IEA INTERNATIONAL ENERGY AGENCY

PHOTOVOLTAIC POWER SYSTEMS PROGRAMME

PVPS

ANNUAL REPORT 2000

IMPLEMENTING AGREEMENT ON PHOTOVOLTAIC POWER SYSTEMS

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PREFACE

This is the last Annual Report for which I write the preface. It has been an honour and pleasure to serve as PVPS chairman for the last three years, in which we as Executive Committee members and Operating Agents have seen a continued growth of our activities and an ongoing increase in PV installations and PV initiatives throughout the world.

The formulation of the PVPS Strategy for the period 1998-2002, a document still guiding our work, heralded a good start in 1998. Two new Tasks have been initiated and approved: Task 8 on very large PV systems, and Task 9 on the deployment of PV technologies in co-operation with developing countries. Together with the IEA Solar Heating & Cooling agreement we have created a joint working group on PV-thermal systems. Last year we established good working contacts with FAO, the UN Food and Agricultural organisation, and will continue to expand this relationship.

We joined the Internet by creating an excellent and well-visited website (www.iea-pvps.org), a site which serves as an important source of information about PV systems around the world. Together with the IEA Secretariat in Paris and ENEL we organised a very successful senior executive conference in Venice, "Il Valore del Sole", 3-5 November 1999, focusing on the added value of PV systems.

We have a seen a growing interest, and I admit I helped to stimulate that interest, from non-member countries to join the agreement (such as India, Hong Kong SAR, and others). I sincerely hope that the year 2001 will be the year in which we see the culmination of these efforts into their formal membership.

For this annual report each Executive Committee member has provided a broad overview of current PV activities in his or her country. More details about PV applications in IEA countries can be found in a separate survey report published annually by Task 1 of the PVPS programme: 'Trends in Photovoltaic Applications in Selected IEA Countries'. For the first part of this annual report the Operating Agents of the seven running Tasks have compiled reports with the results of their work in 2000, and an outlook on future activities.

The year 2000 was characterised, amongst others, by the tedious efforts to arrive at a complete review of our PVPS Agreement text, with the indispensable support of Mrs Lynette Rogers-Goderum of the IEA Office of the Legal Counsel in Paris. Also the PVPS Handbook of Policies and Procedures was revised. On the personal side we were happy to congratulate our Executive Secretary Hester Pruiksma with the safe arrival of her second baby, in November 2000.

Erik H. Lysen
Chairman

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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 2000 nine Tasks were established within the PVPS programme, of which one was completed in 1997 (Task 6) and one is not operational (Task 4).

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. But 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 RD&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.

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

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
- 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
- Task 8. Very large scale PV power generation systems
- Task 9. Deployment of PV technologies: co-operation with developing countries

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 intensified, or stopped. 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.

Photo 1: Executive Committee members and Operating Agents at the 16th ExCo meeting, 17-18 October 2000, Sorrento, Italy.

TABLE 1 – STATEGIES 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 powersystems 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.

TASK STATUS REPORTS

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

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.

Task 1 activities are organized into the following subtasks:

SUBTASK 1.1: Status survey reports
International Survey Reports are compiled from the (currently) internal National Survey Reports produced annually by all countries participating in the IEA-PVPS Programme. The International Survey Reports present and interpret trends in the PV systems and components being used in the PV power systems market, as well as changing applications within that market. This is done in the context of the business environment, policies and relevant non-technical factors in the reporting 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 four issues had been published by the end of 2000.

SUBTASK 1.2: Newsletter
A newsletter, *PVPower*, 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.

Thirteen issues of the newsletter had been published by the end of 2000.

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" and "Photovoltaics in competitive electricity markets". 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". The recent activity "Added values of photovoltaic power systems" continued throughout 2000. A new activity "Costing of energy from photovoltaic power systems" has commenced.

SUBTASK 1.4: Executive Conference
Conferences targeted at senior executives from the PV industry, utilities, the finance sector, government and NGOs are organized periodically. The third of these conferences was held in Italy in November 1999.

SUMMARY OF TASK 1 ACCOMPLISHMENTS FOR 2000

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. Consequently, the ongoing development of the website remains a priority activity for Task 1. 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 fifth issue of the International Survey Report was published in September 2000 and analyzed data collected between 1992 and the

end of 1999. The report was prepared under the supervision of Task 1 by an independent consultant on the basis of the National Survey Reports prepared by all Task 1 participants. These internal reports were completed by most countries within one month of the nominated deadline. Minor amendments to the guidelines for future reports have been endorsed.

The International Survey Report was funded by the PVPS Common Fund and was distributed by Task 1 participants to their identified national target audiences and at selected conferences and meetings. The report is also available on the public website.

The Executive Committee tendered for proposals to write and produce the International Survey Reports in 2001 and 2002.

SUBTASK 20: Newsletter

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

Issue 12 of the newsletter was published in February 2000. Issue 13 was published in September 2000 and contained a new section highlighting relevant websites. Issues of *PVPower* are now available on the public website.

SUBTASK 1.3: Special information activities

- **Added values of photovoltaic power systems** - A Task 1 Working Group organized a second workshop on this topic which was held in Glasgow on 5 May 2000 in conjunction with the European PV Solar Energy Conference. The workshop attracted a broad range of participants. A technical writer for the final report has been contracted by Japan, as lead country for this activity.
- **Answers to frequently asked questions about solar photovoltaic electricity: an international perspective** – Task 1 participants have provided examples of these questions (and the answers) from their countries, the results of which will be posted on the public website.
- **New work** – A proposed new activity on costing of energy from photovoltaic power systems was discussed and endorsed.

SUBTASK 1.4: Executive Conference

Planning commenced for the fourth IEA Executive Conference on PV Power Systems to be held in Japan, May 2003.

SUMMARY OF TASK 1 ACTIVITIES PLANNED FOR 2001

The issue of market implementation has been identified as a key focus for future PVPS activities, and during 2001 Task 1 will develop plans for future special information activities accordingly. The development of the website will continue to be influenced by

LIST OF PARTICIPATING COUNTRIES, KEY TASK 1 PARTICIPANTS IN 2000 AND THEIR ORGANIZATIONS

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	Gerd Schauer	Verbund
Canada	Raye Thomas	NewSun Technologies Ltd
Denmark	Peter Ahm	PA Energy A/S
European Union	Paul Doyle	DG 12
Finland	Leena Grandell	MOTIVA
France	André Claverie	ADEME
Germany	Peter Sprau	WIP
Israel	Yona Siderer	Ben Gurion Solar Energy Center
Italy	Salvatore Guastella	CESI - ENEL
Japan	Masao Kando	NEDO
Korea	Kyung-Hoon Yoon	KIER
Mexico	Jaime Agredano Diaz	IIE
Netherlands	Astrid de Ruiter	NOVEM
Norway	Bruno Ceccaroli	SCATEC AS
Portugal	Gina Pedro	DGE
Spain	Jesùs Garcia Martin	Iberdrola
Sweden	Lars Stolt	Uppsala University
Switzerland	Pius Hüsser	Nova Energie GmbH
United Kingdom	Paul Cowley	IT Power
United States	Charles Linderman	Edison Electric Institute

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

the requirements for information that are identified and revised by Task 1 participants and others. As the website evolves it will be important to understand why the target audience in particular and the public in general are visiting the site, and to build features such as links and navigation around this.

SUBTASK 1.1: Status survey reports

The target date for publication of the sixth issue of the International Survey Report is the end of September 2001. The Executive Committee has contracted a technical writer to produce the sixth and seventh issues. Changes to the format and content of the sixth issue and an agreed timetable for production will be finalized during the March 2001 Task 1 meeting.

National Survey Reports will be completed by the end of May 2001 so that the information can be incorporated in the International Survey Report.

SUBTASK 1.2: Newsletter

Two further issues of the newsletter – issues 14 and 15 – will be published during the year. The existing format and content will be maintained, with minor amendments, while feedback from target audiences continues to be positive.

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.

SUBTASK 1.3: Special information activities

- **Added values of photovoltaic power systems** - a public PVPS report, targeted at policy makers and incorporating the results of the two workshops (Sapporo and Glasgow) and other discussions, will be produced in March 2001.
- **Costing of energy from photovoltaic power systems** – this activity will be developed, researched and reported by Task 1 during 2001.

INDUSTRY INVOLVEMENT

Task 1 activities rely on close co-operation with 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 and continually updated in each country by the Task 1 participants.

KEY DELIVERABLES (2000 AND PLANNED)

An IEA-PVPS Task 1 workshop on "Added values of photovoltaic power systems" was held in Glasgow, GB on 5 May 2000 in conjunction with the European PV Solar Energy Conference. The workshop attracted a broad range of participants.

The following reports were published and also made available on the public website during 2000:

Trends in photovoltaic applications in selected IEA countries between 1992 and 1999
Report IEA-PVPS T1-08: 2000 – September 2000;

Newsletter – *PVPower* Issues 12 and 13.

During 2001, the sixth issue of the International Survey Report and *PVPower* Issues 14 and 15 will be published. The final report on *Added values of photovoltaic powersystems* will be published early in the year. A selection of frequently asked questions and answers will be added to the website. A report on *Costing of energy from photovoltaic power systems* will be published later in the year.

The following internal document was updated during 2000:
Preparing international technical reports Internal report IEA–PVPS T1–01:1997 (updated 2000). This document is contained within the IEA-PVPS *Handbook of policies and procedures.*

National Survey Reports and guidelines are produced and updated each year.

MEETING SCHEDULE (2000 AND PLANNED 2001)

- The 16th Task 1 Participants' meeting was held in Naples, Italy, 15-17 March 2000.
- The 17th Task 1 Participants' meeting was held in Munich, Germany, 9-11 October 2000.

- The 18th Task 1 Participants' meeting will be held in Aarhus, Denmark, 21-23 March 2001.
- The 19th Task 1 Participants' meeting will be held in the USA, October 2001.

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. Maintenance of PV systems and subsystems is an important aspect of long-term plant operation and will be included in the Task activities.
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.

During the first phase of Task 2 (1993 – 1999), the PVPS Task 2 database and related software tools had been developed and upgraded. The international database containing more than 260 PV systems and about 600 annual sets of monthly data had been distributed to Task participants and other Tasks of PVPS.

SUBTASK 2: EVALUATION OF PV 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 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 „Analysis of PV Systems".

SUBTASK 3: MEASURING AND MONITORING

Participants assess 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, 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 in activity „Operating experiences".

SUBTASK 4: IMPROVING PV SYSTEM PERFORMANCE

This activity has started with the second phase of Task 2 (2000-2004). Participants make 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 work in collaboration with Tasks 3 and 7.

SUMMARY OF TASK 2 ACCOMPLISHMENTS FOR 2000

The revised work plan focuses on Subtasks 1 and 2 and puts less emphasis on Subtask 4.

SUBTASK 1: INTERNATIONAL DATABASE

A **new database application** has been designed to substantially improve the existing database programmes. This includes a new structure, which allows to import the existing database and collected data. The new database results in the reduction of the number of essential data fields, in the design of an improved and simplified user interface and the integration of PV system photos as well as system block diagrams into the database (For examples see Figures 1 & 2). The new database features simplified data export to spread sheet programmes, improved filter and sort criteria to navigate in the database and an easy search for a specified PV system. Data import and export facilities have been developed including automatic calculations of annual results. Data export includes plant data (general plant information and component data), operational data (monthly monitoring data) and annual results (sums and mean values of performance indicators).

Data collection was continued and focused on additional data sets from already existing PV systems, new types of PV systems (i.e. building integrated PV, facades and AC-modules) and PV systems in „new" countries. Due to various national programmes (e.g. Japan, Italy, Germany) and corresponding monitoring activities, representative data were collected by each Task participant and 40 new PV system data were imported into the PVPS Task 2 database for the year 2000. The quality of the existing data was checked for all 300 PV systems in the database. While 80 % of the plant information and monitoring data are of good and acceptable quality, 20 % of the data needed further inputs and corrections. An Excel workbook for data import has been developed which includes automatic calculations of annual results and thus can be used for data checking and correction.

LIST OF PARTICIPATING COUNTRIES, TASK PARTICIPANTS IN 2000 AND THEIR ORGANISATIONS

COUNTRY	PARTICIPANT	ORGANISATION
Austria	Michael Heidenreich	Arsenal Research
France	Didier Mayer	Ecole des Mines de Paris
Germany	Mr. Reinhard Dahl Ms. Ulrike Jahn Mr. Wolfgang Nasse	Forschungszentrum Jülich GmbH Institut für Solarenergieforschung (ISFH) Solar Engineering GmbH
Italy	Mr. Salvatore Castello	ENEA
Japan	Mr. Koichi Sakuta Mr. Tadatoshi Sugiura	Electrotechnical Laboratory, METI JQA Organization
Netherlands	Mr. Nico van der Borg	ECN
Switzerland	Mr. Luzi Clavadetscher Mr. Andreas Frölich	TNC Consulting AG TNC Consulting AG

SUBTASK 2: EVALUATION OF PV SYSTEMS

The activity of PV system performance analysis has been continued. All system and subsystem performance data have been evaluated in terms of operational performance and reliability. To a great extent the evaluation procedures are based on the European Guidelines, Document B, taking small modifications into account. Additional parameters are introduced for the evaluation of stand-alone systems. Performance results are presented in standard format using normalised indicators such as energy yields (normalised to the nominal power), efficiencies (normalised to the array plane) and performance ratio (normalised to the in-plane irradiation).

The IEA-PVPS Task 2 report „Analysis of PV systems" was published in April 2000 *(see Figure 3)*. This detailed technical report contains:

- basic information on the PVPS Task 2 database and programmes, evaluation of performance data and presentation of results
- operational performance results and lessons learnt of 260 PV systems
- a documentation of 40 representative PV systems from nine PVPS Task 2 countries includes general information, operational results and a photograph from each plant.

A full version (230 pages) and a short version (30 pages) of this official IEA-PVPS Task 2 report are available on CD-ROM and can be downloaded from the public IEA-PVPS website.

A paper on „Analysis of the Operational Performance of the IEA Database PV Systems" was published and presented at the 16th European PV Solar Energy (PVSE) Conference in Glasgow, Scotland, in May 2000. A very good response has been received to this publication by conference participants.

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. Case studies were conducted to improve the Energy Management Strategies (EMS) and operational conditions for stand-alone hybrid systems.

A paper on „Analysis and Optimisation of the Control Strategies for Stand-alone PV-Diesel Systems" was published at the 1st European PV Hybrid Power Systems (PVHPS) Conference in Aix-en-Provence, France, in September 2000.

SUMMARY OF TASK 2 ACTIVITIES PLANNED FOR 2001

Task 2 activities for 2001 will focus on the effective **dissemination of technical PVPS information** which has been elaborated in all of the four Subtasks. The distribution of the new database application will be carried out through national channels in Task 2 participating countries and on international level. Publications and workshops on PV performance, long-term reliability and sizing of PV systems are planned in conjunction with international conferences.

A **Task 2 public website** will be developed and used to disseminate technical information such as summary reports on performance results of new PV systems, updates of the PVPS Task 2 database and other information like announcements of workshops and related events.

Inter-task communication will be enhanced in order to improve the common PVPS work. The co-operation between Task 2 and Task 3 will be continued to work on control strategies for PV stand-alone

MEETING SCHEDULE (2000 AND PLANNED 2001)

TASK 2 MEETING	DATE	PLACE
2nd Task 2 participants` meeting	28 February – 1 March, 2000	Juelich, Germany
3rd Task 2 participants` meeting	7-8 September, 2000	Horgen, Switzerland
4th Task 2 participants` meeting	19-20 March, 2001	Sophia-Antipolis, France
5th Task 2 participants` meeting	19-21 September, 2001	Yokohama, Japan

systems. Inter-task collaboration with Task 7 is planned in the field of operational experiences and to support the work on recommendation of PV system performance.

SUBTASK 1: INTERNATIONAL DATABASE

The new PVPS Task 2 database and report programmes will be released in April 2001 after successful testing and approval by Task participants. The database will be distributed in form of CD-ROM or via Internet in a non-commercial way as widely as possible. Updates featuring improved software tools and additional data will be made available for download from the public Task 2 website at the end of 2001.

Data collection of new types of PV systems will be continued, while minimum input from Task participants and other sources is expected to reach a target of 10 – 20 new PV systems per year.

SUBTASK 2: EVALUATION OF PV SYSTEMS

The activities of PV system performance analysis will be continued. Performance results will be presented in standard format:

- Summary report updates on performance results of new PV systems will be produced and published on the public Task 2 website.
- A report containing information and recommendations on operational reliability will be prepared.

Task 2 participants will conduct case studies on long-term behaviour of PV systems evaluating data from selected PV systems. This work will focus on the reasons for not working systems and go beyond a statistics of failures. Failure rates and repair times will be considered under the aspect of non-technical barriers.

Figure 1: New PVPS Task 2 database programme showing plant information and photo for selected PV system

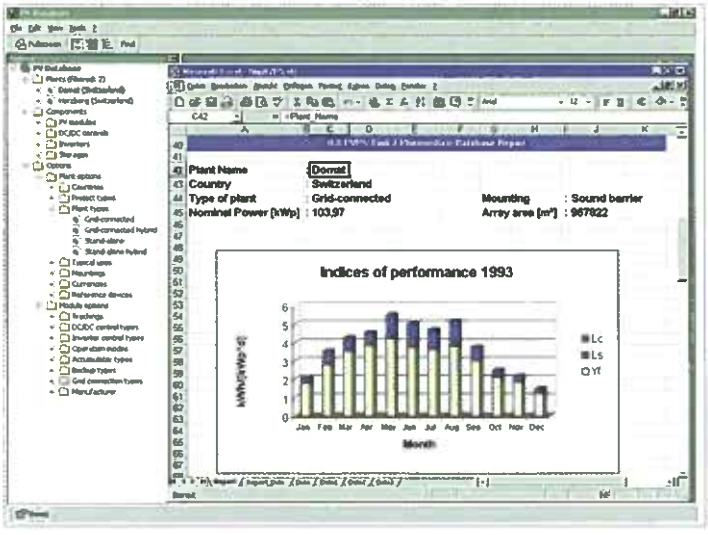

Figure 2: New PVPS Task 2 database programme showing normalised performance results for the same selected PV system (see Fig. 1)

SUBTASK 4: IMPROVING PV SYSTEM PERFORMANCE

Task 2 will start developing a specific methodology on sizing of PV systems to improve PV system operation from the analysis of operational data. An overview of existing Energy Management Strategies (EMS) for stand-alone hybrid systems will be elaborated. Work on PV systems performance assessment will be continued checking the relevance of matching factor and usage factor and defining the minimum parameters required for performance assessment. Case studies will be conducted to improve the EMS and the optimum operational conditions of stand-alone systems.

INDUSTRY INVOLVEMENT

- Data collection from utilities and manufacturers have been proceeded to carry out Task 2 activities.
- PVPS Task 2 database has been and will be delivered to PV producers and distributors.

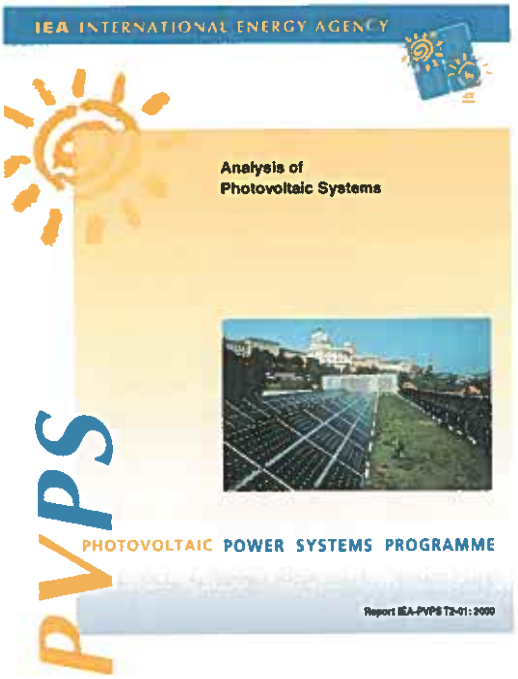

Figure 3: Cover page of Report IEA-PVPS T2-01: 2000 „Analysis of PV Systems", April 2000

KEY DELIVERABLES (2000 AND PLANNED 2001)

The following documents were published during 2000:

- Report IEA-PVPS T2-01:2000; „Analysis of PV Systems", April 2000;
- Paper „Analysis of the Operational Performance of the IEA Database PV Systems", PVSE Conference proceedings, Glasgow, Scotland, May 2000;
- Paper „Analysis and Optimisation of the Control Strategies for Stand-alone PV-Diesel Systems", PVHPS Conference proceedings, Aix-en-Provence, France, September 2000.

The following products have been developed during 2000 and will be released / published in 2001:

- PVPS Task 2 database application for entry, standardised evaluation and export of PV data.
- Database with collected data from 300 PV systems will be released in April 2001.
- During 2001, a manual on database application and on evaluation of PV systems will be published.
- An overview of existing energy management strategies will be compiled.

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.
To this end, a detailed new workplan has been approved by the Executive Committee in May 1999.
The main objective of the Task 3 extension programme is **to contribute to the cost reduction of systems** through collaborative activities focused on **technical issues**, divided into the two main following categories :

Subtask 1 : Quality assurance : quality assurance schemes for improved reliability and lower global life cycle costs
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 main 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 with the large range of stand-alone PV applications, it is necessary to take into account systems operating in industrialised and southern countries.
The list of case studies of installed PV and PV-diesel hybrid systems will be drawn up such that it is instructive for all subtasks : the objective is to have a "multi-purpose" overview on the different selected systems.

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 are working 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)

Major activities in 2000
In an effort to assist the implementation of Quality Assurance for stand-alone and island photovoltaic power systems in both IEA member and non-member countries, it is intended that Task 3 experts should establish communication with the relevant standards and QA organisations. It is hoped that this dialogue will assist in the development of appropriate guidelines for QA procedures.
Prior to the start of this dialogue, however, an understanding of the current status of national and international standards has been formulated. In order to gain a complete picture of the present status of national and international guidelines and QA procedures, the Task 3 experts each completed a survey on current guidelines in their respective countries. In addition, a comprehensive study of international guidelines has also been undertaken. The results of these surveys form the basis for a document which is available on the Task 3 website.

Deliverables
- Survey of national and international standards, guidelines and quality assurance procedures for stand-alone PV systems.

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 2000 and foreseen activities in 2001
The work was focused on the preparation of recommendations dedicated to "Quality management ".
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. In 2002, a final document will be produced, with a collection of quality management data as observed in the field : real practices, success and failure stories collected through feed back from case studies.

Deliverable under preparation
- Quality management of SAPV systems: recommended practices

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.

As learned from experience, relatively high costs of remote maintenance are a major factor in the global life cycle cost of hybrid systems.
Technical development should concentrate on the following recommendations:

1. Encourage modularity to facilitate industry expansion and reduce the capital cost of systems
2. Monitoring system performance to help reduce the maintenance costs
3. Promote controller and user interfaces able to reduce operation complexity and maximise fuel savings

Major activities in 2000

Prospective users of sustainable energy based systems frequently require advice about the technology that best suits their needs. More often than not, different system architectures, monitoring procedures and applications so complicate comparisons between the performance of "stand alone" electricity generation systems, that they confuse the technology capability issue. 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. Having regard to the situation outlined in the previous paragraph, the decision was made to prepare performance indicators of SAPV systems and monitoring guidelines, setting out how to equitably monitor system performance for a range of "stand alone" PV system.
The objectives of the System Performance Assessment Guidelines are to:

- Influence data collection methods to facilitate effective comparison of systems internationally.
- Establish a case study record that can be used to provide prospective PV users with relevant information about PV technology and its applications.

Another activity is relative to PV power system selection.
Third parties, interested in "sustainable energy" solutions, face claims and counterclaims about technology capabilities, and are plied with an assortment of performance data, some derived from the maker's specification, some measured in the field, but nearly all collected on a piecemeal basis without any form of quality management.
Choice of a system to service a 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 choose or identify the technologies that might be appropriate for their situation becomes obvious.
That's the reason why guidelines are 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.

Deliverables under preparation

I. Performance indicators of SAPV systems and monitoring guidelines
II. Guidelines for SAPV systems selection

Major foreseen activities in 2001

I. Guidelines as described above (continued)
II. Contribution to a Workshop on Hybrid Systems held in Canada in September 2001

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 2000

An overview of the batteries used in PV systems in order to have information about lifetime (and full costs) of batteries in different SAPV configurations was launched through a questionnaire.
A technical work programme was undertaken concerning battery management strategy.
In the objective to gather information of possible alternatives to lead-acid batteries for short, middle and long term storage (main performance, field of applications, estimated costs), Task 3 members have been involved in a project whose aim is to build a state of the art of the existing and innovative technologies in the context of renewable energies.

Deliverables under preparation

I. The limits of the management of batteries by voltage thresholds

Major foreseen activities in 2001

I. Best practice guide on battery specifications and test procedures as used and useful in the field
II. Review on alternative technologies to lead-acid batteries for storage function in PV systems (continued)

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 could be an integrating issue which will call 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 2000

A survey of main recurrent technical difficulties with DC and AC appliances as seen in the field was launched. This survey considers the poor compliance of the technical characteristics of DC and AC appliances with the power and energy management design of a stand-alone PV system. The main idea 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.

