham ARBIB
Deputy Chief Scientist and Director
Division of R&D, Ministry of National Infrastructures
P.O. Box 36148
ISR - 91360 Jerusalem
Tel.: 972-2 53 16 12 7/8
Fax: 972-2 53 16 01 7
Email: aarbib@mni.gov.il

ITALY

Mr. Saverio LI CAUSI
ENEA – CASACCIA
Via Anguillarese, 301
ITA - 00060 S.Maria di Galeria – RM
Tel.: 39-06 3048 4110
Fax: 39-06 3048 6486
Email: licausi@casaccia.enea.it

Mr. Fausto SANSON
CESI S.P.A.
via Rubattino, 54
ITA - 20134 Milano
Tel.: 39-02 2125 5710
Fax: 39-02 2125 5626
Email: sanson@cesi.it

Mr. S. GUASTELLO - Alternate
CESI S.P.A.
via Rubattino, 54
ITA - 20134 Milano
Tel.: 39-02 2125 5691
Fax: 39-02 2125 5626
Email: guastello@cesi.it

JAPAN

Mr. Ichiro HASHIMOTO
Director General, Solar & Wind Energy
Technology Development Department
NEDO
Sunshine 60, 30F
1-1, 3-chome Higashi-Ikebukuro
JPN - Toshima-ku, Tokyo, 170-6028
Tel.: 81-3 39 87 94 21
Fax: 81-3 59 92 64 40
Email: hashimotoitr@nedo.go.jp

Mr. Kiyoshi SHINO - Alternate
Director, Solar & Wind Energy Dept.
NEDO
Sunshine 60, 30F
1-1, 3-chome Higashi-Ikebukuro
JPN - Toshima-ku, Tokyo, 170-6028
Tel.: 81-3 39 87 94 21
Fax: 81-3 59 92 64 40
Email: shinokys@nedo.go.jp

KOREA

Mr. Jinsoo SONG
KIER, Renewable Energy Research Dept.
71-2, Jang-Dong, Yusong-Gu
KOR - Taejon 350-343
Tel.: 82- 42 86 03 738
Fax: 82-42 86 03 739
Email: jsong@kier.re.kr

MEXICO

Mr. Jaime AGREDANO DIAZ
Instituto de Investigaciones Electricas
Energías no convencionales
Avenida Reforma n 113
Colonia Palmira
MEX – 62490 Temixco, Morelos
Tel.: 52-777 318 24 36
Fax: 52-777 318 24 36
Email: agredano@iie.org.mx

Mr. Jorge M. HUACUZ VILLAMAR - Alternate
Instituto de Investigaciones Electricas
Energías no convencionales
Avenida Reforma n 113
Colonia Palmira
MEX – 62490 Temixco, Morelos
Tel.: 52-777 318 24 36
Fax: 52-777 318 24 36
Email: jhuacuz@iie.org.mx

NETHERLANDS

Mr. Willem VAN DER HEUL
Ministry of Economic Affairs
P.O. Box 20101
NLD – 2500 AC Den Haag
Tel: 31-70 37 96 413
Fax: 31-70 37 96 872
Email: w.vanderheul@minez.nl

Mr. Job SWENS - Alternate
NOVEM
Catharijnesingel 59
P.O. Box 8242
NLD – 3511 GG Utrecht
Tel: 31-30 239 3744
Cell: 31-6 109 46 326
Fax: 31-30 231 6491
Email: j.swens@novem.nl

NORWAY

Mr. Knut-Erik MADSEN
E-CO Energi AS
P.O. Box 2481 Solli
NOR - 0202 OSLO
Tel.: 47-24 11 69 00
Fax: 47-24 11 69 01
Email: knuterik.madsen@e-co.no

Mr. Fritjof SALVESEN - Alternate
KanEnergieAS
Hoffsveien 13
NOR - 0275 OSLO
Tel.: 47-22 06 57 50
Fax: 47-22 06 57 69
Email: fs@kanenergi.no

PORTUGAL

Mr. Pedro SASSETTI-PAES
LABELEC SA (EDP Group)
Rua Cidade de Goa, 4
PRT - 2685-039 Sacavem
Tel.: 351-21 001 14 80
Fax: 351-21 941 92 54
Email: pedro.paes@labelec.edp.pt

SWEDEN

Mrs. Maria MALMKVIST
Swedish Energy Agency
Box 310
SE – 63104 Eskilstuna
Tel.: 46-16 544 2097
Fax: 46-16 544 2261
Email: maria.malmkvist@stem.se

Mr. Cristian ANDERSSON - Alternate
Elforsk AB
SE - 10153 Stockholm
Tel.: 46-877 25 34
Fax: 46-877 25 35
Email: cristian.andersson@elforsk.se

SWITZERLAND

Mr. Stefan NOWAK, Chairman
NET - Ltd.
Waldweg 8
CHE - 1717 St. Ursen
Tel.: 41-26 49 40 03 0
Fax: 41-26 49 40 03 4
Email: stefan.nowak.net@bluewin.ch

UNITED KINGDOM

Mr. Gary SHANAHAN
Technical Director, Bioenergy and Solar
Renewable Energy Development and Deployment Team
Room 1138, 1 Victoria Street
GBR - London SW1H 0ET
Tel.: 44-207 215 6483
Fax: 44-207 215 2674
Email: gary.shanahan@dti.gsi.gov.uk