Deliverable under preparation

I. Appliances : list of problems due to appliances and related solutions in SAPV systems

OTHER ACTIVITIES

Other activities in 2000

I. Implementation of Task 3 website : www.task3.pvps.iea.org
II. Contribution to a workshop on Hybrid systems, September 2000
III. Papers presented at the 16th European PV Solar Energy Conference an Exhibition , Glasgow, May 2000
"Stand-alone and island applications of photovoltaic power systems : Task 3 of the International Energy Agency Photovoltaic Power Systems Programme"
"Review of standards and quality assurance schemes for PV systems".
Paper presented at the PVHPS Conference, Aix en Provence, September 2000
"Monitoring with effect-performance evaluation of SAPV systems"

Foreseen activities in 2001

- Co-operative work with Task 9 :
  Technical work relative to certification and accreditation of systems, installer training, user training
- Contribution to a Workshop on Hybrid systems, September 2001

MEETING SCHEDULE

Meetings held

14th Task 3 expert meeting, February 1999, Australia
15th Task 3 expert meeting, September 1999, Sweden
16th Task 3 expert meeting, February 2000, Portugal
17th Task 3 expert meeting, September 2000, France

Meetings planned

18th Task 3 expert meeting, March 2001, Norway
19th Task 3 expert meeting, September 2001, Canada

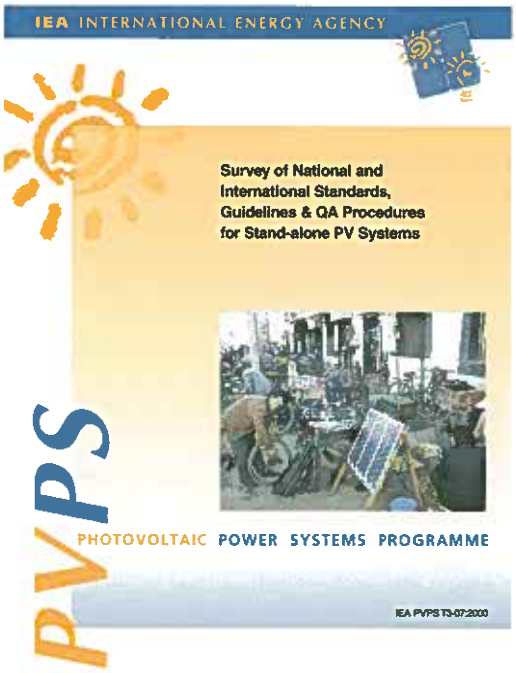

Figure 3: Cover page of Report IEA-PVPS T2-01: 2000 „Analysis of PV Systems"

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Spain	Xavier Valive	TTA
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 is to develop and verify technical requirements, which will serve as the technical guidelines for grid interconnection with building-integrated and other dispersed PV systems. The development of these technical requirements will include safety and reliable linkage to the electric grid at the lowest possible cost. The systems to be considered will be those connected with a low-voltage grid, which are typically of a size between one and fifty peak kilowatts.

MEANS

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

- **Subtask 10**: Review of previously installed PV experiences
  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
  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
  To evaluate by demonstration tests the performance of existing and new technical requirements and devices defined in subtask 20.
- **Subtask 40**: Summarizing results
  To summarize the results of Task 5 and to produce a general report for all participating countries of Task 5 and for Ex.Co. members.
- **Subtask 50**: Study on highly concentrated penetration of grid interconnected PV systems
  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 to enable widespread deployment of solar energy.

OVERVIEW OF PAST ACTIVITIES

- **Subtask 10**
  Survey for existing guidelines and regulations for grid connection of PV systems and difference of electrical distribution systems in Task 5 participating countries were completed as Task 5 internal report open to IEA member countries. Report on inverter and related protection equipment was distributed to expert members as Internal Task Working Document. Summary of PV operating experience from participating countries was included in the Task 5 summary report.

- **Subtask 20**
  Research results on subjects important for interconnection of PV systems were completed as official IEA report. Following are the contents of report for each subject.
  Harmonics; Harmonic effects, present international rules, experimental results were summarized in the report.
  AC-Module; Recent situation concerning R&D, commercial products and regulation on AC module in participating countries were summarized.
  Multiple inventers and AC Grid; Problems and countermeasures for voltage variation, reverse power flow, and grid short circuit fault were summarized in the report.
  Grounding of Equipment in PV Systems; Standards and codes or each country for grounding requirement were summarized.
  Ground-fault Detection and Array disable for PV systems; Fire safety, grounding fault detection on DC side, etc. were summarized.
  Overvoltage protection; Overvoltage due to indirect lightning strokes were analyzed with considering grounding structure of the PV system.
  Islanding; Islanding prevention methods developed and adopted in each country were summarized in the report.
  Electro Magnetic Compatibility; Standards and codes for electromagnetic emission ware collected and summarized.
  External disconnect; Standards and codes of each country for the external disconnecting devices were collected and summarized.
  Reclosing; Theory, problem, and experimental results for the effect of reclosing on PV systems were summarized in the report.
  DC injection and isolation transformer; Influences of DC injection on utility transformer were investigated by experiments.

- **Subtask 30**
  Demonstration tests for harmonics, islanding, PV output variation etc. were conducted using Rokko Test Facility in Japan. Subtask 30 report, summarizing demonstration test results using Rokko Test Facility was completed and published as 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, effect of PV system output fluctuation and others.

- **Subtask 40**
  Summary report of Task 5 activities from 1993 to 1998 was produced as official IEA-PVPS report.
  Summary report is composed of:
  - Executive Summary
  - Summary of subtask activities
    Summary of subtask 10
    Summary of subtask 20
    Summary of subtask 30
  - Future work recommendations

- **Subtask 50**
  5.1 Reporting of PV system grid-interconnection technology
  Draft questionnaires for PV grid-interconnection guideline and

national standards including PV system design and for updated information of inverters and interconnection devices were discussed and approved. Questionnaires for PV testing certification method and for utility inspection and maintenance method were distributed.

5.2 Research on islanding

Discussions about the boundary of islanding for different grid condition were conducted. Preliminary result of measurement of low voltage feeder load and PV output for islanding probability calculation was explained and evaluation method of islanding probability was proposed. Questionnaire for islanding detection methods and testing procedure was distributed.

5.3 Performance of high penetrated PV systems

Preliminary result of grid voltage calculation under PV system penetration using Japanese residential area grid condition was reported. Required data for calculation was proposed. Questionnaire items for distribution planning and design were discussed.

5.4 Capacity of PV systems

Items to decide limiting criteria for PV system penetration and financial aspects of PV system introduction were discussed. Power consumption data for distribution feeder was reported. Discussion for definition of power value and capacity value of PV system was conducted.

OVERVIEW OF ACTIVITIES IN 2000

- **Subtask 50**

51. Reporting of PV system grid-interconnection technologies

Questionnaires for PV grid-interconnection and system design guidelines or standards of Task 5 participating countries and updated information of inverters and interconnection devices have been distributed and collected. The questionnaires for PV testing certification method and utility inspection and maintenance method were collected and summarized. The draft report titled "PV system installation and grid-interconnection guidelines in selected IEA countries" was prepared.

52. Research on Islanding

Survey for grid configuration about customers per transformer was conducted and summarized. The measurement data for load and PV output profile for calculation of islanding probability was collected and summarized. Discussion to determine evaluation method of islanding probability and risk analysis of islanding was made. For islanding prevention method, collection and summarization of questionnaire was made. The method of calculating the probability of islanding (based on measurement of load curve and PV output) was developed. This calculation result suggest that if total capacity of PV systems is under the minimum load (around 20% of peak load) of distribution line, islanding will not occur, however that there is possibility of islanding if PV systems are introduce beyond this level.

53. Performance of high penetrated PV systems

The data for distribution system voltage calculation for different grid conditions were collected. Calculation for the effect of PV system introducing ratio was conducted. Simulation study is ongoing using model distribution line of each participating country. The simulation results suggest that effect of PV system penetration level is notable under minimum load condition (20% of maximum load) and if distribution line has relatively high impedance (overhead line, small size conductor, long line).

54. Capacity of PV systems

Evaluation of the limits for PV system penetration and the financial aspects of PV system penetration have proceeded. Productivity of PV output was evaluated and economic rule for PV system was considered.

SUMMARY OF WORK PLANS FOR COMING YEAR

- Finish subtask 50 works and produce reports for each subject in subtask 50. Results of Task 5 investigations will be presented and discussed at the workshop in November.
- Task 5 is finishing works by Nov. 2000 (Original proposal), if there are no other issues for further investigation for grid-interconnection of PV system. Although there are some concern about the reliability and cost reduction of inverter systems, these subjects had better be discussed among more general natural energy framework including PV systems. Our findings will be able to be transferred to the groups dealing with more general subjects of distributed generator systems.

INDUSTRY INVOLVEMENT

At present, members from utilities and inverter manufactures are participating in Task 5 as experts

Data collection from utilities and manufactures have been proceeded to carry out Task 5 activities.

REPORTS PRODUCED IN 2000

No official IEA report was produced in 2000. Task 5 is preparing to submit the report for approval of publication: "PV system installation and grid-interconnection guidelines in selected IEA countries".

MEETING SCHEDULE

- **Past Meetings (1/2000-12/2000)**
  - 14th expert meeting was held on 5-7 March 2000 in Sydney, Australia
  - 15th expert meeting was held on September 2000 in Cuernavaca, Mexico

- **Future Meetings (1/2001-12/2001)**
  - 16th expert meeting will be held on 5-7 March 2001 in UK
  - 17th expert meeting will be held on 5-7 November 2001 in The Netherlands (with workshop on 8-9 November 2001)

PARTICIPATING COUNTRIES AND LEAD EXPERTS OF TASK 5

COUNTRY	PARTICIPANT	ORGANISATION
Australia	Phil GATES	Energy Australia
	(Alternate) Grayden L. JOHNSON	Energex
Austria	Gerd SCHAUER	Verbundgesellschaf
	Christoph PANHUBER	Fronius KG Austria
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	(Task V Chairman) Tadao ISHIKAWA	CRIEPI
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United Kingdom	Alan COLLINSON	EA Technology Ltd.
	James THORNYCROFT	HGA Ltd.
United States	Ward BOWER	Sandia National Labs.

TASK 7 - PHOTOVOLTAIC POWER SYSTEMS IN THE BUILT ENVIRONMENT

OVERALL OBJECTIVES

The objective of Task 7 is 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 area's 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 will last until end 2001.

MEANS

In order to achieve the overall objectives, participants carry out work in four Subtasks:
Subtask 1: Architectural Design of Photovoltaic Power Systems in the Built Environment;
Subtask 2: Systems Technologies for Photovoltaic Power Systems in the Built Environment;
Subtask 3: Non-technical Barriers in the Introduction of Photovoltaic Power Systems in the Built Environment;
Subtask 4: Demonstration and Dissemination of Photovoltaic Power Systems in the Built Environment.

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

Objective

Participants work 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 are documented. In addition, case studies are followed and evaluated by the Task Participants. Many of these case studies are 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 are developed.

Activities

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

Major activities in 2000

Documentation of high quality projects
The Task 7 BIPV Projects Database of 300 BIPV projects is accessible via http://www.purplepigeon.com/iea-db/ or via the Task 7 website and is open to the public. In addition, 18 brochures of high quality architectural BIPV projects selected out of the Task 7 projects database were prepared via the PISA project, funded by the EC Thermie programme and carried out by Eurec Agency.

Case studies
Task 7 followed a total number of 20 case studies from the design to the realisation phase in order to learn about the process of actually realising BIPV projects and about problems occurring during this process.

Design Tools
The design tools PVSyst 3.01 was released to the market. AllSol will follow soon.

Major activities foreseen for 2001

Book of examples
A high quality book will be presented in the end of 2001: Designing with Solar. The book will focus on PV and architecture, containing examples and reference information for architects.

Case studies
Updating the progress of these case studies will remain crucial for the success of this activity. Collaboration and fine tuning with Task 23 of the IEA Solar Heating and Cooling Programme (working on the same issue) is in process. Publication of the case study report is foreseen at the end of 2001.

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

Objectives

Participants work 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 the 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 Programme.

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

Major activities in 2000

Integration of PV in non-building structures

A report, presenting design issues for PV in non-building structures (street furniture, canopies, etc.) was completed and presented during a design workshop on non-building structures in Sweden in September 2000.

PV/T (combined PV and thermal systems)

Work concentrated on defining a R&D roadmap for PV/T within the IEA PVPS / SHC programmes. A joint working group was established.

New electrical concepts, interconnection issues and reliability

A joint meeting was held with IEA PVPS Task 5, to exchange research results and achievements of both Tasks. Both Tasks keep each other updated on their activities and investigate collaborating opportunities.

Electrical design issues

End 1999, a new activity on 'electrical design issues' was added to the Task. Main purpose of this activity is to include electrical design issues when designing PV buildings. The activity deals with building-related electrical issues only, and not with grid interconnection or grid design. In 2000, this activity analysed the electrical designs of the Task 7 case studies in order to derive some general guides for electrical design.

Major activities foreseen for 2001

Building integration concepts

A workshop on building integration concepts for PV products is due to be held in May 2001, in conjunction to the Sustain 2001 trade fair in Amsterdam.

Reports foreseen on activities of Subtask 2

- Non-building structures: a report on integration of PV in non-building structures in the built environment.
- PV/T: a report on technologies and systems for PV/T (PV and thermal systems)
- New electrical concepts: a report on new and innovative electric concepts
- Reliability: a report on reliability of PV systems
- Electrical design issues: a report with practical electrical information for architects

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

Objectives

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

Activities

3.1: Barrier assessment
3.2: Potential
3.3: Economics
3.4: Strategies

Major activities in 2000

Potential

A report on the potential for building integrated PV was completed.

Market strategies

Work with respect to the analysis and development of market strategies of BIPV will play an increasing role within Task 7. A draft report on this issue was prepared.

Major activities foreseen for 2001

Strategies for barrier removal and utilisation of the PV potential

The work of Task 7 in the field of non-technical barriers will be completed and presented as report on 'non-technical barriers in the field of BIPV and strategies for barrier removal'.
This work will be combined with the work performed under Task 1 of the PVPS Programme, related to the added value of grid connected PV.

The results of the different outcomes of Subtask 3 will also be published in the Executive Summary Report 'Non-technical Barriers to the introduction of BIPV'

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

Objectives

The results of the other Subtasks are 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 in Lausanne. 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 is assessed.

Activities

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

Major activities in 2000

Demosite

The IEA PVPS Task 7 demosite maintained its position as demonstration centre for PV building integration products. Systems demonstrated at the Demosite are accessible via www.demosite.ch.

International Solar Electric Buildings Conference

The 2nd Solar Electric Building Conference took place in Sydney, Australia from March 8-10, 2000. Proceedings are available on the Task 7 website.

International Design Competition

The Task 7 Design Competition for BIPV product design was completed. Designs were evaluated and assessed by the jury and presented at the European PV Conference (Glasgow, May 2000). The jury report is available on the Task 7 website.

Training and education

The Task 7 website was revised. A new Task 7 brochure was issued, pdf copies are available on the Task 7 website.

Major activities foreseen for 2001

Training and education

Work is in progress to establish accredited training courses on BIPV before the end of 2001. A standard programme for such course and minimum attainment levels will be completed.

Deliverables

Key deliverables of 2000

- Internet: Database of more than 300 BIPV projects
- Conference and Proceedings: The 2nd Solar Electric Building Conference in Sydney, Australia (March 8-10, 2000)
- Report: Judges report of the Design Competition "Photovoltaic Products for the Built Environment"
- Brochures: Smart Architecture for a sustainable future. Evaluation of 17 selected BIPV projects (published by the EC Thermie programme)

Key deliverables foreseen for 2001

- Internet: database of BIPV products
- Book: Designing with Solar (BIPV architectural book)
- Report: PV/T, technologies and systems for PV/T
- Report: new and innovative electric concepts for BIPV systems
- Report: Reliability, a survey on the reliability of PV systems
- Report: Electric Design Issues; guidelines for the electric design of BIPV systems
- Report: the BIPV potential in IEA member countries
- Report: international guide for the economic assessment of BIPV
- Report: strategies for the removal of non-technical barriers in the field of BIPV
- Executive Summary Report: Non-technical Barriers to the introduction of BIPV
- Package: an IEA training course for PV designers

Participants

Currently there are 14 countries participating 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 next page.

Task 7 Meetings

Meetings in 2000

7th Expert Meeting
March 5-6, 2000
Sydney, Australia

8th Expert Meeting
4-5 September, 2000
Stockholm, Sweden

Meetings in 2001 / 2002

9th Expert Meeting
March 8-9, 2001
Freiburg, Germany

10th Expert Meeting
17-21 September 2001
Tokyo, Japan

Final Conference
Spring, 2002
The Netherlands

TABLE: LIST OF TASK 7 PARTICIPANTS

COUNTRY	PARTICIPANT	ORGANISATION
Australia	Deo Prasad	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	Sol Source Engineering
Denmark	Kaj Isaksen Henrik Sørensen	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 Elisabeth Kjellsson Miguel Angel Romero	Energibanken Lund University EcoCode
Switzerland	Christian Roecker Daniel Ruoss / Peter Toggweiler	EPFL -LESO-PB ENECOLO
the Netherlands	Michael Colijn Siard Hovenkamp Henk Kaan Tjerk Reijenga Tony Schoen	Shell Solar Energy bv Ecofys Energieonderzoek Centrum Nederland BEAR architecten Ecofys
USA	Patrina Eiffert Steven Strong	National Renewable Energy Laboratory Solar Design Associates Inc.

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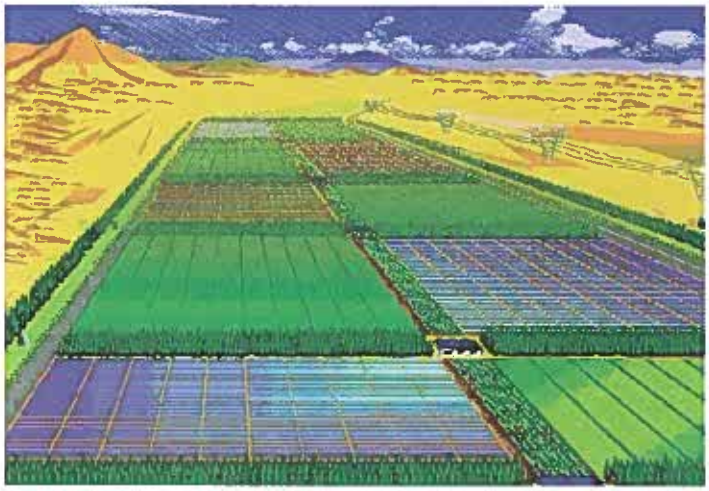
Websites:
Task 7 website: www.task7.org
Task 7 demosite: www.demosite.ch
PV Projects database:
http://www.purplepigeon.com/iea-db/

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

OVERALL OBJECTIVES

The objective of Task 8 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 VLS-PV SYSTEMS

Objective

The conceptual configuration of VLS-PV systems is developed from viewpoint of technological/economical feasibility and 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

Both Life-cycle analysis and input/output (I/O) table analysis are employed as important approaches to carry out case studies. Major desert areas for the case studies were selected: the Gobi desert, the Sahara desert and Middle East desert. Data acquisition activity for the case studies has started. Especially world irradiation database and degradation data were discussed in depth.

Major activities planned for the coming year

The data acquisition activity to complete the case studies will be continued.

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

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

Subtask 2 started in 1999, and the following case studies were tentatively adopted: case studies on world deserts (the Gobi in depth), case studies on the Sahara Desert including network concept and technology transfer, and a case study on the Middle East desert with high concentration technology. For each the case study, plant design and investigation of estimation procedure were undertaken.

Major activities planned for the coming year

All the case study will be completed and the result will summarised.

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

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

Subtask 3 started in 1999, too. Procedures to evaluate various outputs from the subtask 2 were discussed. As described above, the Life-cycle analysis is one of important approaches. In addition, there were meaningful discussions on sustainable scenarios such as sustainable growth of VLS-PV, regional, socio-economical sustainability, and sustainable financial support.

Major activities planned for the coming year

Evaluation procedure will be prepared, and full-scale scenario study will start.

Other activities

The first international workshop on "potential of very large scale

PV Systems on Desert" took place in Glasgow at the beginning of May 2000, as a side event of EUPSEC-16.

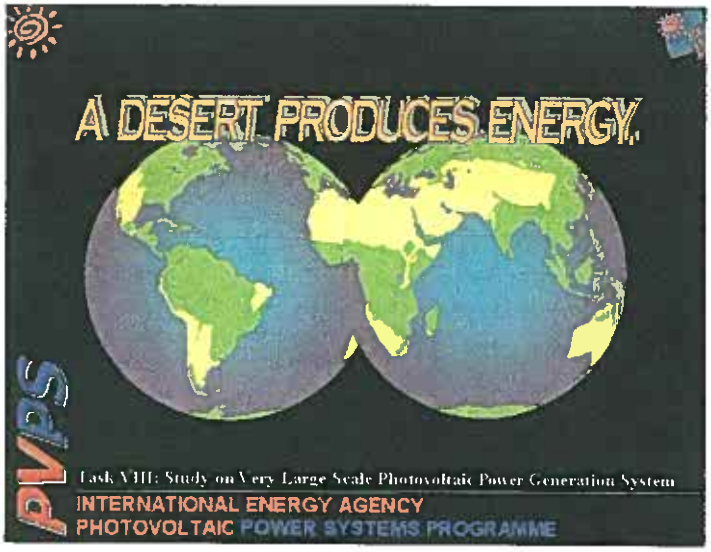
Deliverables

Internal publication

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

External publication

"A DESERT PRODUCES ENERGY", official brochure of Task 8



PARTICIPANTS

As shown on the table, currently there are seven countries participating in Task 8, with representatives from research institute, university, utility, PV consultancy and industry.

MEETING SCHEDULE

Meetings held

1st Task 8 participants meeting, June 28-29, 1999, Paris
2nd Task 8 participants meeting, December 1-2, 1999, Utrecht
3rd Task 8 participants meeting, April 30, 2000, Glasgow
International workshop, May 2, 2000, Glasgow (as a side event of EUPSEC-16)
4th Task 8 participants meeting, September 15-16, 2000, Sacramento

Meetings planned

5th Task 8 participants meeting, June 9-10, 2001, Cheju Island
International symposium, June 2001, Cheju Island (as a side event of PVSEC-12)
6th Task 8 participants meeting, 3-5 September 2001, Ulan Bator
7th Task 8 participants meeting, spring 2002, Israel
8th Task 8 participants meeting, fall 2002, Paris
Final conference, spring 2003, Osaka (as a side event of WCPEC-3)

PARTICIPATING COUNTRIES AND PARTICIPANTS

COUNTRY	PARTICIPANT	ORGANISATION
Israel	Mr. David Faiman	The Ben-Gurion National Solar Energy Centre
Italy	Mr. Pietro Menna Mr. Fabrizio Paletta	ENEA ENEL-SRI PAL
Japan	Mr. Masao Kando Mr. Kosuke Kurokawa Mr. Kazuhiko Kato Mr. Eiichi Waki Mr. Keiichi Komoto Mr. Shuji Yamamoto	NEDO Tokyo University of Agriculture and Technology Electrotechnical Laboratory, AIST, MITI NEDO Fuji Research Institute Corporation 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

TASK 9 - DEPLOYMENT OF PHOTOVOLTAIC TECHNOLOGIES: CO-OPERATION WITH DEVELOPING COUNTRIES

Objective

There is a growing awareness that the conventional electricity grid will not reach the estimated two billion people in developing countries without access to electricity in the foreseeable future.

The principal commercial markets for PV are for off-grid applications, such as telecommunications. PV is also uniquely attractive as a source of electricity for basic services, such as lighting, TV and radio for those people without access to conventional electricity services in the developing world. The technology is already cost-competitive with traditional alternatives, such as kerosene lamps and small diesel generators.

The objective of Task 9 is to increase the overall rate of successful deployment of PV systems in developing countries, through increased co-operation and information exchange with developing countries and the bilateral and multilateral donors.

Approach

In order to achieve its objective, the collaborative work is organised in three Subtasks:

- **Subtask 10: Improvements to the PV Deployment Infrastructure** will be achieved by tackling the critical barriers through assembling experiences, both successes and failures, in a range of countries, and thereby preparing *Recommended Practice Guides*.
- **Subtask 20: Support to Bilateral, Multilateral Donors and Development Banks** will be provided through *Workshops* in the institutions and in client developing countries. Co-operation is also established with the IEA's Renewable Energy Working Party initiatives.
- **Subtask 30: Technical and Economic Aspects of PV in Developing Countries** will be investigated for small stand-alone systems, village mini-grid and hybrid systems, and eventually grid-connected systems. Utilities will be involved. Requirements for further research will be communicated to other relevant PVPS Tasks.

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

SUBTASK 10: DEPLOYMENT INFRASTRUCTURE

Aim

To develop, disseminate and apply 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

PV Deployment in Developing Nations

First draft of a document highlighting the issues pertinent to the large scale deployment of PV in developing countries has been prepared. The document highlights the specific issues relating to the deployment of PV in Developing Countries and will be supported by a series of detailed Case Studies which are also being prepared by the Task Experts.

Recommended Practice Guides

The drafting of four Recommended Practice Guides is under way:

1. Installation, Maintenance and End-user Training
2. Institutional development
3 Financing Mechanisms
4 Certification and Accreditation of Training Programmes

First drafts of these documents are scheduled to be presented at the 4th Experts Meeting in Indonesia in March 2001

Work Planned for 2001

First drafts of the following Recommended Practice Guides will be produced for presentation at the 5th Experts Meeting in Canada. The guides will cover the following topics:

- Government policy and RE planning
- Operation and maintenance of systems
- Infrastructure frameworks
- Awareness raising

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.

Nwanedi School - Northern Province, South Africa

Solar Home System Shop - Tibet

Activities

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

The following workshops have been arranged to take place in conjunction with the 4th Experts Meeting in Jakarta.

- A Renewable Energy Promotion Seminar co-ordinated by SECO and Task 9 for the ASEAN Centre for Energy
- Financing Solar Home Systems in Developing Countries co-ordinated by ISES and Task 9.

In response to a request by the ASTAE Unit of the World Bank, Task 9 reviewed two manuals: *PV Installation and Maintenance Practitioner Certification Infrastructure: Development Procedures.* This manual is currently being developed as one of the Task 9 RPGs.

Task 9 also reviewed a document prepared by the Energy and Atmosphere Programme of the UNDP: *New Financial Mechanisms and Economic Instruments to Speed up the Investment in Sustainable Energy Development.*

Task 9 prepared a paper for submission to the G8 Task Force via a workshop held in Paris in October 2000. The paper was also passed to the IEA's Renewable Energy Unit.

Work Planned for 2001

A series of workshops are planned over the next four years. The following agencies have been identified as host institutions:

- World Bank Group, Washington
- United Nations Development Programme (UNDP), New York
- Asian Development Bank (ADB), Manila
- Inter-American Development Bank (IDB), in-country-office in a Latin American State
- African Development Bank (AFDB), Abidjan
- European Commission (EC), Brussels

Task 9 is working with the PVPS ExCo and Task 3 to organise an Executive Conference, provisionally title: Renewable Energy for Rural Services. The aims of the conference are twofold:

Task 9 Expert's site visit, Oulad village water pump, Morocco

- to bring to the attention of high level decision makers and policy makers, the scope for renewable energy on a large, distributed scale, and
- to exchange information on how to practically achieve a step-change in the use of this technology.

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

Aim

To investigate the techno-economic aspects and potential of PV systems, and the roles of utilities in developing countries. This Subtask will identify areas requiring further research and, in order to avoid duplication, feed this into other PVPS Tasks where appropriate.

Activities

The detailed definition of subtask 30 is now complete and the activity is now due to start. The subtask has three activities.

31 Stand-alone PV systems
32 Village grid and hybrid systems
33 Grid-connected PV systems

Work Planned for 2001

Task 9 will be evaluating tools for planning and designing PV and hybrid mini-grid systems. These tools will be largely computer based and will include Homer, Rapsim, Retscreen, Viper, Hybrid and possibly others. An evaluation of financial analysis tools and techniques will be undertaken and these compiled into a Task Report. The report will also assess relevant economic considerations and the assignment of economic environmental and social benefits arising from the implementation of PV.

TASK MEETINGS

1st Experts Meeting, 14-16 October 1999, Utrecht, The Netherlands.
2nd Experts Meeting, 8-9 February 2000, Washington DC, The USA.
3rd Experts Meeting 28-29 September 2000, Jakarta, Indonesia

PLANNED MEETINGS

4th Experts Meeting, 26-27 March 2001, ASEAN Centre for Energy, Jakarta, Indonesia.
5th Experts Meeting, 6-7 September 2001, Ottawa, Canada.

TASK 9 PARTICIPANTS

COUNTRY	NAME	AFFILIATION
Australia	Gordon Thompson Geoff Stapleton	CASE GSES
Canada	Gerry Collins	CIDA
Denmark	Peter Ahm Jean-Paul Laude	PA Energy A/S DANIDA
Finland	Heikki Tikkanen Heikki Neuvonen	Fortum AES Fortum AES
France	Jean Louis Bal Anjali Shanker	ADEME IED
Germany	Rolf Posorski Klaus Preiser	GTZ Fraunhofer Institüt
Italy	Roberto Vigotti	CESI
Japan	Takayuki Tani Kazuo Yoshino Takayuki Nakajima Eiichi Waki Kunio Asai	Institute of Energy Economics Yoshino Consult Japan Photovoltaic Association NEDO SunTechno
Netherlands	Winfried Rijssenbeek	RR Energy
Switzerland	Alex Arter	ENTEC
UK	Bernard McNelis Jonathan Bates	IT Power IT Power
USA	Mark Fitzgerald Roger Taylor Eric Martinot	ISP NREL GEF
UNDP	Suresh Hurry	Energy and Atmosphere Programme (E&AP)

AUSTRALIA

PV TECHNOLOGY STATUS AND PROSPECTS

DR HARRY SCHAAP, ELECTRICITY SUPPLY ASSOCIATION OF AUSTRALIA

GENERAL FRAMEWORK

The manufacture and use of PV in Australia has continued to increase throughout 1999. Australia's vast size and sparse population have made effective remote area telecommunications, power supplies, navigation aids and transport route signaling critical and expensive. PV continues to provide an important commercial alternative to diesel and central grid supplies for maintaining these links. Off-grid non-domestic applications still dominate Australia's cumulative installed capacity (about 67% by 1999, down from 75% three years earlier) and have an annual growth rate of around 15%. Off-grid domestic applications have also enjoyed strong growth over the last decade.

The Australian electricity industry is playing an increasing role in both remote area power supply and grid-connected PV markets, with interest being shown by both generating and retailing businesses. This has resulted from the industry being increasingly opened up to competition in a number of States (although there is also strong interest from other States and Territories), the development of greenhouse gas reduction agreements or licence conditions and advancements in power conditioning and control system technologies, which have made the use of PV in hybrid systems more feasible. Installed grid-connected capacity has been increasing by 200 to 500% each year over the past few years, and now accounts for over 6% of total installed capacity (up from less than one half a percentage point three years earlier).

The public continues to support the development and use of renewable energy, for example through participation in Green Power schemes, however the relatively low energy prices in Australia and the high capital cost of PV have made it difficult for PV to compete with other energy options at the customer level.

NATIONAL PROGRAMME

The Australian Government has recently initiated a number of new measures to support renewable energy in general and, in some cases, PV in particular. Electricity retailers and other large purchasers of electricity are now required to source an additional 2% of their electricity from renewable energy sources by 2010 (however this is likely to promote commercially competitive renewable energy sources rather than PV). The Renewable Energy Equity Fund (AUD 20 million) has been established to provide venture capital for

"A Pacific Solar 'Plug & Power TM' installation (photo courtesy of Pacific Solar)

commercialising renewable energy technologies, and a Green Power Investment Programme aims to boost commercialisation prospects. Specific renewable energy projects will be supported through the AUD 10 million Renewable Energy Showcase Fund and the AUD 56 million Renewable Energy Commercialisation Programme.

A further two programmes will operate for four years commencing July 2000. Conversion of remote area power supplies from diesel to renewable energy sources will be supported by the AUD 264 million Remote Area Power Supply Programme. PV is being specifically promoted through the AUD 31 million Household PV System Programme, operated by the Australian Greenhouse Office (AGO).

R&D, D

Most of the R&D funding is from Australian governments, both Commonwealth and State (including electricity utilities) and is directed at PV device research carried out within universities. Over the years significantly less funding has been made available for systems R&D, and this mainly came from the systems industry itself.

Commonwealth Government funding for PV R&D, D was about AUD 1.35 million for 1998, including R&D and education funding for PV through the Australian Co-operative Research Centre for Renewable Energy (ACRE). Funding from the State Governments for the same year was around AUD 4.85 million, mainly for demonstration and market stimulation.

Industry funded R&D, D is focused on thin film PV, improvements in production processes, balance of system components and system design. Joint industry and research institution activities continue in standards development and associated component testing. Increasing emphasis is being placed on grid-connected systems, with R&D focusing on interconnection systems and building integration. Pacific Solar, for example, is completing a five-year programme that has addressed low cost manufacturing of thin films deposited onto glass, durable, low cost electronics and rooftop mounting structures and scaling–up of production processes.

The increasing need for specialised PV training in all aspects of system design, installation and maintenance has led to the development of trade, undergraduate and professional courses in PV and renewable energy through a number of technical and further education colleges, universities and ACRE. The PV related courses include PV devices, RAPS systems, an internet-based applied PV course and a new degree course in PV and Solar Engineering.

IMPLEMENTATION

Under the Household PV System Programme rebates of up to AUD 5 500 will be offered by the Australian Government for the installation of small roof top and building integrated systems. In NSW, the existing PV rebate programme (run by the Sustainable Energy Development Authority) aims to boost the Commonwealth's rebate for systems up to 5 kWp. SEDA also offers a rebate of AUD 2 400 per kWp for other types of buildings, such as businesses and investment properties, and a rebate of AUD 4 800 per kWp for installations on community use buildings such as schools, community halls and other public buildings.

"The 70 kWp PV power system on the roof of the Sydney Superdome provides Green Power for energy retailer EnergyAustralia's 'Pure Energy' scheme (photo courtesy of EnergyAustralia and Canon Australia)"

The Remote Area Power Supply Programme will use diesel fuel excise from around Australia to fund investment in renewables by remote area electricity users. A rebate of up to 50% of the capital value of replacement or new renewable generation will be available to all current off-grid users of diesel-based power generation. This includes properties, communities and enterprises.

A number of State Governments currently support off-grid renewables eg the Western Australian Government offers 75% grants (up to AUD 8 000) for renewables used in remote area power systems and AUD 8,75 million over four years has been allocated for a renewable energy rebate scheme for RAPS systems in Queensland. Eligible applicants must not be grid-connected, however no grid-

"Titania Dye Sensitized Cell (DSC) Wall Panel (prototype). The panel utilises STA's patented interconnect technology and was built at the world's first DSC manufacturing facilities at Queanbeyan, Australia (photo courtesy of Sustainable Technology Australia)

connection cost is specified. Systems must have a minimum of 30% renewable energy component, with maximum grants of AUD 7 500.

Recent years have seen a large increase in interest in grid-connected PV by the electricity businesses who have created a need for renewable energy through Green Power schemes. Around 600 kWp of PV have now been installed under Green Power schemes around the country in plants such as EnergyAustralia's 400 kWp Singleton Power Station and 70 kWp roof-mounted system at the Sydney Superdome, Great Southern Energy's 50 kWp Queanbeyan Energy Depot and Advance Energy's 50 kWp Dubbo Zoo plant.

Electricity businesses are also active in the RAPS market, a good example being ETSA Power's Wilpena Solar Power Station which combines a 100 kWp ground mounted PV array in hybrid RAPS configuration with 440 kW diesels, 400 kWh battery bank and 125 kVA inverter/charger.

INDUSTRY STATUS

PV production has been expanded to 10 MWp and is running at full capacity. The two major Australian manufacturers, BP Solar and Solarex, are impacted by the international merger of BP and Amoco-Enron. Their plans for future production or expansion are currently uncertain. BP Solar Australia has canceled plans for a new 20 MW facility, although Solarex is proceeding with production upgrades and technology improvements. New thin film manufacturers are planning 22.5 MWp of new production facilities over the next 5 years.

Other companies are still planning their entry to production phase. These include Sustainable Technologies Australia (using titanium dioxide), and Pacific Solar (with plans for a 20 MW manufacturing plant). Currently, Australia's small manufacturing industry has substantially more production capacity than the current demand for new installations in Australia. PV also provides significant export earnings for Australia, with over 65% of PV production being exported.

Australian RAPS suppliers, often with local designs, manufacture the majority of balance of systems components used. Several battery manufacturers now supply batteries specifically designed for use in PV applications. Locally produced charge control regulators are available with varying degrees of sophistication and built-in diagnostics. Other products available include pumping systems, cathodic protection, street lighting, maximum power point trackers, on-site programmable RAPS controllers, battery chargers and module array trackers.

MARKET DEVELOPMENT

The local market continued to grow at 20% and reached 22,520 kWp by the start of 1999.

Off-grid applications are still the major Australian market, accounting for 75% of sales during 1998. This market is widespread across Australia, is largely unsubsidized and comprises domestic, water pumping, telecommunications, cathodic protection, navigation aid and signaling systems.

The built environment PV market is largely at demonstration phase at present but continues to attract the interest of a variety of parties. A large number of the originally planned 665 x 1 kWp roof integrated systems for the Newington Solar Village, adjacent to the Sydney Olympic site, were installed in 1999. Also at the Olympic site, EnergyAustralia installed the 6.8 kWp PV systems powering each of the lighting pylons along the Olympic Boulevard.

FUTURE OUTLOOK

The near-term outlook for PV applications in Australia is quite healthy with a number of initiatives being introduced for both off-grid and on-grid applications by Commonwealth and State Governments. Also, local government greenhouse gas reduction initiatives are increasing and may see supportive regulations introduced.

Support for Green Power schemes has been enjoying spectacular growth – with sales increasing from 32 GWh in September 1998 to 63 GWh by September 1999. By November 1999, 54 716 domestic and 1 134 commercial consumers were signed up for a Green Power product. Projections are for accelerated growth, however it will be interesting to see how consumers (and electricity businesses) react to the now mandated requirement for electricity retailers to purchase renewable energy.

Few, if any PV installations to date have been for grid support or other distributed system benefits. 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.

AUSTRIA

PV TECHNOLOGY STATUS AND PROSPECTS

DIPL.-ING. HEINRICH WILK, ENERGIE AG

Figure 1: 75 kWp PV rooftop installation of Hartlauer company/Steyr (Electronic and photo stores)

INTRODUCTION

In Austria the renewable fraction of the primary energy consumption is approximately 25 %. This is the second highest figure of all EU member states. Austria has therefore reached twice the 12 % goal stated in the White Paper on Renewables of the European Commission. About 70 % of the electricity used in Austria is produced by hydro power.

The new Austrian law to control the liberalised electricity market "ElWOG" specifies that distribution utilities have to produce or purchase 4 % of their electricity demand using renewable sources like: biomass, wind power, landfill gas, biogas, PV and the renewable fraction of waste processed in incineration plants. Distribution utilities also have to produce or purchase 8 % of their electricity demand using small hydro-powerplants (<10 MW). This regulation will come into power in 2001.

At the Kyoto conference the EU promised to reduce relevant emissions by 8 % until the year 2010. After the Kyoto conference EU member states negotiated the burden sharing on 17th June 1998. Austria has to reduce its emissions by 13 %. Today Austria emits CO_2 at a rate of 7,6 tons per capita and year (compared to USA: 21 tons/capita). Transportation and industry are the most critical sectors with the highest growth rates. To reach the national Kyoto goal of -13 % by 2010 we have to organise major changes. Studies indicated that we need the help of all sectors to come somewhat near our EU reduction goal.

NATIONAL OVERVIEW ON PV

In the Austrian public PV stands for innovation, ecology, renewable, energy efficiency, long term thinking and smart technology. All this attributes attract a wide range of enthusiasts from different sectors of science, industry, utilities and trade. As in most countries of the world PV applications started with stand alone systems to power small loads in places without electric grid. More then a decade ago Austria´s first grid connected PV unit started operation at Energie AG.

Today approximately 660 grid connected PV systems are operated by private house owners (2 MW in total, by end of 2000). Almost all of them are supported by one or another public funding programme. The mean system size of the residential applications is about 3 kWp. The largest installation has a rated power of 75 kWp. The major activities in Austria are system design and application of grid connected and stand-alone PV systems. Up to now we still have no production facility for solar cells and modules.

DEVELOPMENT OF PV MARKET

Between 1996 and 2000 the market growth rate was approximately 23 % per year. This was higher than the growth of the world module market. The reason for this positive development can be seen in various funding instruments.

By the end of 2000 approximately 3 900 kWp of solar modules were installed in our country. In Upper Austria 0,1 % of the population already uses grid connected PV. Calculating the PV penetration for Austria gives a figure of 0,6 Watt peak per capita.

The PV penetration in Upper Austria now reached 1 Watt peak per capita.

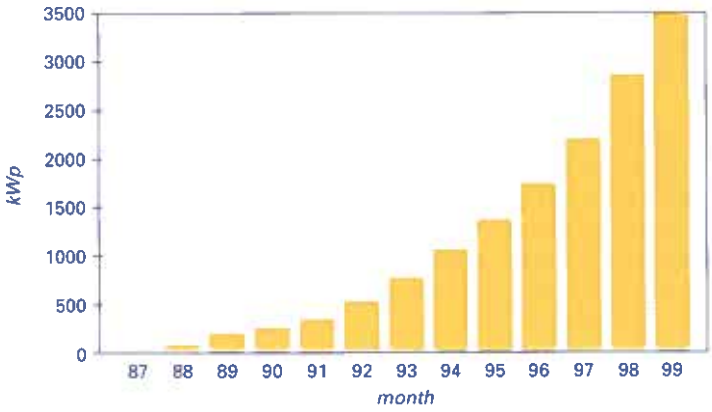


Figure 2: Development of PV market in Austria (Data Source: G. Faninger)

DEVELOPMENT OF SYSTEM COST

System cost could be reduced at a rate of 10 % per year within the last decade. Module costs dropped only slightly in the last 3 years. With the US dollar rising against the German Mark and the Austrian Schilling some imported modules even became more expensive. System costs could be reduced because training of the installers and craftsmen was efficient. Furthermore an increasing number of PV market players started competition on each PV project. Almost no cost reduction could be reached in 1998 and 1999. In the last 3

Figure 3: 20 kWp PV facade, office building of SBL, Linz (Colt)

Figure 4: 4 kW PV shading system, Technogiezentrum St. Florian/ Linz

years specific system costs were stable at a level of 90 000 ATS excl. VAT. In the year 2000 system cost did rise to almost 100 000 ATS/kWp excl. VAT again.

The specific cost data are the result of evaluating the PV rooftop projects funded by the federal government of Upper Austria. The cost figures include all real expenses and are the average of more than 250 residential PV installations of typically 2 to 3 kWp per system. Expenses for mounting and installation are still in the order of 30% of total cost. For solar modules 55 ATS / Watt peak had to be paid in 1999 (excl. VAT).

NATIONAL PROGRAM

In the strategy plan PV systems are included next to other new renewable energy sources like wind and biomass. There are still discussions what incentives, taxes and funding instruments have to be applied to give the right push/pull into the desired direction. We already have high taxes on car-gasoline and other fossil fuels. 1996 an energy tax was issued for natural gas and electricity. With the liberalised electricity market that started on 19th February 1999 utilities are reluctant to take new funding burdens.
In 1992 - 1995 Austrian utilities paid most of the investment subsidies for the "200 kW Rooftop Program". On a local basis PV funding went on in Upper Austria (up to 50 % of the investment, since 1991, then reduced to 37 % in 1998 and at 50 000 ATS/kWp since 1. Jan 2000). PV funding started also in Vorarlberg in 1998 and caused a massive increase in grid connected PV systems there.

There are now discussions to establish a centralised Austrian funding system to support investments in new renewable energy systems (PV, wind, biomass, biogas). The intention is to pay subsidies for the investment only. Projects with the best ratio of produced energy / invested money will come first in the ranking queue. Doing this only the most efficient projects will get money.

R&D

The PV activities at different universities are supported. Within the framework of PVPS Task 7 architects at the Technical University of Vienna help to improve PV building integration. The Association of Austrian Utilities (VEÖ/EFG) funded inverter tests at Vienna's Arsenal test centre. One major point was to analyse the islanding behaviour and the harmonics of the power conditioners. The results are available as a VEÖ/EFG report now and were presented at the 2nd PV World Conference in Vienna in July 1998.
With the help of the Upper Austrian Research Fund the Technical University of Vienna and Fronius KG, an innovative private company, are developing new inverter concepts. In co-operation with the German company Steca an innovative stand-alone inverter unit was produced by Fronius KG.

Austrian PV experts are contributing to the work of our national standards committee OENORM / OEVE E2750 and IEC TC 82. With the participation in PVPS we want to exchange experiences on an international level.

Figure 5: PV and art, "PV tree" in Gleisdorf/Styria (Feistritzwerke, municipal utility)

UTILITY DEMONSTRATION PROJECTS

Energie AG, the electric power utility of the federal state of Upper Austria, is engaged in many demonstration projects. Innovation in the building sector, heat pumps, biomass projects and photovoltaic systems are heavily supported by Energie AG.

INDUSTRY STATUS

ISOVOLTA is producing back sheet foils for almost all module manufactures in the world. FRONIUS KG developed a series of well-known inverters for grid connected PV systems. More than 5000 units have been produced until now. 90 % of them were exported into other countries. Fronius is now Europe's second largest producer of PV inverters. In 2000 the company KW-SOLAR started operation of a plant for laminating modules in Graz.

SUMMARY

We are optimistic that the PV market will steadily continue to grow in Austria at a rate of 30% per year. About 50 % of the increase of grid connected systems can be found in Upper Austria. Starting on 1 January 1998 the federal government of Vorarlberg and the local utility VKW started a similar funding system. If subsidies stop or a certain level of penetration will be reached PV market will grow approximately by + 15 % per year.
Yield increased to almost 850 kWh/kWp.a with new installations. The overall system performance can be further improved by optimising several factors. Better inverters (e.g. without transformer) and modules with correct name plate rating will help to improve the yield of grid connected PV systems in the future.

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CANADA

PV TECHNOLOGY STATUS AND PROSLECTS

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GENERAL FRAMEWORK

Three specific issues on Canada's energy scene are favouring the increased use of solar photovoltaics: first, international commitments to Green House Gas emissions reductions and climate change mitigation given their far-reaching implications for energy and the environment; second, the deregulation and the restructuring of the electricity industry that is leading to an increased acceptance for distributed and on-site micropower generation; third, the coming change in global energy markets in which photovoltaics is among the fastest growing forms of energy and the business opportunities this presents to Canadian industry.

There are still many barriers to the large-scale use of PV in Canada but there is a political will to address many of these barriers. For example, the Government of Canada supported several new initiatives within the Climate Change Action Plan in 2000. Several federal departments have collaborated with the PV industry and regional partners to deliver projects within the Technology Early Action Measures Program. These projects supported the development of new technologies that will contribute to their improvement and cost reduction targets.

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. This market continued to show strong growth with an average of 29% per year (Table 1). The installed power capacity was 5.8 MW in 1999 and is expected to exceed 7MW in 2000. 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. The public perception of solar energy is very positive and the fastest growing sub-sector is the remote homes and recreational power application. Most grid-tied PV building applications are still at the demonstration stage since this technology is not cost-competitive with industrial power generators in Canada. Nevertheless, the economic and environmental arguments for supporting the development and market introduction of PV technology for building applications are quite compelling when we consider its price reduction potential and long-term Green House Gas emission reduction benefits.

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 Diversification Research Laboratory (CEDRL) is responsible for the management of the federal photovoltaic R&D and technology transfer program. This includes technical support for research on components and systems in collaborations with industry and major end-users, as well as the development of standards and codes. This photovoltaic R&D program is financed by the federal fund allocation by the Program on Energy Research and Development (PERD). In addition, the Renewable Energy and Electric 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, D photovoltaic program is:

- 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,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 Diversification Research Laboratory, a National research facility located near Montréal in the Province of Québec. Current projects include:

Table 1: Cumulative PV power capacity installed in Canada

Year	1993	1994	1995	1996	1997	1998	1999
Cumulative PV power (MW)	1.24	1.51	1.86	2.56	3.38	4.47	5.83

- 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, including the participation in an International Energy Agency task group dedicated to PV-hybrid for remote applications;
- evaluating the energy performance of commercial PV modules operating in Canadian climatic conditions and contributing to the development of international PV module standards;
- supporting the validation of solar radiation models for PV module and system designs at high latitude, including the assessment of available resources from satellite derived data;
- assessing the performance of PV products designed for building integration, including participation in an Internal Energy Agency task group that focuses on PV in the built environment;
- support for the development of performance and safety standards, including participation in the International Electrotechnical Commission working groups that aims to develop international standards.

CANMET-EDRL also developed a Project Analysis Software Tool, known as RETScreen that can be downloaded from the web free-of-charge. First released in 1998 for on-grid applications, the RETScreen 2000 model was upgraded to cover off-grid PV applications, including stand-alone, hybrid and water pumping systems. RETScreen Training modules presenting case studies will be completed to provide guidance to those interested in assessing the cost and benefits of PV systems in various applications in Canada (http://RETScreen.gc.ca).

Demonstration projects

ARISE HOME demonstration: The ARISE home research and demonstration project evaluated the use of a comprehensive solar thermal system for residences in Canada. ARISE Technologies Corporation, based in Waterloo, Ontario, aims to provide total energy solutions for residential homes that will make solar a mainstream energy alternative. As shown in Figure 2, the rooftop demonstration blends both solar thermal and solar electric panels over 117 square-meter on the south-face of this home. The 5kW PV system is grid-interconnected and the solar thermal system may be used to space-heat, pre-heat the domestic hot water and swimming pool. A uniform appearance is obtained by ensuring that the same glass is used for both the solar electric and solar thermal panels.

Figure 1. This PV-hybrid telecommunication station owned by NorthwesTel is being studied as part of the Canadian PV-hybrid R&D program at CANMET-EDRL.

Figure 2. ARISE HOME Research and demonstration covering the surface of this rooftop with both solar thermal and 5kW of PV panels. The objective is to develop a comprehensive solar energy system that will provide much of the electricity and heating needs for new homes. (Photo: ARISE Technologies Corp.)

In addition, six new projects demonstrated the application of PV for grid-tied applications or integration on building applications in Canada. These PV demonstration projects benefited from the Government of Canada Climate Change Action Fund as part of the Technology Early Action Measure (TEAM) program.
The British Columbia Institute Technology (BCIT) contributed to three demonstration projects with the goal of demonstrating the seamless integration of PV panels into office and residential building envelopes to create an on-site link between the supply and demand of electricity. These three collaborative projects with BCIT are summarized below:

- *Ventilated façade for TELUS office tower building* - The renovation of this 52-year-old building incorporated a new façade that provides waste heat recovery and maintains an energy balance. Designers laid the building's new glazed façade over the old, creating an aesthetically pleasing, insulating airspace. The integration of twenty PV façade modules now powers twelve DC fans that ventilate this air space. The PV modules were manufactured in Germany by Saint-Gobain by laminating Photowatt solar cells between two 6 mm thick tempered glass sheets. These were installed as part of the new external facade by Advanced Glazing Systems. The 2.5kW system and maximum power point controller was designed by BCIT.
- *CMHC Home 2000 healthy/flex demonstration* - In collaboration with the Canadian Mortgage and Housing Corporation, BCIT demonstrated the use of PV module as a skylight on the roof of a sophisticated, three-story pre-fabricated house. Blue Photowatt solar cells are arranged in glass-on-glass panels with 1 cm to 1.6 cm spaces to allow day-lighting of the third floor attic, creating a beautiful liveable space. The CMHC Home 2000 was exhibited at the Vancouver Home show and then moved to the BCIT campus for future research. The 2KW PV array incorporated into this residential roof could provide most of the electrical demand of this energy efficient home.
- *BCIT Technology Place building:* A 3.5kW PV array was integra-

ted into the glass façade overlooking the entrance to the new BCIT Technology Place building on the east side of the Burnaby Campus. A combination of opaque and semi-transparent thin-film amorphous silicon modules dress the south-west corner of the modern office building, blending seamlessly with the standard window glass. Ninety custom modules were assembled into a curtain wall that conceals the module wiring in mullions. The array was connected to two grid-tied inverters and offsets some of the lighting requirements of the building.

ATS Automated Tooling Systems, in collaboration with Soltek Solar Energy and other regional partners contributed to three grid-tied PV demonstration projects. These three collaborative projects, supported in part by TEAM funds, are summarized below:

- *Victoria Solar House:* SOLTEK, in collaboration with BC Hydro, Trace Engineering, East Penn Battery and ATS, designed and installed a 1kW PV rooftop system on a residence in Victoria. The Victoria Solar House is the first urban residence in the province of British Columbia to generate a significant portion of its own electricity needs. The PV system is synchronized with BC Hydro power and excess could be fed back through the power lines for other customers to use. For consumers that want to use green power generated from the sun, the demonstration shows how individuals can have their own power system with a further benefit of backup power in the event of a power outage. A useful web page was created to inform Canadians of the benefits of a solar energy house (http://www.soltek.ca/news/vicsolar-house.html).
- *Solar Power for the Banff Operational Center:* In the first phase of this project a 1kW PV array and a management energy system developed by Sustainable Energy Technologies based in Calgary were installed on the operation Center for the Town of Banff, Alberta. This is part of a larger project to upgrade the Banff Operational Center and is also incorporating energy efficient technologies.
- *Solar Power at new ATS Systems Building:* ATS, in collaboration with ARISE Technologies Corporation, SolSource Consulting, and Cambridge Hydro, designed and installed a 5.4kW PV roof-top on its new systems manufacturing facility in Cambridge Ontario. The output of the system is synchronized with the Cambridge Hydro grid through a utility interactive inverter developed by ARISE Technologies.