USA

Mr. Robert HASSETT
U.S. Department of Energy
Office of Solar Energy Efficiency and Renewable Energy
Solar Technologies Program
1000 Independence Avenue S.W.
US - Washington, DC 20585 –0121
Tel.: 1-202 58 6816 3
Fax: 1-202 58 6814 8
Email: robert.hassett@ee.doe.gov

Mr. Ward BOWER – Alternate
Sandia National Laboratories, Photovoltaic Systems Applications
Dept. 6218 - MS0753
87185-0753 Albuquerque, New Mexico
Tel.: 1-505 844 5206
Fax: 1-505 844 6541
Email: wibower@sandia.gov

EXCO SECRETARY

Mrs. Mary Jo BRUNISHOLZ
NET - Ltd.
Waldweg 8
CHE - 1717 St. Ursen
Tel.: 41-26 49 40 03 0
Fax: 41-26 49 40 03 4
Email: mary.brunisholz.net@bluewin.ch

WEBSITE

Mrs. Irene DE JONG
OJA Services
Nieuwstraat 29
NLD- 5611 DA Eindhoven
Tel.: 31-40 24 45 262
Fax: 31-40 24 64 133
Email: oke@euronet.nl

ANNEXE B

IEA - PVPS OPERATING AGENTS

TASK 1 - EXCHANGE AND DISSEMINATION OF INFORMATION ON PHOTOVOLTAIC POWER SYSTEMS

Mr. Greg WATT
Australian PVPS Consortium
Mail Box 175
656 Military Road
AUS – Mosman NSW 2088
Tel./fax: 61-299 691364
Email: gwatt@efa.com.au

TASK 2 - OPERATIONAL PERFORMANCE, MAINTENANCE AND SIZING OF PHOTOVOLTAIC POWER SYSTEMS AND SUBSYSTEMS

Mr. Reinhard DAHL
Projektträger Jülich, ERG
DE - 52425 Jülich
Tel.: 49-2461 61 32 54
Fax: 49-2461 61 28 40
Email: r.dahl@fz-juelich.de

Mrs. Ulrike JAHN - Alternate
Institut für Solarenergieforschung GmbH
Hameln/Emmerthal - ISFH
Am Ohrberg 1
DE - 31860 Emmerthal
Tel.: 49-5151 999 0
Fax: 49-5151 999 400
Email: ujahn@easynet.de

TASK 3- USE OF PHOTOVOLTAIC POWER SYSTEMS IN STAND-ALONE AND ISLAND APPLICATIONS

Mr. Philippe JACQUIN
PHK Consultants
17 bis, Rue Jean Marie Vianney
FR - 69130 Ecully
Tel.: 33-(0)4 78 33 3614
Fax: 33 (0)4 78 33 3808
Email: phkconsultants@compuserve.com

TASK 5 - GRID INTERCONNECTION OF BUILDING INTEGRATED AND OTHER DISPERSED PHOTOVOLTAIC POWER SYSTEMS

Mr. Tadashi KANBAYASHI
New Energy Promotion Dept., NEDO
Sunshine 60-28th F1
1-1, 3-chome Higashi-Ikebukuro
JPN - Toshima-ku, Tokyo, 170-6028
Tel.: 81-3 39 87 93 67
Fax: 81-3 35 90 58 03
Email: kanbayashitds@nedo.go.jp

Task V Chairman
Mr. Tadao ISHIKAWA
CRIEPI
2-11-1 Iwato-kita Komea-shi
JPN - 2018511, Tokyo
Tel: 81-33 48 02 11 1
Fax: 81-33 43 04 01 4
Email: ishikawa@criepi.denken.or.jp

TASK 7 – PHOTOVOLTAIC POWER IN THE BUILT ENVIRONMENT

Mr. Michiel VAN SCHALKWIJK
ECOFYS, Kanaalweg 16-G
P.O. Box 8408
NL – 3505 RK Utrecht
Tel.: 31-(0)30 280 84 39
Fax: 31-(0)30 280 83 01
Email: m.vanschalkwijk@ecofys.nl

TASK 8 – STUDY ON VERY LARGE SCALE PV POWER GENERATION SYSTEMS

Mr. Kazuhiko KATO
NEDO
30 F Sunshine 60
3-1-1 Higashi-ikebukuro
Toshima-Ku, Tokyo
JPN - 170-6027
Tel: 81-3 39 87 94 22
Fax: 81-3 59 92 64 40
Email: katokzh@nedo.go.jp

Prof. Kosuke KUROKAWA –Alternate
Tokyo University of Agriculture and Technology
2-24-16 Naka-cho, Koganei-shi
JPN - Tokyo - 184-8588
Tel.: 81-423 88 71 32
Fax: 81-423 85 67 29
Email: kurochan@cc.tuat.ac.jp

TASK 9 – DEPLOYMENT OF PHOTOVOLTAIC TECHNOLOGIES: CO-OPERATION WITH DEVELOPING COUNTRIES

Mr. Bernard McNELIS
IT Power Ltd
The Manor House
Lutyens Close
Chineham, Hampshire
UK - RG24 8AG
Tel.: 44-12 56 39 27 00
Fax: 44-12 56 39 27 01
Email: bernard.mcnelis@itpower.co.uk

COLOPHON

Cover photograph
Ralph Bensberg
Task Status Reports
PVPS Operating Agents
National Status Reports
PVPS Executive Committee members and Task 1 experts
Editor
Mary Jo Brunisholz
Layout and design
Nuance, graphisme, web, communication, Givisiez, Switzerland
Paper
Normaset Puro blanc naturel
Type set in
Rotis
Printed in 1000 copies by
Imprimerie MTL, Villars-sur-Glâne, Switzerland