Figure 3. The renovation of this 52-year-old building incorporated a new façade that provides waste heat recovery and the 2.5kW PV panels now power DC fans that ventilate this air space. (Photo: BCIT)

IMPLEMENTATION

In the post "Kyoto Protocol" setting, Canada is developing a National Implementation Strategy in order to reduce its greenhouse gas emission by 6% from 1990 level. In 1998, the federal government established a Climate Change Secretariat and Climate Change Action Fund. Within this framework, several initiatives have been created to respond to Canada's commitment to reduce greenhouse gas emissions:

Technology Early Action Measures: Cost-shared support for the development and deployment of emission-reducing technologies;

Foundation Analysis: The development of a national implementation strategy via a multi-stakeholder consultation process. This includes the "Horizontal Tables" vast consultative process with stakeholders representing forty sectors in Canada;

Science, Impacts and Adaptation: Targeted research to better understand climate processes and to assess the impact of climate change on the regions of Canada and the options for adaptation;

Public Outreach: Public education and outreach activities directed at informing Canadians about climate change and encouraging them to take action.

Within the Technology Early Action Measure Program, Automated Tooling Systems Inc. and the government of Canada are partnering on a 5 million CAD project to develop advanced photovoltaic module manufacturing equipment. The project will develop automated manufacturing equipment, and undertake 50 kW of demonstration projects of PV products in Canada and in China. The goals of the project are to lower the cost of PV modules, promote the use of PV electricity production, contribute to job creation in Canada and abroad, and contribute to Canada's commitments to the Kyoto Protocol for CO2 emission reductions.

Canada has committed to initiatives that will increase penetration of renewable technologies on the market. Three are of particular interest for PV. The tax system provides incentives to PV investments in two ways: Early intangible expenses are 100% deductible and these can be financed through flow-through shares since December 1996; and, equipment for systems of at least 3 kW of capacity can be written off at an accelerated rate under the Capital Cost Allowance Class 43.1 (30% declining balance). Before 1997, only PV systems of at least 10kW of capacity were eligible.

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 is the first province to deregulate the electricity industry and the price is sold as a commodity on the Alberta power pool. Two major utility companies in Alberta, ENMAX in Calgary and EPCOR in Edmonton, are offering green energy

options to their customers. These initial offers have demonstrated that the public is willing to support the use of renewable energy, and this has supported a growing number of wind farms in Alberta. To date these green energy options have not included PV rooftop financing programs that are critical to the successful market implementation of PV for the grid-tied building market.

INDUSTRY STATUS

The Canadian PV industry has grown steadily serving both its domestic off-grid market and the export market. There are approximately 150 organizations actively promoting PV power. These are mostly system suppliers and installers but approximately 15 companies are involved in manufacturing. Many of them are members of the Canadian Solar Industries Association (http://www.cansia.ca).

Automated Tooling Systems (ATS), based in Cambridge Ontario is a North American leader in automated manufacturing and test systems, and a large volume producer of precision components. It has developed automated manufacturing equipment for manufacture of solar cells and modules. In 1997 it acquired its subsidiary, Photowatt International S.A, that has grown into one of the world's largest solar module manufacturers. ATS/Photowatt is also conducting research and development for a next-generation, flexible and lightweight technology, known as Spheral Solar™.

Xantrex Technology Inc. based in Vancouver, British Columbia, Canada has acquired and formed an alliance with Statpower, Heart interface, Cruising Equipment and Trace to create the world's leading supplier of advanced power electronics. The company is positioned to serve a growing photovoltaic market worldwide, and has products ranging from DC/AC inverters, battery chargers, and grid-interactive power conditioners that targets mobile, recreational, industrial and distributed power applications.

ICP Global technologies, a leading supplier of consumer products in North America, has expanded its operations to manufacture a new line of PV panels. Its new manufacturing facility in Montréal, Québec was inaugurated in October 2000. Custom equipment for the new facility was supplied by NewSun Technologies, based in Ottawa, Ontario.

Vortek Industries Ltd., a manufacturer of high power arc lamps, based in Vancouver, British Columbia, has developed a continuous solar simulator and has adapted its equipment to offer a Rapid Thermal Process furnace.

A network of systems integration companies has established distribution and dealer networks that effectively serves a growing Canadian PV market. These include distributors for Siemens Solar, BP-Solarex, Kyocera, and Photowatt. These module manufacturers offer PV module product warranties ranging from 10 to 25 years and have certified their products to international standards.

MARKET DEVELOPMENT

The Canadian PV installed capacity is now 5.8 MW with a sustained domestic market growth that has averaged 29% over the last 7 years. In 1999, the annual PV module market past the 1.3MW/yr mark. This market is mainly off-grid applications where PV has proven to be a reliable and a cost-effective solution. Most of the growth in recent years is due to the impressive increase in the cottage and recreational PV application market (Table 2). The commercial and industrial applications market showed that sales have stabilized, although it remains the largest total installed sub-market application in Canada. PV power for grid-tied applications is not cost-effective in Canada, therefore most of the projects completed have been supported by government contributions. It is estimated that the Canadian PV industry generated revenues of 40 million CAD and employed approximately 250 people in 1999.

FUTURE OUTLOOK

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. NRCan, through its Renewable and Electrical Energy Division, supported the development of a marketing strategy, with the collaboration of the Canadian Solar Industries Association, to help remove barriers or perceived barriers to a wider penetration of off-grid PV systems in the domestic market. The implementation of the proposed action plan is currently being evaluated in light of budgets and priorities established by the different government programs. In the near term, the favoured approach is to begin with an initiative targeted at the Parks' sector since it has the most outreach potential and will contribute to promoting the technology and educate the general population.

Although the low cost of electricity has delayed the implementation of PV technology for the grid-tied market, activities to remove barriers to the use of PV are continuing. Research and development of building integrated PV technology, support for the development of a technical guideline for the interconnection of small power supplies, and adoption of product safety standards will contribute to facilitating the market introduction of PV technology for grid-tied applications in the medium to long term.

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Table 2. Annual PV power sales within three sub-markets

application markets	1995 (kWp)	1996 (kWp)	1997 (kWp)	1998 (kWp)	1999 (kWp)
Off-grid residential	133	166	242	525	776
Off-grid commercial/industrial	200	505	565	562	550
On grid PV demonstration	17	29	13	3	30
Total Power	350	700	820	1090	1356

DENMARK

PV TECHNOLOGY STATUS AND PROSPECTS

FLEMMING KRISTENSEN, ENCON, DENMARK
PETER AHM, PA-ENERGY A/S, DENMARK

Fig. 1: House from the Sol-300 project with 3 kWp roofintegrated BP-Solarex thinfilm laminates.

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 CO_2 by 20 % before year 2005 and partly to diversify the energy sector now being based on fossil fuels. At present about10 % of the gross national energy consumption originates from renewable energy sources. Energy 21 outlines 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.

NATIONAL PROGRAM

PVs have been included in the action plan of the Danish Energy Agency (DEA) since 1992 and have received increasing attention in the current Solar Energy Action Plan of 1998-2000. Since 1992 the Renewable Energy Development Programme of the EA has supported about 85 PV projects, and by the end of 1999 about 1 MWp have been or are being installed in the context of demonstrations plants. A 300 roof-top's project including 750 kWp was launched early 1998, and about half of the installations were completed by end of 1999.

A special support programme for PV applications in the commercial sector, funded by the CO_2 tax on electricity, has been 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.

Net-metering for privately owned PV systems was established mid 1998 for a pilot-period of four years.

Late 1999 the parliament allocated 30 million DKK 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.

RESEARCH & DEVELOPMENT

R&D on PV cell manufacturing (mono-X Si) has taken place at the Technical University of Denmark for more than a decade. This R&D effort led to the establishment of the first Danish PV cell/module manufacturer in 1992. However, the company folded mid 1996 after a period in receivership, and is now reconstructed as a module assembling plant. Research into Si cell production with focus on surface layer structure and contacts has been stopped for the time being. However, as part of the new 3-year programme mentioned above R&D activities into PEC cells (Grätzel type cells) and maybe other cell types will be initiated.

Mid 1995 the Photovoltaic System Laboratory (PVSyslab) was established in collaboration between Risø 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 has established R&D PV plants and has put examples of building integrated PV technology on display. The PVSyslab has established a national database for demonstration systems and operational data from these systems are published regularly. 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 PV GAP initiative. The Solar Energy Centre Denmark has recently entered the field of technology cooperation with developing countries.

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

IMPLEMENTATION

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

Several grid-connected, building integrated PV systems were commissioned in 1999. One of the most high profile actions has been the Sol-300 project, including implementation of about 750 kWp on 300 single family houses. (See enclosed two-three photographs).

The project intends both to demonstrate highly visible and architectural acceptable integration of PV technology on existing single family houses and to reduce costs. A secondary objective has been to disseminate information and experience on PV roof-top deployment to eight distribution utilities.

Several projects for building integrated PV systems including commercial buildings, apartment buildings and schools have been implemented, typically in the range of 2-10 kWp.

Fig. 2: Houses from the Sol-300 project. In front 2,4 kWp BP-Solarex laminates integrated in a pergola.

INDUSTRY STATUS

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. In 1999 a couple of new companies have announced their presence as PV system houses.

Some medium to large scale industrial corporations long established in the building industry, such as Velux Industries and Dansk Eternit, continue their serious actions to integrate PVs in their main stream products. The products are currently under field tests in a few demonstration projects.

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.

An increasing number of companies are acting as PV system houses, 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 growing business area.

Total PV business volume is estimated to be about USD 22 million in 1999 and appears to be growing.

MARKET DEVELOPMENT

Market development incentives already in place are mentioned above under National Program. A standard incentive for privately owned roof-tops is not yet in place, but a subsidy for PVs on apartment houses is part of the new three-year programme.

The cumulative installed PV capacity in Denmark (including Greenland) is by end of 1999 estimated to about 1 MWp.

FUTURE OUTLOOK

It is expected, that the ongoing Sol-300 project – targeting 300 roof-tops and 750 kWp – will be followed by new utility driven initiatives to promote the deployment of roof-tops. In this context it may be expected, that the so called PSO funds (Public Service Obligation) accumulated by the utilities via the electricity bills, in the future not only can be used in the context of PV R&D projects, but also to buy down the cost of standard installations such as PV roof-tops.

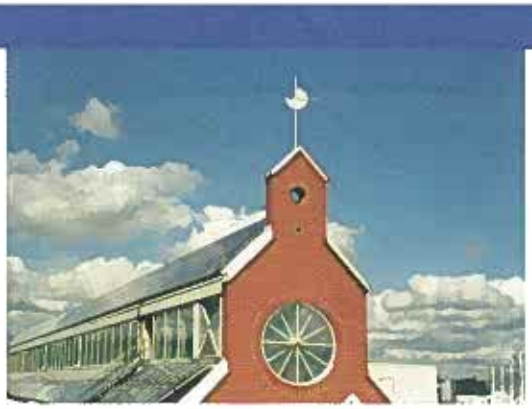
The new three-year programme targeting building integrated PVs on apartment houses and institutions is expected to lead to the future availability of increasing Government funds for PVs.

However, a constant development towards commercial sustainability for PVs is seen as critical for continued support from the Government and the utilities.

FINLAND

PV TECHNOLOGY STATUS AND PROSPECTS

LEENA GRANDELL, MOTIVA OY



Lielahti Citymarket, Tampere. A photovoltaic system with a surface of 330 m² and a capacity of 39 kWp. Picture: Fortum Oy.

NATIONAL GOALS

During 1990's the main emphasis in Finnish activities in the photovoltaics area was concentrated on research and development. The National Advanced Energy Systems and Technologies Program (NEMO2) comprising among other technology areas also photovoltaics ended in 1998. A new industry driven and restricted program "Photovoltaics in Finland" was finished in 2000. In future there will be no national research programme for photovoltaics but research will be funded on project level.

Besides research and development activities more emphasis will be given to market development of photovoltaic technologies. In autumn 1999 an Action Plan for Renewable Energy Sources was launched by the Ministry of Trade and Industry. The Action Plan sets objectives for the volume of energy generated by renewable sources in year 2010. A prognosis on the development until 2025 is also included. The relative increase of photovoltaic markets sought until 2010 is significant even though its' absolute volume is still modest.

RESEARCH AND DEVELOPMENT

The research conducted within the NEMO2 program focused on building integration of photovoltaics as well as hydrogen based storage systems with main interest on amorphous silicon and new thin film technologies. The bulk of R&D were done at Helsinki University of Technology and within the units of Fortum Ltd.

"Photovoltaics in Finland" program managed by Tekes, Technology Development Centre, focused on industrial solar cell production with the intention is to provide technological requisites for inducing industrial production.

INITIATIVES FROM GOVERNMENT

The ambitious goal set by the Action Plan for Renewable Energy until 2010 is to increase the production by 50% when compared with the year 1995. A further goal is to double the use of renewable energy sources by the year 2025. This increase is to a large degree foreseen to rely on bioenergy and hydropower, but ambitious goals have been set also for photovoltaics. The objective for photovoltaic electricity generation 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 in creating the needed infrastructure (awareness, information dissemination, export, industrial activities) whereas volume effects are sought later. Then impact of photovoltaics on the total environmental effects of the Action Plan are assessed to be less than 1%. in 2010.

DEMONSTRATION PROJECTS

The largest Finnish demonstration project is mounted at the Lielahti Citymarket in Tampere, southern Finland. The modules set up on the roof of the hypermarket have a surface of 330 m² and a capacity of 39 kWp. The electricity generated by the system is fed to the premises own consumption and it is estimated to cover 4-5% of the buildings total energy consumption during summer months.

Several smaller demonstration projects have been built, such as the electrification of telecommunication base stations at remote areas or a number of building integrated amorphous silicon facades.

INDUSTRY STATUS

The main industrial player is Fortum Ltd with its business unit NAPS Systems Oy. Fortum markets different PV applications. Its market share in Europe is approximately 10%. On systems technology some 10 companies are active. Typical products include controllers and also total systems are marketed.

MARKET DEVELOPMENT

The photovoltaic markets in Finland can be divided into three main segments:

- 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 dominated by small solar home systems for vacational houses, typically 50-100 Wp in size. The estimated potential is some 120 000 units. Navigational aids (typically 50-150 Wp) along the coastline form another significant market segment. Examples of larger applications in remote areas are telecommunication base stations. Also the Finnish coast Guard operates some 20 larger stand-alone hybrid systems with a PV capacity of 500-1000 Wp.

In the current state investment subsidies (up to 30%) are only available for communities, organisations and enterprises.

FINNISH PV SYSTEMS 2000

Market Segment	Number	Power (kWp)
Solar home systems	35 000	2 225
Stand-alone systems	2 030	230
Grid-connected (utility)	1	30
Grid-connected (roof-top)	11	67
TOTAL	37 042	2 552

FRANCE

PHOTOVOLTAIC TECHNOLOGY STATUS IN FRANCE
ANDRÉ CLAVERIE, FRENCH AGENCY FOR ENVIRONMENT AND ENERGY MANAGEMENT (ADEME)

Figure 1 – A Municipal separate collection centre is equipped with a stand alone PV system (Face fund). photo APEX.

1 GENERAL FRAMEWORK

In February 1998, the French Government formally approved a policy regarding energy management and development of renewable energy sources. The Cabinet acknowledged that renewable energies could contribute to sustainable development, to limit green house effect, to save non-renewable resources, to create jobs and to contribute to local and regional development. An annual public budget of 46 MEUR for promotion and development of renewables was announced, starting beginning of 1999. This budget slightly higher in 2000 was planned to increase by 60 % for the year 2001. The Government Organization ADEME with its partners from industry and public research set up new programmes of activity.

In France the solar resource is generally very good, however most other forms of energy are low cost and abundant. Photovoltaic (PV) power systems are not cost competitive with conventional technologies as a base load source. Nevertheless several factors triggered the development of a competitive industry: a) a few well-motivated small and medium companies, b) a tradition of public research in solar energy, c) a demand for a diversification of energy sources in French Overseas *Départements (Guadeloupe, Martinique, Réunion, Guyane)* where energy is expensive to produce and d) the entry of the national electricity utility Électricité de France (EDF) into the field in 1993.

During the last four years, the French photovoltaic module manufacturers and the photovoltaic system companies which pioneered the field took advantage of new French public financial incentives to respond to a growth of demand and also seized the opportunity of the implementation of new rural electrification programmes abroad.

2 NATIONAL PROGRAMME

The French Agency for Environment and Energy Management (ADEME) –a Government Organization– is in charge of promoting the development of renewable energy sources including photovoltaics (PV).

The ADEME's promotion strategy is twofold:

- to support research and technological development (RTD) on PV components, photovoltaic systems and applications;
- to subsidize demonstration and dissemination projects.

ADEME's four-year RTD programme on PV system components aim at reducing their manufacturing costs and improving their performance and their reliability. Specific targets according to projects have been negotiated with industry. The implementation of pilot projects to demonstrate the technical validity and viability of solar photovoltaic electricity prepared the basis for larger dissemination projects that now make use of various public financing schemes. The European Commission also contributed to the RTD and demonstration/dissemination of photovoltaics in France.

ADEME has put in place mechanisms for promoting national co-operation between industry and public research and share the financial costs (up to 50 %) of applied research and technological development projects on all the components of PV systems and their application. ADEME also provides information pertaining to photovoltaics to target groups such as utilities, industry, government, local/regional authorities and other users and has developed operator and user training courses for photovoltaic power systems. An annual workshop on PV systems issues (11 July 2000) and a seminar on materials and processes (21-22 November 2000) at the ADEME's Centre in Sophia-Antipolis allowed the French photovoltaic community to exchange technical information and to assess novelty of approaches. On the international scene, ADEME sponsored the first photovoltaic hybrid power systems conference organized by Genec in Aix-en-Provence (7-8 September 2000).

ADEME also participates with its partners in international activities such as those of the International Energy Agency (IEA) co-operative programme on photovoltaic power systems or those of the International Electrotechnical Commission (IEC) for standardization.

3 RESEARCH AND TECHNOLOGICAL DEVELOPMENT

France has a well-established photovoltaic research base. Collaborative efforts worked to pool the nation's resources in order to maximize technology advancement under ADEME's financial incentives. Other organizations like CNRS, CEA and EDF are also the financial contributors to PV RTD projects and some selected research topics receive pre-competitive RTD funding from the European Commission programmes (DG Research).

Main goals of ADEME's RTD programme are cost-reduction for photovoltaic cells and modules by decreasing their manufacturing costs and by increasing their conversion efficiencies through innovative manufacturing processes or technical optimization of existing low

cost processes. The ADEME's programme is also geared to the improvement of photovoltaic system components and system applications. Reducing costs, increasing reliability and efficiency of storage lead-acid batteries, charge regulators, inverters, hybrid PV/diesel systems, pumping devices, etc. are part of the programme activities.

Photowatt International focuses its technological development on manufacturing process steps: the 4-year "PV-16" RTD project partially funded by ADEME aims at reducing cell/module manufacturing cost by a factor of two, increase conversion efficiency of larger cells to 16 % and reduce thickness of wafers by a factor of two. Innovative applied research carried out by public laboratories of CNRS and Universities in cooperation with industry include bulk and surface passivation of cells, selective emitters, studies on impurity-defect interactions, high yield continuous casting of multicrystalline silicon ingots and rapid thermal CVD processing. New projects on feedstock silicon started to be investigated such as purification with a combination of electromagnetic techniques and inductive plasma torch.

Thin layers of (micro or poly)-crystalline silicon or so-called polymorphous (a mixture of amorphous and microcrystalline) silicon material deposited on foreign substrates (glass, ceramic) are a priority topic for CNRS public research laboratories (involved in a jointly funded CNRS-ADEME multidisciplinary research programme called ECODEV). Several deposition techniques are investigated: rapid thermal CVD using trichlorosilane, plasma enhanced CVD, hot-wire catalytic CVD, inductive plasma torch deposition and liquid phase deposition on ceramic substrate.

In the year 2000, two research projects funded by ADEME have been undertaken. First, thin film polycrystalline CuInGaSe2/CdS materials and devices prepared by electrodeposition on glass substrate are studied by a consortium of research teams including EDF, CNRS-LEAA and Saint-Gobain-Recherche. Electrodeposition processing has been chosen for its low cost potential compared to co-evaporation. Second, a project carried out by CEA–LETI in cooperation with the CNRS-LPM laboratory of INSA-Lyon intends to demonstrate the feasibility of reporting a thin layer of single-crystal silicon to a foreign substrate to prepare a cell of high conversion efficiency (20 %).

In addition, ADEME supports small and medium size photovoltaic companies in developing new products for domestic and export markets. Companies such as Apex and Total Énergie have developed microprocessor–based energy management units that not only incorporate battery charge/discharge controllers but also new functions with varying degrees of sophistication and built in diagnostics including advanced data logging and remote communication capabilities. Decentralized lighting pre-payment systems and electronic cheat-proof devices received development attention (Transénergie). Such devices are used in pilot dissemination projects in France and abroad. Other developments include high performance water pumping devices and a range of inverters to respond to various photovoltaic applications.

Specific studies and testing of photovoltaic components including PV modules (energy rating approach), lead-acid storage batteries ageing and other PV related products are an important part of the ADEME's programme. Hybrid PV/diesel village power systems are studied by Genec and Armines for testing and standardization purposes. Other studies carried out by Genec, EDF and partners contribute to the drafting of International Energy Agency's reports on recommended practices (IEA–PVPS co-operative programme, Tasks 1, 2, 3 and 9) and pre-normative work that feed elaboration of international Standards within the International Electrotechnical Commission/Technical Committee 82 (IEC/TC82). A good example is the international recognition of ADEME-EDF's *Specifications for the use of renewable energies in decentralized rural electrification* by the IEC to become an IEC-PAS document bearing the number 62111. On that topic a new IEC joint coordination group (TC82/TC88/TC21/SC21A) led by EDF was set up in 2000 with the objective of preparing a document intended to be used as an international reference in assessing the quality of the service to the end users. The ADEME's public budget for photovoltaic RTD was 5 MEUR in 2000.

During the year 2000, Atomic Energy Commissariat (CEA) decided to be more involved in photovoltaics announced that cell research and system activity would be carried out under the umbrella of Genec laboratory with an increase of manpower.

4 IMPLEMENTATION

ADEME's policy consists of implementing conditions for preparing efficient products offering quality service to users who are beyond the reach of electricity networks. The implementation of suitable structures taking up concessions through EDF on PV installations, and the access to various sources of financing (FACE fund, Tax exemption, Regional Authorities, etc.) were decisive factors of progress.

Photovoltaic rural electrification programmes are financed up to 95 % with FACE fund. FACE (Fund for amortization of electrification costs) is a public fund traditionally devoted to extending and reinforcing electricity networks in French rural areas. So far, around 22 MEUR of FACE fund were allocated to install PV systems in rural areas. At this stage, 1 306 installations have received FACE agreement (900 kW). For a number of rural electrification projects where FACE fund does not apply, ADEME, EDF and Regional Authorities provide financial support. A Tax exemption scheme in Overseas Départements such as Guadeloupe has also substantially contributed to market growth: ADEME, EDF, Regional Authorities and European Commission grant this PV system. In 2000, the PV systems' turnkey price was down from 27 EUR/W to about 20 EUR/W for typical 1 000 W autonomous PV power systems. This price includes house wiring, a storage battery shed and a 15-year guarantee of service (storage battery replacement after 7 years). The 4 year FACE fund programme avoided 115 MEUR of line extension and saved 82 MEUR to the community. A database called ISIS was developed in co-operation with EDF, ADEME and Technosolar (French association of installers and engineering companies) to store information about stand-alone systems installed under FACE fund. Each site is described by more than 300 different data. The

Figure 2 – GENEC has demonstrated that poor lead-acid battery energy management results in electrolyte stratification and early ageing of battery plates (Genec, traceur.gif))

objective is to improve knowledge about users, get technical feedback on system sizing and about users' profiles and energy needs. In parallel, a technical, economical and sociological audit of rural electrification projects funded by ADEME and EDF took place in the year 2000 and preliminary results allowed to detect successes and difficulties that will be taken into account in future installations.

A new initiative took place by the end of 1999, when ADEME decided that grid connection of photovoltaic power systems would be able to receive public funding within an European demonstration project called "HIP-HIP". The objective is to install 500 kW in 3 years at 5 EUR/W with the following subsidy: 35 % from the European Commission and 15 % from ADEME. The PV electricity is purchased by EDF at 0,036 EUR/kWh.
The annual 2000 public budget for market implementation was around 9 MEUR.

5 INDUSTRY STATUS

There are three photovoltaic cell and modules vertically integrated manufacturers in France: Photowatt International S.A., Free Energy Europe S.A. and Solems S.A. There are four main system companies: Total Énergie, Apex, Fortum AES and Sunwatt, two battery manufacturers: CEAC/Fulmen and Hawker and one electricity utility, Électricité de France (EDF).

Photowatt International is a fast growing company that produces the thinnest screen printed multicrystalline photovoltaic cells available on the market, and makes modules in the peak power range of 10 W, 50 W, 75 W and 100 W with 25-year warranty. The company is ISO 9002 certified and holds the IEC Certificate of Approval of electronic component manufacturer. In 1998/1999, Photowatt increased their investment in RTD and production capacity, expanding their ingot casting and wafering facilities and installing a new automated cell manufacturing line. Photowatt increased PV wafer and PV cell to reach the level of 14 MW in 2000. Cell manufacturing capacity is 20 MW per year with the new automated line set up in 1999.

Free Energy Europe S.A. manufactures hydrogenated amorphous silicon modules on glass substrate (maximum size 30 cm x 90 cm) with stabilized peak power of 1,8 W, 4 W, 6 W and 12 W and a range of product systems (lighting kit, etc.). Module annual production is around 500 kW with a manufacturing capacity of 1 MW per year.

Solems S.A. is a small enterprise specialized in small-size custom-designed amorphous silicon modules (maximum size 30 cm x 30 cm) for low power applications.

Concerning other photovoltaic components than modules, the companies Total Énergie and Apex manufacture a range of PV system components and applications (multifunction energy management and control devices, small PV personal electrification systems, prepayment devices, hybrid systems for rural electrification, pumping systems, inverters, etc.). Transénergie, Cythélia, PHK, IED, SERT and Tecsol are active companies of consulting engineers specialized in PV technology and project management. They participate in strategic, feasibility and marketing studies funded by the European Commission, development banks, utilities and ADEME.

Battery manufacturers have designed storage batteries that are more suitable for the charging regimes associated with photovoltaic and hybrid applications. CEAC/Fulmen Company is developing with photovoltaic system firms and Genec new concepts of energy management of photovoltaic lead-acid storage batteries.

Électricité de France (EDF) plays a role in remote area power supply markets. The agreement signed in 1993 between ADEME and EDF, to promote the use of PV in sectors where it proved to be commercially viable, allowed photovoltaic power systems to access to a public source of subsidy called FACE. By the beginning of 2000, EDF acknowledged that photovoltaic electricity would be paid 0,096 euro per kilowatt-hour (corresponding to net metering system) to the on-grid PV system owners.

EDF started in 1996 the ADEN programme (renewed in 1999 and called ADEN2) with two aims: a) to improve the reliability of the PV technology and b) to propose a range of standardized rural electrification systems able to respond to the requirements of various types of users. Within the so-called POLLEN programme is the study by EDF, ADEME and theirs industry partners of the conceptual development of commercial companies selling energy services in developing countries. The purpose of the designed model is to assess the needs, to evaluate system costs and sizing and to elaborate a business plan in relation to the users' financial resources.

6 MARKET DEVELOPMENT

The main stream of photovoltaic activity in France is that of off-grid applications where PV has proven to be a cost-effective solution. The ADEME and the Regional Authorities along with FACE fund and the tax exemption contracts in Overseas *Départements* are contributing to the growth of domestic applications that represent 60 % to 70 % of installations. The off-grid non-domestic (also called professional) market represents 30 % to 40 % of business and does not receive any public subsidy. The on-grid built-integrated applications are an emerging market through demonstration operations (400 kW installed). The total installed capacity in continental France and its overseas *Départements* is around 10,5 MW. The average annual level of installation is 1 MW per year.

Photovoltaic industry increased production and diversified their range of products and services for which exportations represent an important part of their business. Total business value of main PV companies (cell/module manufacturers and PV system houses) increased 25 % in 2000 to reach 105 MEUR.

Until the end of 1999, grid-connected PV domestic power systems were not promoted by ADEME and EDF as a priority but a private initiative of a user's association installed around 230 "PV roofs" in the peak-power range of 1 kW with partial funding from the European Commission. For this limited number of installations the electric meter was allowed to turn backwards. In the North of France, Regional Authorities introduced within their "green building" projects build-integrated photovoltaic power systems in their newly built secondary schools (6 kW range). Several other buildings are planned. By the beginning of 2000, ADEME set up a targeted demonstration programme on dispersed on-grid built-integrated photovoltaic systems in co-operation with European Commission programme (DG TREN) aiming at installing in continental France 500 kW in three years.

ADEME is involved in decentralized rural electrification cooperation projects in Morocco (training programmes), selected African countries and Indonesia (Transindo project of 4 hybrid PV/diesel village power systems).

7 FUTURE OUTLOOK

ADEME, in partnership with public organizations will continue with its photovoltaic promotion programme to stimulate sustainable and growing market for PV system and associated services. Research and technological development on PV materials, manufacturing processes, balance-of-system components, systems and application as well as technical recommendations and standards will remain important elements in the 4-year programme. The ADEME's objective is to grant 1 MW per year of off-grid PV systems and 500 kW of on-grid built integrated dispersed PV systems in 3 years. ADEME public PV intervention budget for RTD and dissemination programmes tripled in 1999 and was slightly increased in 2000.

By the end of 2000, ADEME started negotiation with the Ministry of Industry on higher photovoltaic electricity buy back rates in order to implement a new dissemination programme as it is expected by the French renewable energy professional association SER. At the international level, ADEME was involved in the G8 Task force in charge of proposing a renewable energy strategy to the eight industrialized countries Head of states.

GERMANY

PV TECHNOLOGY STATUS AND PROSPECTS

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PROJEKTTRAGER JULICH-PTJ

1 GENERAL FRAMEWORK

The reduction of emissions of greenhouse gases is an important target of all environmental policies in Germany. It is expected that photovoltaic (PV) may contribute to this target in the long term. Therefore, research, development and demonstration in the field of PV are supported from several sides, especially the Federal Government, the Federal States, local authorities and utilities.

2. NATIONAL PROGRAMME

Within the Federal Government the responsibility for applied energy research as well as the market introduction is with the Federal Ministry of Economics and Technology (BMWi). Basis for the German PV Research, Development and Demonstration (R,D&D) is 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 conducted by the Project Management Organisation PTJ.
In 2000 the support for R&D on PV amounted to about 37 MEUR shared by 108 projects in total. The distribution of the budget to the various sectors of R&D shows that public funding will be more concentrated on the long-term options and activities to create a technological basis for small and medium enterprises whereas industrial R&D is directed to shorter term achievements.

In January 1999 the so called **"100 000 Rooftops Solar Power 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 new **Renewable Energy Law** guaranteeing a feed in tariff of 99 DPf/kWh (0,56 EUR/kWh) for PV works.

3. 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 of other obstacles preventing the use of PV in different types of buildings.
- PV for decentralised, grid-independent electricity supply.

Today PV plays an important role in the manufacture of high technology products where either the costs of producing electricity are negligible or where a grid-independent source of power results in major advantages. While these are still niche markets at present, a growing number of small and medium enterprises are active in this field. Funding is available in this area under the concept **"PV for Devices and Small-scale Systems"**.

Following, selected topics of important R&D-activities in Germany are described.

3.1 Crystalline Silicon

Crystalline silicon is still the most important material for manufacturing solar cells. After supporting the pilot production plants of ASE GmbH, Alzenau, and Shell Solar GmbH, Gelsenkirchen, now the emphasis is put onto efficient manufacturing techniques. In 2000 new R&D activities are focused on

- solar grade silicon,
- an improved crystal growth concept for multi crystalline silicon and
- an innovative transport system for solar cell production lines.

The aim is to strengthen technological oriented small and medium sized companies and by this to create a productive supply industry.

3.2 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 are existing:

Technology	new R&D activities with federal support
Currently amorphous Silicon (a-Si) has the highest technological maturity. In Putzbrunn the company ASE GmbH is running a small production line of a-Si.	TCO layers (transparent conducting oxide)
Thin Film Solar Cells on basis of CuInSe2 (CIS) have been developed in Germany for 20 years. Based on the work of the University of Stuttgart and the Zentrum für Sonnenenergie und Wasserstoff-Forschung (ZSW) Würth Solar GmbH&Co. KG is now building a first pilot production line.	development of efficient deposition techniques
Antec Solar is constructing a Cadmium Telluride (CdTe) pilot plant in Rudisleben, State of Thuringia.	support of a further improvement of the production process
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

3.3 System Technology

Beside the ongoing development of PV powered devices and small scale systems like a Solar Home System tester or a LED lightning system the evaluation of PV-systems is a topic of interest. The corresponding activities to the latter are partly carried out under Task 2 of the IEA-PVPS Programme.

3.4 Demonstration

Today, the Renewable Energy Law together with the „100 000 Rooftops Solar Power 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.

4. IMPLEMENTATION

In the last 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 new PV-funding sources with growing importance mainly in the area of market introduction have been established recently:

- The "Electricity Feed Law" introduced in 1991 was substituted by the **"Renewable Energy Law"** in April 2000. The new law rules the input and favourable payment of electricity from renewable energies by the utilities. For PV systems built before the end of 2001 a feed in tariff of 99 DPf/kWh (0,56 EUR/kWh) will be paid.
- In January 1999 the **Federal Ministry of Economics and Technology** (BMWi) started the "100 000 Rooftops Solar Power Programme". Until December 2000 almost 18 000 applications were received and a PV capacity of 49,1 MWp was granted (see Fig. 1). 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. The BMWi offered a budget of approx. 460 MEUR for the whole period of this programme.
- Moreover, the BMWi supports the application of renewable energies (solar-thermal, geothermal, biomass etc.) with soft loans or subsidies. The PV initiative **"Sun at School"** is part of this programme.
- 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, established in 1990) 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 kilowatt hour of energy fed into the public grid from PV and other renewable energy systems is offered by some utilities belonging to cities and communities.

5. INDUSTRY STATUS

During the last years a certain industrial infrastructure has been created with the main focus on crystalline Silicon technologies. But like everywhere the PV market still strongly depends on governmental support.

The main focus of future activities is to achieve a closer collaboration between research institutes, PV-industry and new industrial partners, especially small and medium enterprises.

6. MARKET DEVELOPMENT INCENTIVES

The programmes described above have accelerated the installation of PV-systems in Germany significantly (Fig. 2). Following a first estimate there could be roughly 100 MWp on the grid at the end of 2000. Moreover, it is expected that this capacity will increase steadily within the next years due to the "100 000 Rooftops Solar Power Programme" together with the Renewable Energy Law.

7. FUTURE OUTLOOK

Following the guidelines of the "100 000 Rooftops Solar Power Programme" for the coming years the installed grid connected PV capacity is expected to increase notably (see Fig. 1 also):

2001	+65 MWp
2002	+80 MWp
2003	+95 MWp

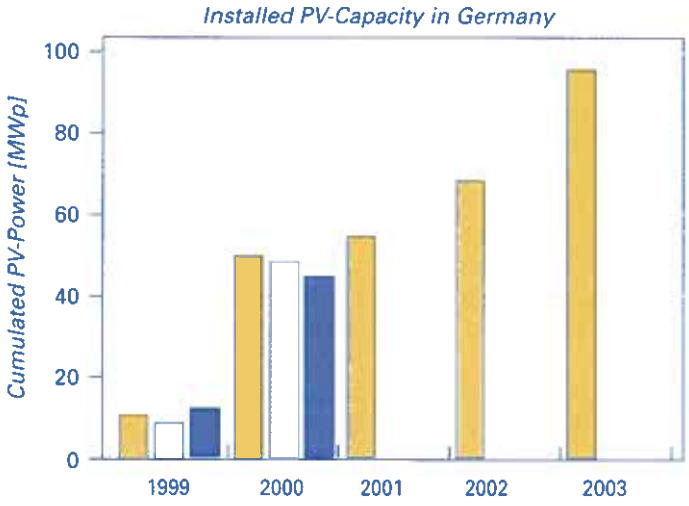

Fig. 1: Grid conected PV power supported by the Federal "100 000 Rooftops Solar Power Programme"

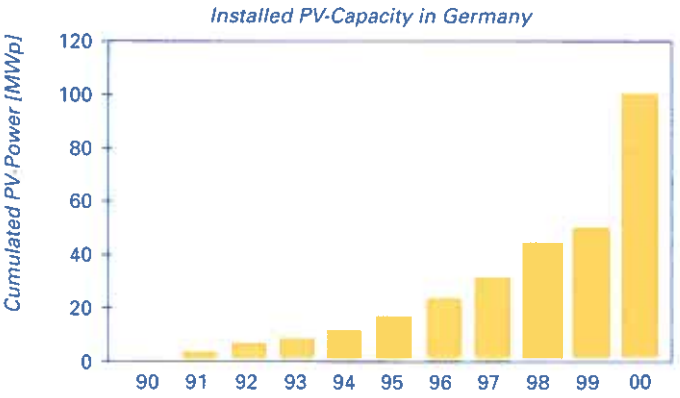

Fig. 2: Comulated grid connected PV-Power in Germany

ISRAEL

PV TECHNOLOGY STATUS AND PROSPECTS: AN UPDATE
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GENERAL

Photovoltaic activity in Israel continues to be 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 400 kWp have been installed so far; 93 kWp were installed in 1999. 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 is required to purchase electricity from private producers, according to rules set by the Ministry of National Infrastructures.

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

INDUSTRY INVOLVEMENT

Eight 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:

- The possibility of making thin-film solar cells from carbon, in its new form of buckminsterfullerene(C60), is being investigated at the National Solar Energy Center in Sde Boker;

Fig. 1: Instructors from the Nitzana Project visiting the Ben Gurion National Solar Energy Center.

- A team at the Jerusalem College of Technology is working on development of solar cells for efficient conversion of highly concentrated radiation, whose strong point is simplicity of fabrication;

- A research at the Hebrew University of Jerusalem seeks to improve energy conversion yields and stability of solar cells based on semiconductor nanocrystallites in the form of porous layer (Graetzel and Weller cells).

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

DEMONSTRATION SYSTEMS

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

- The Israel Electric Corporation has installed a 5 MWp grid-connected PV system on a house in Mitzpe Adi in the Galilee, at a total cost of 100,000 USD. When the system produces more electricity than is being used in the home, electricity can be added back into the power grid. Operation has been practically trouble-free for the last four years. Overall efficiency is about 10.3% (AC).

- 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.

Fig. 2: A new small PV application for Palm 5 (Millennium Electric).

- A PV Controlled Lighting System was built at a road junction in the Jerusalem mountains by Solartec Ltd. for the Israeli Public Works Department. This system automatically adapts the lighting levels to the actual needs, thus achieving considerable energy saving (instead of about 70 kWh per night for a standard lighting system, it uses only about 7 KWh per night). The system is designed for junctions having a traffic flow of less than 6 000 vehicles per day, located in sites which are far from the electric grid (the break-even point is a distance of 1.5 km from the grid).

- In a cooperation project within the EU 4th Framework Programme, the Israel Electric Corporation has built a reverse-osmosis (R.O.) desalination plant, powered by wind and PV generators. The purpose of the project is to investigate the energy balance of a renewable energy hybrid system connected to a battery bank. The PV array capacity is 3.5 kWp, and the desalination unit can provide 400 L/h. The system was erected in Kibbutz Ma'agan Michael (30 km south of Haifa), where a brackish water source is available. The unit will represent a fresh water source for a small and remote community, and the project concentrates on aspects such as meeting the community daily water needs, reliability and economics.

EDUCATIONAL ACTIVITIES

In the Nitzana youth village in the Negev desert, an educational project was recently started, called "Science following the sun". The project will bring to hundreds of school children the message of solar energy, including photovoltaics.

GOVERNMENT ACTIONS

No special plans are being considered by the Government for the near future. However, 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 185,000 USD in 1999; however, additional funding is available in this area from various research foundations.

- Supporting grid-connected demonstration projects by 30% of investment when it can be proven that this is enough to make the project cost-effective.

Fig. 3: 1.05 kW array on a remote home in Galilee (Interdan).

ITALY

PV TECHNOLOGY STATUS AND PERSPECTIVES

S. CASTELLO, ENEA
S. GUASTELLA, CESI

Grid connected 2,3 kW facade at a professional school in Trento

GENERAL FRAMEWORK

Since the early eighties Italy has been involved in a wide photovoltaic program, ranging from research on materials to the development of medium and large grid connected power plants. ENEA (the Italian Agency for New Technology, Energy and Environment), ENEL spa (the largest Italian Utility) and some Italian PV industries (Eurosolare, Helios Technology, ANIT SpA and Gechelin Group,) have been the most active operators.

Currently, on technology side, crystalline silicon cells, amorphous silicon integrated modules and heterojunction devices are developed by ENEA, while improvements are being studied on a completely integrated production process developed by Eurosolare.

From the systems point of view, the total cumulative PV power installed in Italy at the end of the year 2000 is expected to be about 19 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 is still showing a behaviour strongly dependent on subsidized projects.

The experimental phase on medium and large size grid connected plants has demonstrated the technical maturity and reliability of this technology, but distributed generation became more and more dominant all over the world. In this context experimental activities in this field have been carried out mainly by ENEA during the last years. Besides, the Italian Ministry of Environment and Industry have defined in co-operation with ENEA the Italian Roof-top Program, also in consideration of the new emerging world-wide strategy for PV market penetration.

Moreover, during this year the popular acceptance for this technology is sharply increased mainly driven by environmental and climatic concerns. In particular, a wide interest to the Italian Roof-top Program of both private and public end-users, Utilities, first of all ENEL, and PV Industries has been proved.

In year 2000, in the frame of the privatisation of the Italian electric system and the consequent reorganisation of the National Electric Company (ENEL), CESI acquired from ENEL its R&D activities in generation, transmission, distribution, end-use of electricity, environment and renewable energies. In this way, CESI became a high-qualified reference for researches on the national electric system and, in particular, for the Italian Independent System Operator, which is a CESI shareholder.

In the same time, ENEL established ERGA, a wholly owned subsidiary to grow its existing set of competencies and assets in the renewable energy segment of its business. With the recent acquisition of the company CHI ENERGY, which represents ENEL's entry into North American Market, ERGA became the world's largest company dedicated exclusively to renewable energy.

NATIONAL PROGRAMME

The interest of the Italian Government for the development of PV technology is confirmed by the multiyear Programme Agreement that the Ministry of University and Scientific Research has signed with ENEA, devoted to the development of short and medium term technologies and to long term research activities.

Photovoltaic activities, in Italy, are currently focused on two main lines, namely R&D on materials and devices and on the Italian Roof-top Program. This Program is intended to widely diffuse the PV roof-top technology in Italy, by means of the installation of PV systems for distributed generation with a final capacity of 50 MW.

R&D AND DEMONSTRATION

Most of these activities are carried out directly by ENEA at his own laboratories, while some specific topics are studied in cooperation 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. Interesting results have demonstrated the feasibility of the process on full size multicrystalline substrates with an efficiency of 13%. Moreover, to improve the efficiency and stability of devices, both single-junction and tandem structures are investigated at Portici Laboratories The process steps for an amorphous p-i-n solar cell exceeding 11% efficiency have been scaled-up to a large area reactor allowing the fabrication of a 900 cm^2 module with an initial efficiency of 8.5 % and a stable efficiency of 7.3 %. At the ENEA Casaccia Laboratories crystalline silicon devices based on laser assisted processes or on advanced screen-printing technologies have been currently realized with efficiency greater than 16%.

The cooperation program between ENEA and Eurosolare, aimed at upgrading the production processes through a strongly innovative pilot line, is almost completed. The line is based on the "buried contact cells" simplified concept with an efficiency of 15%, developed by M. Green patent and partially financed by ENEA.

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.

Building integrated 2 kW system at the University of Rome

Analysis and tests on medium and large power plants have been carried out by ENEA on Delphos 600 kWp (1 unit of 300 kWp and 3 units of 100 kWp, called PLUG) grid-connected plant, on Alta Nurra PLUG and on Vulcano PLUG, to test the high penetration of PV in a small isolated grid.
Furthermore performance evaluation of PV components and plants have been carried out by CESI on ERGA plants (3.3 MWp Serre plant, 80 kWp Vulcano plant and 72 kWp Adrano Test field) and on several stand-alone plants owned by ENEL Distribution (in all over the Italian territory), in order to assess long term behavior of PV technology in different climatic conditions and in different electric configurations.
In the framework of preliminary activities foreseen by the Italian Roof-top Program, during the year 2000 10 small pilot plants have been installed by ENEA on public buildings of Municipalities and Universities in some important Italian cities, while other 3 prototypes are under construction. Moreover, is still in progress the data collection and analysis, by CESI and ENEA, of the first five pilot plants realized in close co-operation between ENEA and ENEL in June 1999.

IMPLEMENTATION

In the field of fiscal aspects, the already existing tax reduction for building refurbishment, which includes PV plant installation, has been reduced from 41% to 36% of the investment cost.
Concerning tariff issues, the National Authority for Electricity and Gas has fixed a preferential tariff of 362 ITL/kWh for PV electricity produced by plants commissioned within the year 2000 and 428.4 ITL/kWh for the ones which will be commissioned in the period 2001 – 2002.
Initiatives from Utilities are evident in ENEL's program aimed at the achievement of energy significance of renewable energy sources.
Besides, some Local Utilities have showed an increasing interest on Photovoltaics starting or continuing their demonstration PV programmes.
Moreover, both ENEL and Local Utilities have demonstrated their strong consensus to the connection of the plant to the grid, co-operating with ENEA to overcame some technical barriers, such as grid interface devices, grid connection requirements and plant maintenance.

INDUSTRY STATUS

The Italian PV industry consists of two major module manufacturer, 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 (totally controlled by ENI, the National Board for Fuel Supply) with a staff of about 70 people. Its manufacturing facilities have a production capability of 2.5 MWp/year per shift. Both single-crystal and polycrystalline silicon cells are currently produced; polycrystalline wafers are home-made, while single crystal wafers are bought on the international market. Eurosolare production includes also specially designed modules for roof tops and facades. Eurosolare module manufacturing process is completely integrated and comprehends the fabrication of polycrystalline silicon wafers, cells and modules. It is worth mentioning that Eurosolare carries out R&D on wafer, cell and module production. On the overall, in 2000 the Eurosolare module production is expected to be 1.5 MWp.
The second Italian module manufacturer is Helios Technology. Its manufacturing facilities have a production capability of 2.2 MWp/year. In 2000 the Helios Technology module production is expected to be 2 MWp. Helios Technology module manufacturing process comprehends the fabrication of cells and modules from mono-crystalline silicon wafers
In the field of PV system it is worth mentioning that both Eurosolare and Helios Technology activities include the commercialisation, design and turn key supply of PV system. Other industrial operator 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 the year 2000 is about 19 MWp. In particular it results that rural electrification (about 5.7 MWp), off-grid domestic applications (about 5.3 MWp) on-grid centralised systems (about 6.7 MWp) and on-grid distributed (about 1.3 MWp) constitute the most important sectors of the Italian market.
Up to now the national PV market has been showing a 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 government, the European Community, ENEL and ENEA projects.

FUTURE OUTLOOK

The major future initiative is the Italian Roof-top Program which although has been defined two years ago it is not yet started, mainly because of some bureaucratic problems. However, the Program is ready to be launched, being fully defined all the management procedures, successfully overcome most of the fiscal and legal barriers and demonstrated the technical feasibility of the experimental solution adopted in pilot plants. Moreover, during this year a positive context has been established, providing the best condition for the success of the initiative.
In addition, some strategic benefits are expected during the Program concerning the diffusion of the photovoltaic technology and of the environmental awareness and the expansion of the market. Moreover a "driven" decrease of photovoltaic costs, the creation of job opportunities and the local development in unfavored regions is expected as well.

JAPAN

PV TECHNOLOGY STATUS AND PROSPECTS

KEN-ICHIRO OGAWA, NEDO

Fig 1: PV system installed on southward semi-transparent wall (19.4 kW, 229 sq. m) and canopy (1.7 kW, 56 sq. m) of plant

GENERAL FRAMEWORK

The Total Primary Energy Supply Outlook prepared by the Advisory Committee for Energy (an advisory body of MITI) was announced in June 1998. In the Outlook, the target for photovoltaic (PV) system introduction was settled to be 5 000 MW by FY2010.
The Law for New Energy Promotion Introduction was enacted in 1997 and defined the fundamental framework of the Government, local governments, energy users, energy suppliers and PV system manufacturers.
In FY1998, "Basic Guideline for Promotion Measures to Arrest Global Warming" was enacted, and the Government has made an effort to promote strongly the introduction of new energy and to reduce CO2 emission. Furthermore, "Law Concerning Promotion Measures to Arrest Global Warming" and "Law for Green Purchase" were enacted.
In December 1999, the New Energy Subcommittee was established in the Advisory Committee for Energy and continues to discuss in depth on what energy policy in Japan should be. Residential PV System Programme will be terminated in FY2002 because it is predicted to be fully achieved the expected target. Regarding the research and development (R&D), R&D on photovoltaics technology, Phase I finished in FY2000, and the implementation of R&D Phase II was decided to start in FY2001 to aim the further cost reduction of PV systems.

NATIONAL PROGRAMME

The Government has implemented R&D demonstration and promotion policies towards the achievement of targeted introduction capacity 5 000MW of PV systems by FY2010. In the field of R&D, technical development for cost reduction of PV systems, technical development of silicon feedstock for PV cells, and technology development for PV deployment. Regarding demonstration test, the followings have been continued; cost reduction demonstration test by standardisation of PV systems for industrial use aiming at introduction and promotion of PV systems to private facilities; demonstration test for new type of PV systems. As for promotion policy, Residential PV System Dissemination Programme has been strongly moved forward. In addition, the Government has implemented supporting programmes for introduction of new energy to local governments and private entrepreneurs.
The budgets for FY2000 of major National PV Programmes are as follows;

1) New Sunshine Project (R&D): 7 840 MJPY
2) Technology development to deploy PV system(new): 1 240 MJPY
3) SOG silicon production technology development: 530 MJPY
4) Residential PV System Dissemination Programme: 14 500 MJPY
5) Field Test Programme for industrial use: 4000 MJPY
6) Financial support for industries introducing new energy: 11 490 MJPY
7) Introduction and promotion of new energy at the regional level: 6 430 MJPY
8) Support for local efforts to develop the vision of new energy use and energy-saving: 1 230 MJPY
9) Support for local activities to introduce new energy (new): 1 060 MJPY

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

R&D,D

Regarding the New Sunshine Project established in FY1993 to promote a comprehensive, long-term R&D programme, R&D Phase I came to a close in FY2000, and the preliminary evaluation has approved to continue the R&D into Phase I from FY2001 throughout FY2005. The R&D policies are designed to encourage the development of technologies that facilitate the start of a "favorable circle" enabling mass production at a cost low enough to spur further demand, which improve the scale of economy for production and sustainable PV market in consequence.
The short-term target by 2000 is to develop technology that can realize the generation of PV electricity at a prime cost equal to conventional electricity charges, i.e. 20-30 JPY/kWh. The target by 2010 is to develop technology that rises to the cost level necessary for large-scale power generation.
R&D, Phase I of PV technology is focused on solar cell production technology (thin-film solar cell and super-high-efficiency solar cell manufacturing technology,, solar cell evaluation system, etc.), PV power generation system technology (system evaluation, BOS, demonstrative research), development of low energy consumption type manufacturing process for SOG-Si, and development of practical technology for high-efficiency multicrystalline silicon solar cells.
Main demonstration programmes that were implemented in FY2000 is "PV Field Test for Industrial Use", implemented by the Ministry of International Trade and Industry.

PV Field Test for Industrial Use

This programme started in FY1998. The aims are; (i) to install in trial PV system using new technology effective to introduce to industrial sector, such as industrial facilities, (ii) to demonstrate availability for introduction of PV system by collecting data and analysing a long-term operation under demonstration test and (iii) further standardisation and diversified introduction applications

toward full scale deployment of PV system. Eligibles for subsidy are private company, local public organisations and other organisations, which are going to install modular type PV system and novel application of PV system. Half of PV installation cost is subsidised. 73 PV systems, total 1 940 kW, in FY1998 and 93 PV systems, total 2 790 kW, in FY1999 have been installed. In FY2000, 151 PV systems, 3 710 kW are accepted.

PV Field Tests for Public Facilities implemented since FY1992 achieved successfully the expected target and completed in FY1997. Since FY1998 only acquisition and analysation of the operation data are continued. 1 830 PV systems, 4 900 kW were installed to schools, welfare facilities, private facilities, office buildings and factories under PV Field Tests for Public Facilities.

IMPLEMENTATION

1 **The Ministry of International Trade and Industry**

PV System Dissemination Projects were enhanced, and new promotion projects for PV system were established.

As regards new projects in FY2000, two programmes were initiated; "Technology development to deploy PV system " aiming at promotion of PV system; "Support for local activities to introduce new energy" aiming at introduction of new energy and renewable energy at regional and local level through NGO activities.

Residential PV System Dissemination Programme

"Residential PV System Dissemination Programme", the latter of "Residential PV System Monitor Programme", was initiated in April FY1997. It aimed to enlarge further the scale of PV promotion, and to subsidise the PV installation cost for individuals on the condition that they perceive the significance of PV and provide the operation data of their PV system. The subsidy is given three categories, (i) an individual who is going to install PV system to his own house, (ii) ready-built house supplier of housing development complex and (iii) local public organisation who is going to introduce PV system to public house. PV system with reverse flow connected to low voltage line is subsidised.

Subsidy in FY2000 is provided 270 000 JPY/kW (up to 10 kW) in the first half, and 180 000 JPY/kW (up to 4 kW) in the second half.

Residential PV systems have been installed to 6 352 houses, 24,1 MW in FY1998, 5 654 houses, 19,5 MW in FY1997, to 1 986 houses, 7,5 MW in FY1996, to 1 065 houses, 3,9 MW in FY1995 and to 539 houses, 1,9 MW in FY1994. 17 396 houses were accepted in FY1999, and 8 034 houses in the first half of FY2000, 10 873 houses in the second half, totalled 18 907 houses were accepted in FY2000.

Regional New Energy Introduction Project

This project aims at accelerating new energy introduction by supporting the regional projects that local governments established for new energy. Eligibles for subsidy are local public organisations who are going to introduce and promote PV, wind power, solar heat, differential temperature energy, natural gas co-generation, fuel cell, wastes generation, use of waste heat, production of wastes fuel, clean energy car, energy saving measurements. PV system is subsidised to 150 kW output and over. Half of system installation cost is subsidised. 16 systems in total were subsidised in FY1998, and 4 systems out of them were PV systems. Total capacity installed was 500 kW. 37 systems in total were subsidised in FY1999, and 19 systems out of them were PV systems. Total capacity installed was 1 539 kW.

Subsidy Programme for New Energy Industrialists

This programme aims at accelerating 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 cell, wastes generation, use of waste heat, production of wastes fuel, from a viewpoint of energy security and global environmental protection. Eligibles for guaranteed debt or subsidy are private industrialists who set about new energy business. A third of system installation cost is subsidised and guaranteed debt is 90% of a debt. 18 systems in total were subsidised in FY1998 and one system out of them was PV system with 116 kW. 32 systems in total were subsidised in FY1999 and one system out of them was PV system with 100 kW.

2 **The Ministry of Construction**

Trial PV installations to road traffic facilities, especially of expressways, have been gone on with as before. Under "Guideline for Planning Environmentally-Friendly Government Facilities (Green Government Office Building)", construction of green government office buildings with PV system have been promoted. Furthermore, the Ministry developed "New Water and Sewage Technology 5-year Project" and are encouraging in installing PV systems to water and sewage facilities.

3 **The Ministry of Posts and Telecommunications**

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

4 **The Ministry of Education**

The Ministry continues "Eco-school promotion Pilot Model Project" in partnership with MITI and is promoting introduction of PV systems to elementary and junior high schools in Japan.

5 **The Ministry of Transport**

120 kW PV system was installed at Narita International Airport in 1999 under "Eco-airport Plan" oriented environmental protection. The Ministry is planning to use PV systems under "Beacon Provision Project" and " Coastal Environmental maintenance Project".

6 **The Environment Agency**

The Ministry is promoting project of CO_2 emission reduction measures by use of natural energy under "Basic Guideline for Promotion Measures to Arrest Global Warming" settled in FY1986. In addition, Government established "Law for Green Purchase", and decides to replace commodities procured by Government to environmentally-friendly products. As PV system is included in the products, introduction of PV systems to national facilities is expected.

Fig. 2: Arch roofing integrated PV system (7.8 kW) to children's science museum "Fort of Sun and Wind"

7 **The Local governments and municipals**

As the movements to grapple positively with environmental issues are spreading, there is an increase in some local governments and municipals to plan and implement the introduction of PV systems and develop their own plan under MITI's Regional New Energy Introduction Vision. Some local governments and municipals also provide their own additional subsidy to the public financing and their number is increasing year by year. Promotional supports to PV systems are enhanced at local governments and municipals level.

8 **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. The capacity by buy-back contract totaled 35 488 000 kWh at the end of March in 2000.

10 electric power companies in Japan established "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 installation of PV systems and wind power systems.

9 **Financing Institutes**

Some financing institutes, such as banks provide preferential financing at low interest rate with introduction of residential PV system for private use.

INDUSTRY STATUS

PV cell production had continued to hover around the low level since 1992, but got out of the level in 1996 and then has been expanding and growing. The production of PV cell in Japan is increasingly expanding from 50 MW level in 1998 to 80 MW level in 1999. It will be considered as the background of the above-mentioned circumstances that the continuation of "Residential PV System Dissemination Programme" by MITI, the promotion of "PV Field Test Project" and the focus on sales of " house with PV system as standard specification" by housing manufacturers with approval of PV as building materials by the Ministry on Construction have paid a role in leading PV market and served as strong driving force to increase PV production.

To correspond to increasing of PV cell demand, PV cell manufacturers in Japan have been expanding their production capacity one after another. There are PV cell manufacturers with production capacity of over 50 MW. In addition, new PV manufacturers are entering into PV industry one after another through acquisition or cooperation with overseas manufacturers in expectation of further expansion of PV cell demand. Main manufacturers are Kyocera, Sharp, Mitsubishi Electric, Sanyo Electric, Canon, Kaneka, Matsushita Battery, Showa Shell Sekiyu and MSK. Furthermore Kobe Steel, Kawasaki Heavy Industries, Matsushita Seiko and Mitsubishi Heavy Industries announced the entry into PV market. Many of major housing manufacturers in cooperation with PV cell manufacturers commercialise the houses with PV system as standard specification under "Residential PV System Dissemination Programme" by MITI. Besides above-mentioned manufacturers, building material manufacturers, who produce roofing material, outer wall material and sheet glass, commercialise building materials integrated with PV cell for PV market. Moreover some builders start to construct buildings integrated PV cell as "environmental co-existence" buildings. As above-mentioned, industry from different fields is commercialising products with PV cell concerning photovoltaics, and therefore the range of PV industry is expanding.

MARKET DEVELOPMENT

The initial market development for PV systems has increasingly made progress, in the market sector of private houses, public facilities, industrial facilities and commercial buildings by financial support to PV systems of MITI. PV cell manufacturers commercialise thin type modules, lightweight modules, triangle modules, lighting type modules, coloured modules, flexible modules roofing integrated modules, wall material integrated modules, which correspond to user's needs to improve design and function. Especially housing manufacturers are enhancing sales of the houses with PV system as standard specification using these modules. The market range of 3-5 kW residential PV systems is expanding to the annual market scale of 10-20 thousand systems. Also the introduction of PV systems by local governments and private enterprises are increasing, and standardization of 10-100 kW PV systems for industrial use is developing. Local governments have installed PV systems mainly to schools, governmental offices, welfare facilities, hospitals, public halls. And private enterprises have applied PV systems to roof-tops and roofs of head office buildings, business offices, factories and warehouse. Some private enterprises are planning to introduce systematically to restraints, railway stations, service stations, etc. Besides, off-grid non-domestic PV systems without governmental support are actively utilised as commercial power supply sources for telecommunication, traffic sign, remote measurement, ventilating fan, lighting and the like.

FUTURE OUTLOOK

With backing to promote PV systems by the Government's policy, the PV market, especially for residents, public facilities, commer-

Table 1: The cumulative installed PV power in 4 sub-markets.

Sub-market/application	1992	1993	1994	1995	1996	1997	1998	1999
off-grid domestic	150	200	250	300	350	400	450	500
off-grid non-domestic	15 260	19 170	23 260	29 360	35 890	44 900	52 300	56 400
on-grid distributed	1 220	2 300	5 130	10 820	20 500	43 100	77 750	145 500
on-grid centralised	2 370	2 600	2 600	2 900	2 900	2 900	2 900	2 900
TOTAL	**19 000**	**24 270**	**31 240**	**43 380**	**59 640**	**91 300**	**133 400**	**205 300**

cial buildings and industrial facilities, will be deploying more and more. The expansion of PV system market will result in enlargement of production capacity of PV cell manufacturers and cost reduction of PV systems, and then PV system market is expected to grow to be self-sustainable. In addition, while the expansion of PV system market get individuals, local governments, private entrepreneurs deepen the understanding of significance of PV system introduction, the roofing industry, the housing industry, the construction industry and the power source equipment industry will be stimulated to enter into PV market, and subsequently sustainable PV industry will be established

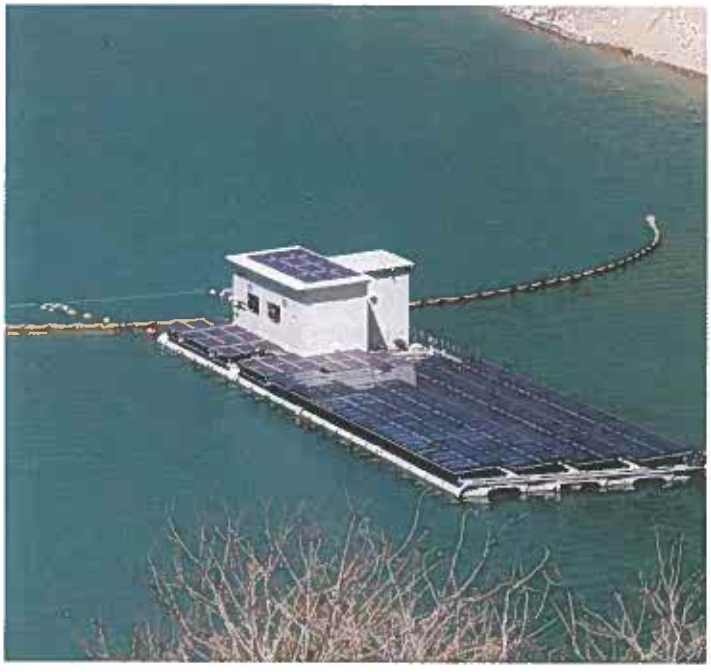

Fig. 3 and 4: 28 kW stand-alone PV system (25 kW mc-Si and 3 kW a-Si) on the moored barge; PV power is mainly used for water purity control equipment, and the surplus PV power is supplied as emergency power source at the parking lot through an underwater cable.

KOREA

PV TECHNOLOGY STATUS AND PROSPECTS

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GENERAL FRAMEWORK

As indigenous energy resources are poor, Korea has to rely almost entirely on imports to meet its energy needs. In 1999 the dependency rate on imported energy, including nuclear energy, was 97.2 % and its cost nearly amounted to 22.6 billion USD, equivalent to 18.9% of the nation's total inbound shipments. The high rate of increase in energy demand is expected to persist in the future because of expected sustained economic growth, despite nationwide efforts driven by the government to encourage energy conservation and higher energy efficiency. In these circumstances, development and dissemination of renewable energy are crucial for meeting many challenges, including reducing dependence on imported energy, diversifying energy resources and supply systems, expanding Korea's export of energy technologies, reducing environmental pollution and eventually alleviating the energy burden of the national economy.

In recognition of the necessity to enhance the effort of dissemination of renewable energy, the Government amended the "Promotion Act for New and Renewable Source of Energy (NRSE) Development, Utilization and Dissemination" in late 1997. The Major objective of this Act is to increase the share of renewable energy to the national energy supply from 1.03% in 1998 to 2.0% in the year 2006.

NATIONAL PROGRAMME

Based on the Act, the ministry of Commerce, Industry and Energy (MOCIE) published on aggressive action program named "Three-year National plan for NRSE Technology Development and Dissemination", which covers the period 1999-2001. The national PV program have been modified in order to both propel current R&D and enhance utilization of developed technologies.
The key goals of the new program are:

- development of high efficiency thin film solar cells
- mass production of c-Si solar cells and balance of systems
- standardization of performance test and evaluation
- field test for solar-roofs and BIPV

However, the Government support for PV activities was moderate in 1999 due to, in large part, the foreign currency crisis in Korea. The MOCIE and the MOST funded various R&D and demonstration projects. The MOST provided funding for R&D only. In 1999 the total budget for R&D was 1 382 MKRW which corresponds to a half of that invested in 1998 (2 839 MKRW). The budget for demonstration was 454 MKRW in 1999, and it was 1 200 MKRW in 1998. Until now no public funding has been allocated for market stimulation. The Korea Photovoltaic Research Association(KOPRA) made up of members from research institutes, universities and industries gives a considerable contribution to the execution of R&D program by carrying out feasibility studies and making suggestion to the Government.

R&D AND DEMONSTRATION

The R&D projects supported by the Government in 1999 are divided into four categories: materials and solar cells, balance of system(BOS), system technology and performance evaluation. The highest priority has been given on solar cells, especially thin-film solar cells. National Laboratory such as the KIER and universities play a leading role in R&D on thin-film solar cells. In the case of CIGS solar cells, the use of binary compound as evaporation source as well as the improvement of efficiency was studied and have achieved its efficiency more than 15% already. The development of CdTe solar cells using CSS (close-spaced sublimation) method and fabrication of GaAs by MOCVD are still under way. In 1999 a joint project among industry/institute/university was newly started to develop multi-crystalline solar cells and modules and its application to the rooftop system. This project includes the development of inverters for distributed grid-connected systems.

In 1999 two on-grid PV systems and one PV-diesel hybrid system were installed under this program. A 12 kWp on-grid system was installed on the roof of a public building owned by Changwon municipality. This system together with a 10 kWp on-grid system installed at the KEMCO aimed at the demonstration of on-grid system and enhancing the public awareness of the PV. The PV-diesel hybrid system with a power of 10 kWp system was installed at a shelter house located at 1500 meter altitude in Hanra mountain, Cheju island. In 2000 five on-grid PV systems were installed. The all installed systems have 10 kWp capacity, among which three systems were installed in the building of college or high school and the other installed for specific applications like water-pumping.

INDUSTRY STATUS

LG Industrial Systems and Samsung Electronics produced PV modules. At the end of 1999 the total production capacity was 1500 kWp and the total production volume was 500 kWp remaining at the same level that of the previous year. The main steps of the production process and the technical characteristics of the modules remain unchanged. LG Industrial Systems produced PV modules using solar cells supplied by High Solar Company and solar cells imported from Siemens Solar Industries in USA. High Solar company became independent from former LG Siltron Co. in May 1999. In 1999 LG Industrial Systems produced only one type of modules with a rated output power of 50 Wp. In 1999 Samsung Electronic Company produced about 300 kWp of PV modules using mc-Si PV

cells supplied by BP Solarex, USA. Only one type of modules with a peak output of 50 Wp was produced.

Depending on the PV system type installed, system prices ranged between 25 000 KRW/Wp and 15000 KRW/Wp. In the case of off-grid system, the system price was lower as the system size increased. The price is 25000 KRW/Wp for a street lighting PV system with a unit power capacity of 200 Wp. An off-grid system with a power of 10 kWp for a shelter house at high altitude was installed a price of 20 000 KRW/Wp. The system price of on-grid systems is lower than the off-grid systems, because the battery cost can be saved in the case of on-grid systems. The average price was 14 400 KRW/Wp. 1 USD was equivalent to 1 188 KRW approximately in 1999.

MARKET DEVELOPMENT

The PV market was still dominated by off-grid non-domestic sector that occupied about 82.5% of total installed power followed by off-grid domestic sector with a market share of about 9.1%. Among the various off-grid non-domestic applications, telecommunication is still the largest sector of application, followed by lighthouse, street lighting, etc. The largest application sector in 1999 was PV systems for the aviation warning lamps of the high-voltage transmission tower, which were constructed by the KEPCO.

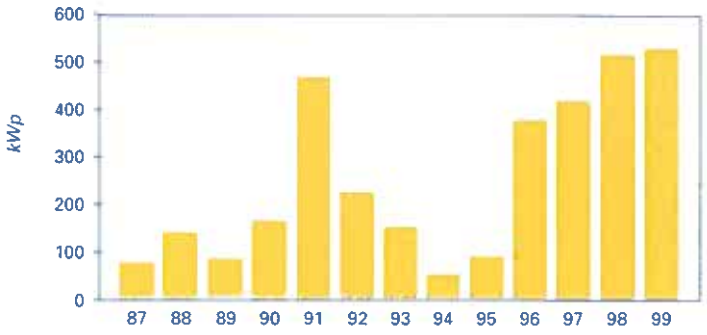

Fig. 1: Annual installed capacity in Korea (kWp).

The installed capacity of PV systems in Korea at the end of 1998 was 3 459 kWp, almost doubling over the recent five years. The total installed PV power in 1999 was 518 kWp, which is a few percent more than 507 kWp achieved in 1998.
The share of off-grid domestic sector is about 9%. The PV-diesel hybrid system for remote islands and isolated houses take the large part of this market sector. These systems were essentially installed under the Government demonstration or filed test programme. However, only one system with a capacity of 10 kWp was installed in 1999. In 1999, two distributed on-grid systems with an installed capacity of 10 and 12 kWp started their operation. This sector accounted for only about 8% as of end 1999.

FUTURE OUTLOOK

At present, high cost is the main hindrance to the full-scale application and market expansion of PV systems. In addition, there are no market incentives or subsidies for PV system installation and electricity production in Korea. For some time, it is unavoidable that the Government, local communities and public organizations including the KEPCO continue to play a dominant role in the PV market. We expect the PV technology will become more competitive in stand-alone systems for rural electrification in the near-term. In the long-term, PV application areas will expand to grid-connected systems such as solar rooftop or building integrated systems in the urban areas.
In recognition of the importance of PV technology and to increase the domestic market volume of PV system to an appropriate extent in near-term, creating a near-term targets for installed PV capacity was discussed, but not reached a concrete conclusion yet until the end of 1999.

Total PV installations for various applications in 1999

Installed capacity (kWp)	
Residential and electrification	44
Telecommunications	55
Lighthouse and street light	254
Emergency telephone	35
Road, aviation signaling	10
Inspection of water quality	19
Others	101
TOTAL	**518**

MEXICO

PV TECHNOLOGY STATUS AND PROSPECTS

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Experimental PV-wind hybrid system

GENERAL FRAMEWORK

PV systems have been systematically used for rural electrification in Mexico for more than ten years. Solar home systems are the preferred solution to bring basic electrical services to remote and small communities with no access to the grid. Over 60,000 such systems have been installed to date in more than 2,000 rural communities, benefiting more than 250,000 people. Productive applications are also underway, and other systems such as PV-wind hybrids and roof tops are also being implemented.

NATIONAL PROGRAMME

There is not a clear cut national PV program in Mexico. PV projects have been carried out in the context of more general programs, such as poverty alleviation, agricultural infrastructure and technology R&D. Early projects were typically implemented by the federal government. Today, state and municipal governments are taking the lead, fostering the installation of SHS and other PV and PV-wind hybrids for productive applications, in regions where grid extensions are considered uneconomical. This means that PV is gaining its place as a proven alternative for remote applications in Mexico.

RESEARCH & DEVELOPMENT

Grid-connected PV R&D activities continued during the year 2000 at the Electrical Research Institute (IIE) with support from the Mexican Energy Secretariat. The aim of this project is to test roof-mounted PV systems for peak power shaving in regions with high ambient temperatures during summer time. Four more such systems, between 1 800 and 2 000 watts in power each, were installed in the year 2000, in a city in northwest Mexico where peak power demand is very high due to the heavy use of air conditioning equipment. Technical guidelines and specifications are also being developed as part of this project, as a means to eventually support the massive implementation of PV roof-tops for peak power shaving.

PV-wind hybrids are being studied from two perspectives: by monitoring the performance of mini-grids powered by hybrid systems in remote communities, and by working on an experimental system installed by IIE in the city of Pachuca, a few kilometers north of Mexico City. PV-wind hybrids represent an important option for electricity supply in isolated and remote areas of Mexico where good solar and wind resources are available.

First Grid connected PV system in Mexico

Studies on solar home systems have been extended to cover field and laboratory evaluation of SHS using nickel-metal-hydride batteries. Around 30 such systems have been installed in rural communities and close monitoring of battery performance is underway. Eighty more such systems are soon to be installed.

IMPLEMENTATION

Professional applications of PV in telecommunications, warning signals, satellite telephones, road emergency phones and others, continue on a business as usual mode.
Rural electrification projects are also been carried out by municipalities and federal agencies such as the National Institute for Indian Affairs. A program to finance the implementation of PV water pumps and other agricultural applications has been implemented by the Ministry of Agriculture, with financial support from the World Bank through the GEF.

INDUSTRY STATUS

Mexican PV industry is mainly devoted to produce balance of system components for SHS, including batteries, lamps and charge controllers. PV modules are still being imported from abroad as is the case of inverters for PV grid connected systems. A number of companies have been created for the commercialization of PV and renewable energy systems. Foreign companies are venturing with Mexican companies for the same purpose.

MARKET DEVELOPMENT

Total PV capacity installed in Mexico is currently estimated to be12.9 MWp. Capacity installed in the year 2000 was close to 1 MWp.

FUTURE OUTLOOK

PV installations in Mexico will continue its current trend. Driving rural applications is the fact that around 5% of the country's population, equivalent to around 5 million people that live in very small, disperse and remote communities, still do not have access to the national electric grid. New government programs to foster productivity in rural areas will call for local sources of energy, including PV. Professional applications such as satellite telephones, signaling and automatic control devices in offshore oil platforms, cathodic protection and others, are under construction in growing numbers. PV systems used for small eco-hotels is becoming common practice. Grid-connected applications will steadily increase, although at a modest rate in the next few years.

THE NETHERLANDS

PV TECHNOLOGY STATUS AND PROSPECTS

MICHIEL VAN SCHALKWIJK; NETHERLANDS AGENCY FOR ENERGY AND THE ENVIRONMENT &
EDWIN KOOT (EKOMATION SOLAR ENERGY CONSULTANCY)

GENERAL FRAMEWORK

In the Netherlands, the Ministry of Economic Affairs is responsible for the policy in the area of energy efficiency and renewable energy. In 1997, the Ministry published an Action Programme for renewable energy, which covers the period 1997 - 2000. The policy is aimed at increasing the share of renewable energy to the national energy supply from less than 1 % in 1996 to 3 % in the year 2000 and 10 % in 2020. PV is widely regarded as the most promising renewable energy option for the Netherlands on the long run. The focus is on building integrated application of pv, because this offers both technical advantages and marketing opportunities.

On a national level, the targets for PV set by the Ministry of Economic Affairs are the installation of 12,5 MWp by the year 2000, 250 MWp by the year 2010, and about 1 500 MWp by the year 2020. In order to achieve the goals for the coming years, the Ministry is taking the following measures:

1. Strong financial support for research, and for technological and market development
2. Development of various fiscal instruments, beneficial to investments in Renewable Energy
3. Stimulating public support for renewable energy by means of a nation wide promotional campaign
4. Co-signing of the PV Covenant (a treaty between 27 parties, ranging from industry, utilities, R&D sector, government to building industry).

Utilities play an important role in pv. All utilities sell green energy and therefor invest in renewable energy. Some of these green energy products contain also a portion of electricity generated by pv power. Although in 2000 utilities planned to end the special funds for environmental investments (like pv), some utilities will still have money available in 2001.

Project developers, the building industry, installers, housing corporations and municipalities are key players for building up experience with pv in the built environment, and also for introducing pv into regular building practices. Co-operation between these parties are tested and investigated in several demonstration projects. The market for pv is not only directly stimulated with subsidies and other financial incentives, also various policy instruments, aimed at stimulating energy efficiency and sustainable building in the construction sector, have proven to be part of the growing interest for mainly grid connected pv.

Furthermore environmental organizations like Greenpeace and WWF actively promote the use of pv. Based on the results of inquiries, Greenpeace initiated the Solaris campaign, where small PV systems are being sold to private households. WWF supported their logo for low energy houses with pv.

Fig. 1: One of 23 houses in the lagune project in Langedijk, wich form part of the 5 MWp City of the Sun. The houses have systems varying in size between 3 and 8 kWp, adding up to a total of 130 kWp. Because of smart project organisation and system design, system prices were achieved of less than 5 Euro per Wp (excl of VAT) (Copyright Novem - Hans Pattist)

NATIONAL PROGRAMME

The Netherlands national photovoltaics programme (NOZ-pv) is financed by the Ministry of Economic affairs and managed by Novem. Increasing budgets for research on fundamental issues and cell technology are made available through other programs and organizations as well.

An important starting point of the national pv program is the necessary improvement of the price/performance ratio of pv which will be achieved by both technological and market development. The goal of the program is *"To prepare the market and the technology for large scale implementation of pv solar energy in the Dutch energy supply of the 21st century."* The program therefore supports the following activities:

- research on cell technology and on building components
- development of quality standards and certifications
- experiments and demonstration projects with pv in the built environment (aimed at building up experience and know-how among the regular building industry)
- market implementation and development of both grid connected pv in the built environment and of stand alone pv
- feasibility studies and research aimed at stimulating export of pv to southern countries
- dissemination of information

In 2000 budget was made available for the market development of building integrated pv, small systems as well as pv on large buildings, in a new subsidy scheme PV-GO!

Furthermore, in November 2000, an additional budget was created for PV systems larger than 0,5 MWp, specifically focussing on organizational en financial issues.

Fig. 2: The fire station of Houten was designed by the Belgian architect Philippe Samyn to combine esthetics and functionality. The semi-transparant panels provide an interesting light pattern in the black and with interior, that is livened up by the bright red fire trucks and colourful childrens' paintings on the interior wall (Copyright Novem - Hans Pattist)

RESEARCH AND DEVELOPMENT

Solar cell research in the Netherlands is performed on various types of cells. Research on multi crystalline silicon is concentrated on metallization, passivation and texturing in order to improve the efficiency of the solar cells. New texturing and passivation technology has been proven on lab-scale and R&D is now focussed on industrial implementation. Dutch companies together with European partners are jointly working on research on silicon feedstock in order to obtain a sustainable position for this raw material. In another initiative Dutch and German companies are working on joint Si-wafer production.

As important cost saving factor a large effort has been put in the development of new concepts for solar panels and production methods. One example is the PUM panel with reduced front-side metallization and backside tabbing and connecting.

Amorphous silicon still is the most promising thin-film candidate for industrial upscaling in the Netherlands in five to ten years. Joint research by several Dutch universities leads to promising results on plasma deposition and the speed of cell production. Akzo Nobel increased their efforts for the development of a demonstration facility for a high-speed large area production of amorphous silicon solar cells.

For the long term research organic solar cells are important and promising as probably the cheapest solar cells of the future. The Dutch infrastructure for R&D leads to promising results, shown by the research on the concept of the dye-sensitized solar cell which is now focussing on the production process. And together with Austrian research institutes a record efficiency of 2,5% has been achieved for the bulk hetero junction cell.

Inverter developments were concentrated both on refining existing products and extending the product range. Several new inverter types were developed, for the home-market and abroad.

Concerning the development of new pv building products Laura Star Roof finalized the development of an a-Si/steel roofing element which will be applied in 2001. Products for pv integration in tilted roofs, like Intersole and Unisole of Econergy, were installed in projects in 2000, just as the RBB 700. RBB also developed a new integration system specifically aimed at integration of amorphous silicon cells. The a-Si/bitumen roof elements of NECO are still under development. Lenco started their own production of solar sun shading elements and introduced these on the market in 2000. Oskomera finalized the development two profile system techniques for pv facades. In 2001 these will be applied in demonstration projects.

Fig. 3: In the Nijrees project in Almelo three different PV integration systems are applied on private houses, by three developer/architect combinations . Goal of the project is to compare the systems on esthetics, price and building logistics. Systems used are the Shell Solar BOAL, the RBB PV 700 and the Econergy/Unilin integration system (Copyright Novem - Hans Pattist)

Besides technology the product logistics and more specific the market chain is very important for market development. Some of the above mentioned companies started investigating the market channels in 2000, like Ubbink, while others finished this.

Together with these developments a national standardization committee was established in the beginning of 2000, for the building specific aspects of solar energy systems (SDHW and PV) integrated in the building skin.

INDUSTRY STATUS

The Shell Solar plant in the Netherlands is running with a cell production capacity of 4,5 MW and a panel manufacturing capacity will be expanded to 15 MW in The Netherlands. In Germany Shell Solar will increase their cell production capacity to 25 MW per year the coming year.
In 2000, the number of pv inverter manufacturers increased to five (Mastervolt, NKF, Philips, Victron and De Drie Electronics), leading to availability of Dutch inverters in the range from 100 W to several kW's.
Eager to learn and establish new business contacts, 17 delegates of Dutch PV companies and organizations visited Japan and its PV industry and relevant projects during a one week tour.

DEMONSTRATION PROJECTS, IMPLEMENTATION AND MARKET DEVELOPMENT

The market for grid connected pv in the Netherlands is developing well.
After the realization of the 1,3 MW project in Nieuwland, Amersfoort in 1999 the focus in 2000 was pointed at the 5 MW project 'City of the Sun', world's largest PV housing project. The first part of 150 kW was finished and other sub contracts (for the total of 1 MW) were signed, including one contract for 130 kWp with a turnkey price of less than 5 Euro/Wp (excl. VAT) for fully roof integrated PV-systems. The goal is to realize the 5 MW by the year 2004, where PV is integrated in the town planning and architecture from the beginning of this new housing project.

Several attractive and innovative demonstration projects have been realized in 2000. Examples are a flat roof retrofit project of 175 kWp in Rotterdam, a fire station with semi transparent crystalline PV-modules beautifully integrated in the functional building design in Houten, and a retrofit project of sun shading elements in a facade of a building of the Research Institute ECN in Petten.
Furthermore the first PV power plant of 180 kWp was built in the province of Drente initiated by energy utility Essent.
Typical for 2000 is the progress in development of roof integration

techniques by the Dutch building Industry with companies like Unidek, Isover, RBB Lafarge, Laura Star Roof and others. A new generation of products evolves due to the need for quality assurance, new and large projects and the need to decrease BOS cost. In 2000 an extra publication was launched for subsidies for PV power plants (>0,5 MW). A condition is the multi functional use of the ground or building were the power plant will be build on. It is expected this extra subsidy round will lead to over 4 MW of new contracts.

Besides large systems the progress of large scale projects with small pv systems on private homes, like the Sunpower (with 4 modules) for project developers and the Solaris campaign (1-3 modules) for consumers, was running smoothly in 2000. More initiatives are started in 2000. A specific marketing project was launched for small businesses of medics who pay income taxes. For them special fiscal incentives make it possible to get back more than 90% of the investment cost.

For autonomous an extensive market research has been executed for the application on caravans and mobile homes.

Concerning the dissemination of information the PV Info database on the internet is worthwhile mentioning, with an extensive overview of details and photo's of almost all demonstration projects realized in The Netherlands.

FUTURE OUTLOOK

In 2000 the first PV Covenant ended successfully with the realization of over 9 MW grid connected PV systems in the past years, even more than the target of 7,7 MWp. Based on this success a new covenant with a much higher level of ambition and a focus on market introduction and development is under preparation. A extensive market study "The PV market after 2000", focussing on market segmentation and a scenario study called "PV on the map" showed there are possibilities to realize 250 MW cumulative installed power by 2007. This target will be the basis for the new Covenant. The aim is to sign this agreement with the Ministry of Economic Affairs and over 35 companies (energy utilities, project developers, installers, PV industry, building industry) and other involved organizations from demand and supply side of the market this year. The objective for BIPV with this PV covenant is to reach a self-sustaining market by 2007, with substantial lower prices and without the necessity of any more investment subsidies.
Part of this scheme are yearly decreasing fiscal investment contributions. Already in 2001 a substantial fiscal investment 'subsidy' of around 3,4 Euro (including VAT) has been introduced for housing associations and private households.
In 2001 more attention will be paid on training and education and on retrofit projects with large roof integrated pv systems.
Concerning inverters a focus will be the standardization and modular approach with prefab systems based on one inverter for several modules. Of course the focus on cost price decrease and quality of pv systems and components still remains, being an essential part of the Covenant.
With the subsidy scheme for PV Power plants and the continuation of the National Solar Program will create a sound base for an increasing PV market in The Netherlands.
The market for renewable energy will be liberalized already in 2001. With the energy utilities focussing on the sales of green energy with PV as a component, this will lead to interesting chances for the installation of new PV power plants.

NORWAY

PV TECHNOLOGY STATUS AND PROSPECTS

KNUT-ERIK MADSEN

GENERAL FRAMEWORK

The political and administrative authorities are discussing the introduction of new pollution taxes (e.g. climate gasses). This will however have an impact on fuel prices and energy consuming industry (metallurgy, paper etc) as well as on future domestic gas utilization. We do not foresee a direct influence on PV dissemination in the country.

The political willingness to encourage and promote research on new and friendly energy sources is unanimous. The public financial supports remains however modest, not increasing and limited to development of some basic materials.

NATIONAL PROGRAMME

There is one program with name NYTEK organized and financed by the Norwegian Research Council, stimulating research in the field of new renewable energy sources. Photovoltaic in this program is competing with bioenergy, wind, waves, hydrogen, thermal solar energy and others. During the period (1998-99) the NYTEK program has founded research in the field of solar grade silicon at a level of approximately 4 million Norwegian kroner (NOK) each year. The background for this research is the existence of a strong national metallurgical silicon industry and a new silicon wafer industry, both having strong competence and interest for such a program.

Annual budget 1998 or 1999 (in million Norwegian kroner NOK) for R&D, demonstration/field test programmes and market incentives.

	R & D	Demo/ Field test	Market
National in NOK (million)	4	0	0
State/regional	0	0	0
TOTAL	4	0	0

R&D, D

Funding of research & development (R&D) for PV has been kept at a fairly low level, primarily because of the limited number of researchers and companies involved in the area in Norway. However, due to recent industrial initiatives, this picture may be changed in the near future.

Two major competence programmes launched in 1998-1999 with the support of the Norwegian Research council and the industry

- 5 Ph.D and 1 post doc study at Agder College in the field of renewable energy incl. 2 on PV/solar grade silicon
- 5 Ph.D and several post doc at Trondheim Technical University. All on PV. Emphasis on silicon.

The programs mainly focus on the first steps of the value chain, feedstock and ingot production and are supported by the Norwegian Silicon and pv industry.

Elkem ASA, the world's largest producer of Silicon metal has significantly strengthened its focus on solar grade Silicon feedstock. Elkem has been active in this field in the past decade and is now significantly stepping up the R&D activities mainly centered in Kristiansand. Elkem is working on several projects with different partners with the aim of meeting the increasing demand for solar grade Silicon feedstock. Limited availability and increasing prices for solar feedstock is considered a major threat to the further growth of the pv industry.

There is only a limited manufacturing activity in PV in Norway. One production facility for multicrystalline silicon wafers is in operation since 1997. The current production capacity is approximately 6 MWp with a planned increase to more than 30 MWp over the next three years. There are also some plans to start production of silicon cells in the next period. With the planned expansion of production capacity, employment is also expected to increase significantly over the next 5 years. Furthermore, this increase in industrial activity is expected also to provide an increase in R&D funding and public funds for demonstration and field test programmes.

IMPLEMENTATION

Two new demonstration projects have been launched and both will be opened and operating from mid 2000. These are:

Energy Park at Dømmesmoen, Agder College

The purpose of the project is both education and research. One multicrystalline silicon line and one amorphous silicon triple junction cells line of each 10 kWp are feeding an electrolyser to generate hydrogen. The college is financed by the national budget on education and research. The project is also sponsored by the regional energy companies (AEV, KEV, VAE) and by the Norwegian

Table 1: The cumulative installed PV power in 4 sub-markets.

Sub-market/application	1992	1993	1994	1995	1996	1997	1998	1999
off-grid domestic	3 700	3 970	4 240	4 460	4 680	4 900	5 100	5 400
off-grid non-domestic	50	80	110	140	170	200	250	270
on-grid distributed								
on-grid centralised								
TOTAL	3 750	4 050	4 350	4 600	4 850	5 100	5 350	5 670

Water Resources and Energy Administration (NVE). The program is linked to the previously mentioned PhD and postdoc program at Agder College.

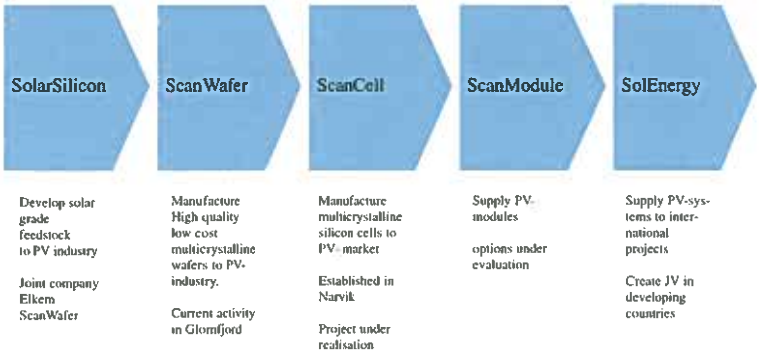
The Solar Wall at the Norwegian Technical University of Trondheim

The purpose is to study the esthetical integration of PV in existing large utility buildings. A new facade of 450 m^2, comprising 192 m^2 PV modules made of 102 m^2 multicrystalline silicon solar cells having a power capacity of 16 kWp is installed in a glass sandwich doubling the existing facade. The project is conducted by Prof. Anne-Grete Hestnes, professor in architecture at the Technical University of Trondheim and is funded by BP Amoco Norge AS with the participation of BP Solarex. The cost of the project including research, design, construction and complete realisation is approximately 5 million NOK. For more information consult the website:
http://www.sintef.no/units/civil/ark/ark/Norsk/Prosjekter/BPASolar_090500 .

INDUSTRY STATUS

There was no production of cells or modules in the period 1998-99 in Norway. In this period, however Norway has become a significant producer and supplier of multicrystalline silicon wafer for the world solar cells industry through the company ScanWafer AS. The technology applied is directional solidification of silicon followed by wafering by means of a multiwire sawing. Established in 1994 the company started to produce in 1997 and since then has been continuously increasing its output as combined results of internal improvement and capacity expansion. The nominal output capacity at the end of 1999 was corresponding to 6,3 MWp. All production is exported and purchased worldwide by cells and modules manufacturers. An emerging Norwegian PV industry is clustering around ScanWafer. The figure illustrates the companies in the value chain:

From Silicon feedstock to Solar Energy Systems



There are no producers of other PV components (PV inverters, storage batteries, battery charge controllers, DC switchgear, supporting structures) in Norway. Neither are inverters sold for on-grid applications.

MARKET DEVELOPMENT

The total cumulative installed PV power for each sub-market on the 31 December of each year from 1992 onwards is shown in Table 1.

FUTURE OUTLOOK

The most interesting trend in Norway for the development of PV is the emergence of a PV industry taking advantage of the national competence and resources.

The programs where Elkem are involved are adressing perhaps the most critical issue for the global PV industry, the emerging lack of sufficient volumes of feedstock for PV.
ScanWafer AS, the manufacturer of multicrystalline silicon wafer for the international PV industry, presently represents the emerging PV industry. This company is rapidly expanding anticipating the market's needs. There are also plan to start production of silicon solar cells in Norway.

PORTUGAL

PV TECHNOLOGY STATUS AND PROSPECTS

PEDRO SASSETTI PAES, EDP

GENERAL FRAMEWORK

Portugal has no fossil energy resources. The strong dependence on imports of oil and coal, which are the basis of the energy consumption structure, is much higher than the European Union average. On the other hand, Portugal is one of the EU countries which makes more use of its available renewable energy resources (mainly biomass and hydro power), as part of its energy mix.

The government energy policy has, therefore, the following objectives:

- to reduce energy dependence and develop endogenous resources;
- to reduce dependence on oil and coal and diversify sources and origins;
- to reduce the environmental effects of production/use of energy;
- to reduce the energy bill;
- to increase the efficiency of supply;

These goals are expected to be achieved through an energy policy based on:

- renewable energies
- rational use of energy and energy efficiency
- natural gas project
- restructuring and liberalization of the electric and oil sectors.

Nevertheless, the main priorities have been focused on the introduction of natural gas (aiming at the progressive substitution of oil in the energy balance) and the energy market liberalisation (by opening this former state-owned sector to competition and private investment).

NATIONAL PROGRAMME

No specific programme or targets for Renewables (PV in particular) have been formulated so far. The most relevant government's initiatives for promoting the use of RES and stimulating market development has been the ENERGIA programme (1994-1999) - partly supported by the European Union (EU) Framework Programmes - and the Independent Power Producers (IPP) law, introduced in 1988. So far, this particular legislation has mainly benefit mini-hydro schemes (up to 10 MVA) and wind farm developments, which are currently the most cost-effective applications of RES.

The IPP law, in particular, was introduced in 1988 and further revised (1995 and 1999), for consistency with the implementation of a new regulatory framework for the electricity sector. The IPP law allows for public or private entities or private individuals to generate electricity from any type of renewable energy source and sell it to the grid, provided certain technical conditions for interconnection are guaranteed. Tariff paid for renewable electricity is based on the avoided cost by the Public Electric System (investment in new power plants, transport and O&M costs) and on the environmental benefits of the use of RES ("green tariff" component, guaranteed for the first 12 years of the plant operation). For the most common applications, the tariff rate ranges from 5,5 to 6,5 cEuro/kWh, whatever type of RES. No net-metering or special technical specifications and buy-back rates for PV have been developed so far.

A broader national programme, the POE (Operational Programme for Economic Development), launched in 2000, includes, for the energy sector, incentive schemes on renewables, energy conservation and rational use of energy. Specific regulations will only be available in 2001.

Other indirect market development incentives for renewables consist in reduction of VAT rate from 17% to 5% on renewable equipment, custom duties exemption and income tax reductions.

RESEARCH, DEVELOPMENT AND DEMONSTRATION

The R&D activities in PV did not change significantly in 2000 compared to previous reported years (1994-1999). The total annual R&D expenditure lies in the range 0,7-1 MEUR, including financial support from the relevant EU funding programmes (5th R&D Framework Programme).

In the solar cell technology field, R&D carried out in Universities and National Laboratories mainly addresses amorphous and thin film crystalline silicon.

Applied research, demonstration and dissemination activities, involving Public Research Laboratories, Energy Agencies, Universities and utilities, are the most relevant PV activities. The applications concern mainly remote electrification and professional systems (TV and telephone repeaters, parking meters, water pumping), as well as some of the few grid-connected systems.

IMPLEMENTATION

The EDP Group, the largest Portuguese electric utility, partially privatised (~70% of its share capital) in 1997, 1998 and 2000, has been involved in several PV initiatives as part of its R&D activities on New Energy Technologies. These include participation in international networks (e.g., EURELECTRIC, EURE) or co-operation programmes (e.g., IEA PVPS) and in demonstration projects supported by the EU or ENERGIA, either in stand-alone, on-grid distributed or building integrated applications.

EDP has been involved in the following PV projects:

1 "Grid-connected PV/Inverter Units on Flat Roofs of Office Buildings and Hangars in Portugal and The Netherlands" (THERMIE, 1993-1996). The project resulted in the installation of Portugal's first grid-connected PV system (10 kWp), in one office building of EDP's distribution company (Setúbal) and has been in operation, successfully, since July 1994.

2 "Use of PV or hybrid systems for supplying electric power to small, isolated villages not connected to the national grid, as an alternative to its extension" - a feasibility study carried out by CCE (the Centre for Energy Conservation) and INETI (National Institute for Engineering and Industrial Technology) for assessing the potential market for PV in stand-alone applications.
3 "OURIQUE - Optimised Use of Rural Integrated Quality Electrification" (THERMIE + ENERGIA, 1996-2000), aiming at demonstrating the feasibility of supplying electricity from renewable energy sources to remote hamlets, on an equivalent grid quality basis. Three PV/Wind/Diesel centralised systems (totalling 42 kWp/55 kW/3x15 kVA) were realised, supplying electricity through low voltage distribution grids to 5 small villages (~120 inhabitants) located in the Ourique municipality (South of Portugal). The national partners included CCE, EDP and the local municipality.

Fig. 1: 5 kWp AC-Module PV System (EDP, Faro)

4 "AC-Module PV systems in Italy, Portugal and the Netherlands" (THERMIE, 1997-2000), aiming at demonstrating the use of ac-modules in buildings. A 5 kWp grid-connected system was installed and put in operation, in the early 1998, in one of EDP's distribution company office building (Faro).
5 Studies to provide electricity to remote locations in Portugal mainland, including small islands, are underway.

The most visible PV private initiative in the past two years has been the BP "Sunflower Project", leading to a significant increase in the share of grid interconnected systems to the total installed PV capacity. The Sunflower Project, started in 1998 with a pilot plant installed in the neighbourhood of the Lisbon Expo'98 site, consists in the integration of PV modules on BP gas station canopies. Fourteen grid-connected systems, with installed power ranging from 14 to 22 kWp per system, were realised in the period 1998-2000, representing a total capacity of about 250 kWp.

Fig. 2: BP "Sunflower" Project: 20,9 kWp grid-connected system (BP, Lisbon)

INDUSTRY STATUS

There are no PV cell/module manufacturers in Portugal. About 10 companies are supplying and installing PV modules and other system components imported from EU (BP, Shell, Siemens, Atersa), USA (Solarex) and Japan (Kyocera). The manufacturing capacity in the PV sector is limited to solar type or stationary battery manufacturers (SPAT, AUTOSIL) and some small power charge regulators and appliances.

MARKET DEVELOPMENT

The total installed PV capacity by the end of 2000 is about 1 000 kWp, of which 73% are stand-alone applications (52% in the domestic sector and 20% in the service sector). The BP "Sunflower" Project (canopy integrated PV systems in gas stations) was responsible for the significant increase in grid-connected applications, which represent currently about 26% of the overall PV capacity. The average annual growth in the period from 1995 to 2000 was 25%.

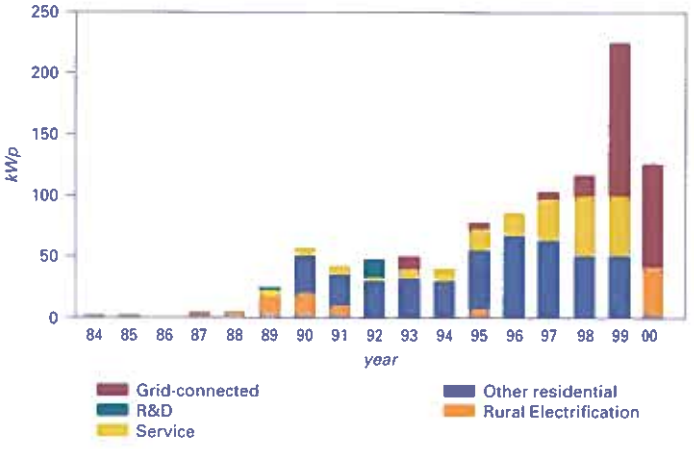


Fig. 3: Annual installed PV Capacity in Portugal.

Table 1: Installed power in Portugal (1984-2000)

Year	Rural Electrification	Other residential	Service	R&D	Grid-connected	Total
1984	0,6					0,6
1985	0,6					0,6
1986						0,0
1987	1,5					1,5
1988	1,5					1,5
1989	15,0		2,6	2,3		19,9
1990	22,2	28,8	4,5			55,4
1991	7,2	30,5	4,9			42,5
1992		30,5	1,8	15,0		47,2
1993		33,0	6,9		10,0	49,9
1994		31,4	8,4			39,9
1995	4,5	48,4	22,2		2,0	77,1
1996		65,9	22,6			88,5
1997		63,0	34,7		5,0	102,7
1998		50,0	50,0		20,9	120,9
1999		50,0	50,0		146,4	246,4
2000	42,0	n.a.	n.a.	n.a.	83,5	125,5
TOTAL	94,9	431,3	208,5	17,3	267,8	1019,9

FUTURE OUTLOOK

The EU strategy for the promotion of renewables in Europe and, in particular, the expected Directive on the Promotion of Electricity from Renewable Energy Sources in the Internal Electricity Market, will likely contribute to the definition of a national Renewable Energy Programme based on targets for each type of RES.

The indicative figures for Portugal targets for renewable electricity, expressed as a percentage of gross electricity consumption by 2010, are 21% without large hydro (~5% in 1997) and 45% with large hydro (38% in 1997).
Although this target will mainly be reached through wind and mini-hydro power, the opportunity exists for developing other applications, such as biomass, PV and wave energy.
However, as far as PV is concerned, critical barriers still need to be overcome in Portugal in order to allow a large scale market penetration: price, equipment certification, specific legislation for grid interconnected PV systems, eventual development of modules and inverters industry.

Fig. 4: Stand-alone hybrid PV/wind/diesel system (EDP, Ourique)

SPAIN

PV TECHNOLOGY STATUS AND PROSPECTS

JESÚS GARCÍA MARTIN & ALFONSO DE JULIÁN, IBERDROLA GENERACION
LUIS ALBERTO CALVO & ESTEFANIA REOLID, EXTERNAL COLLABORATORS

GENERAL FRAMEWORK

General framework that Renewable Energies present in Spain remains quite advantageous. The objective is to achieve a 12% (from 6% nowadays) renewable energies contribution to the energy national balance by year 2010, in line with the content of the European Union White Paper. This objective requires different measures, both at national and regional level, to be approved in order to promote the development of renewable energies.

Photovoltaic solar energy was, until recent years, one of the most unknown renewable energies. Nowadays photovoltaic energy has a very positive perception on the part of the society, thanks to the realization of singular projects, publicity campaigns, and a major presence in the media. On the other hand the solar resource in Spain is very important, so photovoltaic solar energy can help to reduce the dependence from fossil fuels and contribute to improve the environment by reducing polluting gases.

All these reasons, together with the legal obligation for the utilites of buying at an advantageous price the energy generated by photovoltaic systems connected to the grid, are promoting the advance of PV energy development. It can be shown in the amount of photovoltaic installations, mainly grid connected, which have experienced a very important growth in Spain during the last years.

NATIONAL PROGRAM

The Spanish Government has opted for renewable energies to make its contribution more important to the national energy balance. Spain's first step in promoting renewable energies was the development of the Renewable Energy Program 1991-2000, whose main objective was to increase the contribution of renewable energies to the national balance of energy. In the photovoltaic solar energy area, the objective was to increase the installed power of 2.5 MW during the Program. These figures have been easily exceeded and photovoltaic power has increased by 5 MW since the start of the Program.

In order to continue with this strategy, a new Plan for the promotion of renewable energies was approved by the Government at the end of 1999. The new Plan for the Promotion of Renewable Energy during the period 2000-2010, will serve to set a new pace for the development of these energy sources and consolidate Spanish policy on renewable energy, in line with the content of the European Union White Paper.

Fig. 1: "40 kW grid-connected PV plant in La Moncloa, Madrid"

Concerning photovoltaic solar energy the main measures and incentives included in the new Plan are:

- Public subsidies to R&D projects whose objectives are the improvement of PV technologies and the improvement of production, commercialisation and installation processes.
- Public subsidies to the installation of PV systems, both off-grid and grid connected systems.
- Establishment of a new regulation for the connection of PV systems to the grid.
- Tax benefits for PV installations.

The implementation of this Plan has presented a first important result during the year 2000: the approval of the Royal Decree 1663/2000 which establishes the technical conditions for the connection of photovoltaic systems to the low voltage grid. This is a very important step in order to get a major penetration of photovoltaic installations into energy system.

On the other hand, the Royal Decree 2818/1998 which establishes the incentives to photovoltaic solar energy injected to the grid has not modified their contribution during the year 2000, its value remaining at 0,4 euro for installations under 5 kW and 0,2 euro for installations larger than 5 kW.

R&D AND DEMONSTRATION

Cells

The main objective of manufacturers and research centers is to reduce costs and to increase the efficiency and the reliability of photovoltaic modules to promote the competitiveness of solar PV energy in Spain.

· **CIEMAT**

PV Modules Optimised for Building Integration - PV-MOBI

The project, co-ordinated by CIEMAT has the objective of developing new designs of PV modules for building integration applications based in the study of its optical, thermal and electrical generation characteristics. At present the final prototypes have been manufactured and are being tested.

Improvement of Photovoltaic Modules. Measure for Withstanding Electrical and Thermal Effects caused by reverse biasing of cells - IMOTHEE

The objective of IMOTHEE project is to improve the design of photovoltaic modules of different cell technologies with respect to the hot-spot safety measures for longer lifetimes and a greater system efficiency.

Study of the Degradation of PV Modules

Electrical and thermal characterisation of modules that apparently have suffered degradation. Infrared thermography techniques have been used to detect failures in PV solar modules.

· **IES (Institute of Solar Energy)**

Crystalline silicon

A dynamic model has been developed which clarified the impurity extraction process. Thank to this method, bifacial cells have been obtained with efficiencies of 17.7% (back face) and 15.2% (front face). These are the best values recorded in the world with this material.

Thin film

IES together with Ioffe Institute have developed solar cells of GaAs with an efficiency of 26.2% to 1000X and 25% to 2000X.

Photovoltaic concentrator

Design and performance of a solar concentrator (1300X). Using AsGa cells to 1000X, IES has achieved 20% of efficiency with this system.

· **ISOFOTON**

PV venetian store: PV module which combines bifacial and concentration cells.

PV MOBI: Big PV modules to integrate in buildings

INFLATCOM: Concentration modules (1000 X) with AsGa

HISICON: Concentration modules (200-500 X) with Si

Inverters

The main Spanish companies involved in the development of inverters for PV applications are ENERTRON and ATERSA. During this year, ENERTRON has developed inverters of 630 kW and 1 MW to work with high DC voltages. On the other hand, ATERSA has developed a digital control system for grid-connected inverters.

IMPLEMENTATION

1. "Grid connected PV plant in "Palacio de La Moncloa" - Madrid

A 40 kW grid connected PV plant has been installed in Madrid, in the gardens of the Palacio de la Moncloa, official residence of the Spanish President. This project consists of the PV integration in a special structure, where the President can receive his guests for receptions, press meetings and others uses. The technical objective of the project is to develop PV solutions adequate for the integration of PV in open areas. To achieve this goal, new modules were developed together by the three PV Spanish manufacturers with a new design based on both flat and curved surfaces. Four elements are important in this project: reliability and costs, aesthetics, technical quality and monitoring and energy.

The building integration concepts, support structure and civil works of the installation was carried out by IBERDROLA who also performed the grid-connection. Another collaborators of the project were IDAE, IES (ETSITM-UPM), CENTRO PARA LA CONSERVAÇAO DE LA ENERGÍA, ENERTRON, BP SOLAR, ISOFOTON and ATERSA. The project was supported by the EU.

2. Grid connection in the New Technologies Building

This year, ATERSA has performed the installation of a 17.28 kWp photovoltaic system connected to grid in the new technology building in Cádiz. The main goal of this project is the self supplying of some internal networks of the building and also the research and developement of this type of energy. To achieve this objective, there are an acquisition system and a monitoring system. The photovoltaic modules are located on the roof of the building as the following figure shows.

Fig. 2: "11.28 kW grid-connected PV plant in Cádiz

3. Photocampa

This project consists of 318 kW photovoltaic plant connected to grid in which the modules are integrated on parking-lot structures. This installation is located in Tarragona and covers an area of 5 000 m^2. Also, it is researching the possibility to use this PV installations to charge batteries of hybrid or electric cars. The partners of the project are ISOFOTON, SUNWATT FRANCE, BIOHAUS, ICAEN, Newcastle PV Aplications Centre, and BERGË Y CIA owner of the campa.

INDUSTRY STATUS

At present, there are 3 important manufacturers of photovoltaic cells and modules in Spain which are developing new technologies to improve the efficiency and cost. These manufacturers are ISOFOTON, ATERSA, BP-SOLAREX.

The technologies, which these manufacturers are developing, are mainly thin-film cells, concentration cells, and photovoltaic modules to integrate on roofs.

The production of modules and PV cells is represented in the following table:

Table 1: Modules manufacturers in Spain

Company	Cell Production (MWp)	Production Capacity (MWp)
Atersa/Astrasolar	2	3.8
BP Solar Espa(a	7	10.0
Isofoton	6	10.0

In the scope of power conditioning systems, Spanish manufacturers are developing new equipments, mainly connected to grid, with a wide range of power.

MARKET DEVELOPMENT

Nowadays development of the photovoltaic market in Spain is strongly tied to the existence of subsidy and promotions programs for this type of energy. The main measures to promotion photovoltaic solar energy can be summarized as follows.

- Renewable Energies Plan 2000-2010. This new Plan offers economic and regulatory measures to favour photovoltaic solar energy. Economic measures have not been defined in the new Plan yet but it is expected that new lines of public subsidies for photovoltaic installations will appear in a short period of time. According to regulatory measures the most important one is the new law which regulates the technical conditions of the connection of PV systems to the grid.

- Regional Plans for the Promotion of Renewable Energy. Besides the National Plan, several Spanish Autonomous Regions have developed specific programs to support renewable energies. Concerning photovoltaic solar energy, these programs subsidise PV installations, both off-grid and grid connected. The subsidy concerned is about 30-35% of the total installation cost.

- The Royal Decree 2818/1998 provides an advantageous power rate to kWh produced by photovoltaic solar facilities connected to grid. Utilities must buy photovoltaic electricity at 0,4 EUR/kWh for systems of less than 5 kW and at 0,2 EUR/kWh for systems of more than 5 kW.

This sort of measures, together with a major knowledege and acceptance of photovoltaic energy on the part of the public, have contributed to the constant growth of photovoltaic sector in recent years. This photovoltaic market growth is reflected in the increase of new companies devoted to engineering, comercialization and installation of photovoltaic systems.

In year 2000 the total PV power installed in Spain was about 10 MW. During that year power installed experimented an increase of 12% with regard to year 1999. The major power percentage corresponds to isolated systems although grid connected systems are the ones that are experiencing a bigger development.

FUTURE OUTLOOK

Isolated PV systems present a wide range of applications perfectly defined, so its market share is stabilized. Grid-connected PV systems are those that present the best growth opportunities due to the regulatory frame existing nowadays and it is foreseeable that this sort of systems will be predominant in a few years.

Whithin grid connected systems innovation will be the key to change the power busines. For this reason building integration offers one of the most promising ways for the development of photovoltaic market. Photovoltaics can be installed on a wide range of surfaces and can be integrated into materials such as glazing, opening up the possibility of combining energy production with other functions of the building envelope, such as roof and facade integration.

Because of continuing price decreases, some time in the near future, whether it's 5-6, or 10-12 years, the price of photovoltaic is going to be in the competitive range against retail electricity. At that point, customers are going to have the cost-effective option, and are going to exercice that option, of choosing photovoltaic solar energy.

Despite uncertainties of this time of transition as utility systems undergo restructuring and begin to face competition, now is the time to move forward with serious grid-connected PV commercialization and to develop and implement utility PV business strategies.

The successful, accelerated commercialization of the domestic, grid-connected PV market needs to be a collaborative effort of many participants. Utilities, local agencies and different companies involved in this subject must join together.

Manufacturers need to invest now in this market development and in new production, to create a profitable market for the future.

This report has been produced with the collaboration of BP-SOLAREX, ENERTRON, ATERSA, ISOFOTON, IES, CIEMAT.

SWEDEN

PV TECHNOLOGY STATUS AND PROSPECTS
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GENERAL FRAMEWORK

The Swedish National Energy Administration 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 the Association of Swedish power producers, the Swedish electricity suppliers and 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 off 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-of-grid sector, typically recreational applications like holiday cottages.

Today there are no market initiatives or regularly subsidies directly promoting PV in Sweden. However the National Energy Administration takes part in the discussion regarding the directive on the promotion of electricity from renewable sources in the internal electricity market within the EU and is also involved in developing a future system for promotion of renewable energy through green certificates. The government provides funding for cost-shared Research, Development & Demonstration projects as outlined below.

NATIONAL PROGRAMME

In 1996 a joint decision together with the Swedish Foundation for Strategic Environmental Research, MISTRA, was taken 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.

In the beginning of September 2000 the programme was evaluated with a very good outcome both regarding the scientific level and the industrial relevance. The scientific platform and activities were judged excellent and at the international research frontier. For example, the Thin Film Solar Cells activities have led to a new world efficiency record for a module.

In November 2000, based on the results from the evaluations and a revised programme plan, the Swedish National Energy Administration and MISTRA decided to support Ångström Solar Center, phase II, until the end of year 2004 with a total financing of 80 000 000 SEK, approximately USD 8 million.

Grid connected 7,3 kWp wall mounted thin film system, Gothenburg Energy Ltd. Office building in Gothenburg, Sweden (Photo: Gothenburg Energy Ltd., 2000)

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

Furthermore the Swedish national co-financed programme on PV systems and applications, managed by Elforsk, has been launched for a new three-year period (2000-2002). It primarily involves the energy and building industry. Architects represent new partners.

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 realisation. The other projects should move along the same line. The Smart Windows project is currently ahead of the Nanostructured Solar Cells project in this respect, but the latter has interesting potential for niche applications.

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. Recently, 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. Performance and cost goals shall be achieved by utilising processes and materials that minimize the impact on the environment. The aim is that the CIGS technology should be brought to a state where performance and manufacturability make it ready for large-scale commercialisation.

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.

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 energy source as well as a building component, identify possible applications of PV and rise 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 the IEA-PVPS Programme.

The programme is in progress to establish a rational evaluation process for Swedish PV installations through:

- Evaluation of procurement, installation and start ups
- Establishing a well-defined evaluation and monitoring process for existing and future grid connected PV-installations
- Verifying long term stability

Effort concerning niche applications is focused on cathodic corrosion protection of power pylons. Previous results indicate that it could be a cost-effective application. The potential market is large and not limited to Sweden and further steps to realise applicable system configurations are undertaken.

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. Recent program activities includes conceptual studies of criteria for building permission for integration in existing buildings, development of tools for physical planning concerning design and structure of the built environment and information and education concerning BIPV.

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 demonstrations such as Älmhult (IKEA), Gothenburg, Kristianstad and The Nordic Ark. In the near future we are to see further developed demonstrations of PV in buildings. One example is the result

Sickla kaj by NCC AB (Architect: White Arkitekter). Winning contribution to the environmental competition announced by the City of Stockholm. NCC ABs will install a total of 420 square meters of PV in their Hammarby Sjöstad projects (Picture: White Arkitekter, 2000).

Installation of PV-module for cathodic corrosin protection of power pylons. There are approximately 50 000 pylons of this type in Sweden (Photo: Märit Forssander, The Swedish Corrosion Institute 1998).

of an environmental competition concerning Hammarby Sjöstad, Stockholm's largest residential building project. The winning contribution (see figure), will be realised.

As PV is a promising energy source for the future, schools are a good base for implementing the technology. EU/Alterner has approved a Nordic PV School Programme. It will hopefully lead to several grid-connected PV systems on Swedish schools. The installations, together with the linking of schools in several EU countries, introduce the students to PV technology and will be a good complement to the current Swedish PV system programme.

IMPLEMENTAION

In Sweden, there are no general subsides for PV, contrary to other renewable energy sources like solar thermal, wind and biomass. The Swedish policies, which indirectly could promote the use of PV power systems, are taxes and fees related to energy production and environmental protection. The current levels of these taxes and fees, at current PV system prices, are however too low to have an impact on the PV market in Sweden. 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, poor economy for PV projects and consequently low interest from private investors are high barriers.

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 two companies, Gällivare Photovoltaic (GPV) and Fortum Advanced Energy System Sweden AB (Fortum AES).

GPV - Gällivare Photovoltaic is the only producer of photovoltaic modules in Sweden. The company is situated in Gällivare, north of the Arctic Circle in Lappland and is owned by The SolarWorld AG (70%), BP Solarex (25%) and the GPV management (5%)

The company purchases solar cells, both monocrystalline and multicrystalline cells, on the world market and produces modules. The process steps include cell testing, soldering, lamination, attachment of junction box, framing and module testing. GPV offers a wide range of products of standard modules in sizes from 40 to 160 Watts. The company can also manufacture customer-designed modules and laminates for building integration and other special applications.

Fortum AES is designing, marketing and selling products and systems based on PV modules. System controllers and the majority of solar modules are of own design. Fortum AES 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 main volume of the Swedish PV market is the domestic-of-grid sector. The total installed power during 1999 was 214 kWp, which is slightly less than in 1997 and 1998. One grid-connected system was installed during 1999, a 10,1 kWp. By the end of 1999 the total cumulative installed capacity in Sweden was about 2,6 MWp

The main part of the system components is imported and the dominant fraction, around 90%, of the Swedish module production is exported. The module production is approximately 1 MWp /year (50 % monocrystalline and 50 % multicrystalline).

FUTURE OUTLOOK

The high quality research and development that is carried out at Ångström Solar Center will continue another 4 years.

The ÅSC programme is highly relevant for the Swedish National Energy Administration 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 to see new initiatives bringing PV closer to a commercial 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 other factors 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

BY STEFAN NOWAK, NET NOWAK ENERGY & TECHNOLOGY LTD.,
ON BEHALF OF THE SWISS FEDERAL OFFICE OF ENERGY (SFOE)

GENERAL FRAMEWORK

The year 2000 was a special year for energy matters in Switzerland as the most important decision since 10 years regarding the future energy policy was to be taken in a public referendum in September, following many years of a strong political debate. Expectations for a stronger role of renewable energies and energy efficiency were very high due to expected longer term promotion, based on the introduction of an ecological tax reform on the one hand and an intermediate energy levy on non-renewable energies on the other hand. Although these energy levies were adopted by both chambers of the Swiss Parliament, the political system in Switzerland also requires an adoption by the citizens in a public referendum.

To the strong deception of the interested parties, the result of the public referendum went against all proposed changes. In the short term, there will therefore be no stronger promotion of renewable energy and energy efficiency as originally planned. On the other hand, the goals set in the Kyoto protocol are still valid and may require the introduction of a CO2 tax in the next few years unless the necessary progress is achieved regarding climate change issues.

In spite of the general deception about these negative decisions amongst interested parties, some positive aspects can be discerned: The support for a stronger promotion of renewable energies and energy efficiency was nevertheless by 46% of the population which is a strong minority. Moreover, a detailed analysis of the referendum results shows that many of the urban areas were favourable towards the proposed changes, indicating the sensitivity in these areas suffering more strongly from air pollution and traffic consequences.

This does not change the fact that the promotion of renewable energies will be limited in the years to come, as far as market introduction is concerned. RTD activities are not subject of the discussion and will continue, including the international cooperation within IEA programmes. Support for renewable energies will be based on more regional initiatives in general and on utility involvement for photovoltaics. In the legal framework, the new law on the electricity market will establish full liberalisation for small scale renewable energy. As from 2001, a follow-up of the National Action Programme Energy 2000, EnergieSchweiz – SuisseEnergie – SvizzeraEnergia - SwissEnergy has been launched and will continue the efforts for a sustainable energy supply by promoting energy efficiency and the use of renewable energies in a market oriented approach. As one of the short-term contributions, electricity from renewable energy will be marketed using recently developed, labels (naturemade basic® and naturemade star®) for certification.

PV roof integration in a low energy house with SOLRIF(Solar Roof Integration Frame), 12 kWp, Enecolo

NATIONAL PROGRAMME

The missing short-term support of broad-based incentives for the market introduction of photovoltaics does not imply a strategy away from the market, on the contrary. The Swiss National PV Programme will subsequently continue and even increase the focus on advanced but market oriented technology concepts in all parts of the photovoltaic energy system. Strong industry involvement for a rapid technology transfer remains a strategic issue. Building integration of photovoltaics will be the main application area but activities in other niche markets will be enhanced in order to favour industrial activities. Enhancement of international co-operation and quality assurance measures will follow a continuous, market oriented approach. As established successfully during the last years, a very broad range of stakeholders will be involved in the further technology development and implementation of photovoltaics in order to ultimately form a robust, market-driven energy technology. The recent field of activity on technology co-operation, triggered by the participation in IEA PVPS Task 9, will be further explored to establish more substantial contributions in this area.

RESEARCH, DEVELOPMENT AND DEMONSTRATION

With a focus towards the development of new solutions, products and applications, the Swiss Photovoltaic RTD Programme emphasises cost-reduction, efficiency and industrial compatibility in a system-oriented approach. With more than 80 active projects in R,D&D, all major elements of the photovoltaic (PV) energy system are being investigated: Solar cells covering a large variety of materials, modules and building integration, system technology and quality assurance, combined use with other energy technologies as well as accompanying measures for efficient planning and control. A number of innovative solar cell concepts, derived from advanced semiconductor physics and photoelectrochemistry, have been proposed in the last years. There is a strong focus on thin film silicon materials and their combinations, such as the "micromorph" concept. While terrestrial energy applications are the primary aim of these investigations, small scale appliances and, more recently, space applications using thin film solar cells on polymer substrates have received increased attention. Industrial involvement in the solar cell technology area is increasingly being addressed leading to first industrial production facilities to be expected in a near future.

New solutions for building integrated photovoltaics are being developed with the aim of better integration concepts for a variety of situations (flat and sloped roofs, facades, other building elements and noise barriers). This constitutes the primary application sector targeted and a number of successful products and systems have been developed in the last years. Due to the increasing number of installed PV systems in the last 10 years in Switzerland, system technology has matured towards a range of industrial products for inverters, electrical connections products and planning tools. Practical experience from realised projects is collected, carefully analysed and used to further improve the products and solutions. Further technological development in the area of building integrated PV is expected from the introduction of thin-film technologies.

PV roofs in the old town of Interlaken, semi-transparent modules, 6 kWp, Fabrisolar

International co-operation through the programmes of the EU and the IEA is sought in all these sectors and has been successfully established. As the programme follows an application and system-oriented approach, a strong co-operation involving all stakeholders exists between the research community, the industry, the public sector and the utilities.

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 2000, more than 100 utilities (1996: 7) provided solar electricity to their customers. Different financial models are being implemented according to the preferences of the utilities. More than 3 Mio customers meanwhile have access to solar electricity and more than 21 000 customers annually subscribe to about 3,5 GWh of this new energy service. Through the past 4 years, this concept has enabled about 4 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 identified also by the utilities in introducing new customer relationships. A marketing study revealed that there remains an untapped potential for this action to further contribute to the deployment of PV systems.

INDUSTRY STATUS

Swiss industrial PV products used to cover mainly components for grid-connected building integrated systems where inverters, components for electrical connection, mounting systems for building integration and custom designed PV modules form the major products. 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 last years, assembled PV modules based on crystalline silicon technology were introduced into the market to form aesthetically attractive products for building integration, in particular regarding roofing shingles.

More recently, industrial activities have started in the field of process equipment and small scale products based on thin-film technology. This development reflects the existing technological

Table 1: Swiss photovoltaic energy statistics from 1989 – 1999 (grid-connected systems)

Year	Number of systems	Installed Capacity [MWp DC]	Energy Production [MWh]	Specific Energy-Production [kWh / kWp]
1989	60	0,3		
1990	170	0,8	400	
1991	380	1,8	1 100	
1992	490	3,1	1 800	800
1993	600	4,0	3 000	810
1994	680	4,8	3 500	800
1995	740	5,4	4 000	815
1996	820	6,2	4 700	825
1997	950	7,4	6 000	880
1998	1 100	9,1	7 100	858
1999	1 220	10,9	7 700	770

know-how within the research community, combined with an increasing awareness of new market opportunities by the industry. In the future, this could evolve towards integrated PV products for building integration based on thin-film technology. Solar cells "made in Switzerland", a long expected evolution, are about to become a reality.
Besides this increased interest from the manufacturing industry,

PV façade on a school building in Zurich, insulating glass modules, 11,5 kWp, TNC (façade view)

the finance sector is currently developing new products oriented towards renewable energy. Increased investments have occurred in the renewable energy sector, including photovoltaics, and new, dedicated funds have been established by important finance organisations. This trend clearly demonstrates the growing perception of the renewable energy sector as a field of increasing business opportunities.

MARKET DEVELOPMENT

Thanks to the campaign "solar electricity from the utility" and together with the support from the federal government subsidy programme (including pilot & demonstration systems), the annual market volume for grid-connected systems was about 1,6 MWp. The total installed capacity thus rises to 15 MWp or more than 2 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 increased focus on industrial developments, new products for niche markets and ongoing international involvement. For solar cells and modules, the next generation of thin film technologies are about to enter into the market, including some products from Switzerland. Efforts in the technology development will concentrate on market oriented approaches and continuous quality assurance.
PV market implementation will be limited to indirect promotion measures within the federal energy programme, the activities of regional authorities and the initiatives by the utilities. These activities nevertheless form interesting opportunities which will however lead to stronger regional differences than in the past. With the new law on the electricity market and the introduced labels for ecological electricity products, new opportunities for renewable energy technologies are expected due to increased product differentiation and free trade of these products. Further support is sought within the structure of the feed-in tariffs for renewable energies.

UNITED KINGDOM

PV TECHNOLOGY STATUS AND PROSPECTS

RAY EATON, DEPARTMENT OF TRADE AND INDUSTRY, UNITED KINGDOM

GENERAL FRAMEWORK

Renewable sources of energy are an essential ingredient of the Government's climate change programme and are set to make an increasingly important contribution to the provision of secure, diverse and sustainable energy supplies.

The Government intends to impose an Obligation on electricity suppliers ("The Renewables Obligation") which will require them to deliver a designated percentage of their supplies from electricity generated by specified sources of renewable energy or make a buyout payment. The primary legislation to allow this is the Utilities Act which received Parliamentary approval on 28 July 2000. The new Renewables Obligation will be imposed by Order, which will also require the approval of Parliament. The Renewables Obligation will enable the UK to make progress towards its target of generating 10% of its electricity from renewable energy sources by 2010.

In addition to the new Renewables Obligation the Government intends to provide support by means of capital grants for off-shore wind and energy crops. The contribution of these forms of renewable energy will be essential if the Government's target of 10% of electricity by 2010 is to be achieved. .

The Government is committed to expanding its supporting programme for renewables including research, development, demonstration and dissemination. For the UK, photovoltaics is regarded as a longer term technology, and as such will benefit from the RDD&D support programme. It is less likely that photovoltaics will benefit from the Renewables Obligation in the period to 2010 unless costs fall more rapidly than is currently anticipated. At the time of writing the possibility of a market support programme for PV is under review, but it is not possible to say what the outcome of that will be.

NATIONAL PROGRAMME

The main elements in the UK's programme on photovoltaics are the DTI RDD&D Programme, the EPSRC Programme and the "Foresight Initiative".

The existing DTI funded RDD&D Programme has continued in col-

PV Thermal Facade experimental programme at IT Power (Task 7).

laboration with industry. In addition to R&D projects normally recruited through a competitive call for proposals, a field trial of domestic PV systems is currently underway. This is intended to provide a learning opportunity for builders, electricity suppliers and the PV industry by installing PV on clusters of properties. DTI support totals £1.4 million for three years which will allow the installation of a total of 221 kWp on 166 dwellings. A total of 25 proposals were received of which 9 were judged to be of sufficiently high quality to justify support. The budget was increased from the £1 million originally announced to allow these projects (all but one of which is for new build) to be supported. Two year's monitoring is a key element of the trial.

It is intended to launch a similar trial for larger scale systems (>20 Wp) for commercial and industrial buildings later this year. The budget for that Programme, excluding the costs of the Scheme Management Contractor has been set at £3 million, and the project duration will be 5 years in order to allow sufficient time for construction and two year's monitoring following commissioning. This should allow 12-15 projects to be supported and it is intended that a call for proposals will be made in the late Spring (2001).

Testing portable PV lanterns at IT Power (Task 3 and 9).

The Engineering and Physical Sciences Research Council provides support for University based research including semiconductor R&D. The EPSRC is supporting a good number of PV R&D projects under its Renewable and New Energy Technologies Programme which is worth £3.5m per annum.

The SCOLAR Programme to install PV systems (0.5-0.7kWp) on schools and colleges throughout the UK is expected to result in the installation of 80 systems (original target 100). A number of the Consortium Members are preparing proposals for follow-up projects. SCOLAR was a consequence of the Office of Science and Technology Foresight exercise which identified photovoltaics as a priority technology.
A number of UK based companies carry out or sponsor development work on PV materials and systems, and there are several UK consultancy firms with PV expertise. UK workers are also involved in European Commission supported PV RDD&D programmes.

RESEARCH AND DEVELOPMENT

Industry is carrying out a large amount of R&D to commercialise new PV modules including crystalline silicon and thin film materials. Research work is also carried out into developing PV material fabrication technology and there are several companies involved in PV consulting work and systems design. Research and Development is also being undertaken on a range of new niche applications for PV. Examples of R&D projects on which the DTI programme is working collaboratively with industry include inverter development and BIPV products. The Programme and industry continue to work collaboratively with European partners through the EC framework programmes and an example of work recently completed relates to the dissipation of heat from BIPV.

UK University groups are involved in a wide range of PV materials and systems related research projects. These activities range from state-of- the-art research into new PV materials and cell structures through to improvements to PV system applications, such as water pumps and refrigeration units, and grid connection issues. The main PV R&D groups are located at the following universities: Northumbria, Durham, Imperial College, Southampton, Dundee, Cardiff, Reading, Loughborough, Ulster and the Open University.

UTILITY INTEGRATION PROJECTS

The DTI N&RE Programme has supported projects that are directed to the establishment of technical guidelines for the connection of PV to utility networks. There has been close collaboration between university groups, the electricity supply industry and the PV community that has produced draft guidelines suitable for single-phase PV systems up to 5 kVA. This document was published by the Electricity Association as a draft engineering recommendation (ERG77) that is expected be ratified after an 18 month period of field experience. New research work will complete outstanding technical issues of grid-connection, develop guidelines for domestic PV installations as well as a training syllabus for electricians. Two other studies will look at the effects of increasing levels of installed PV on the design and operation of UK utility networks contributing to the PVPS Task 5 sub-task 50 workplan that started in 1999.

The collection and analysis of performance data from PV buildings in the UK has also been a major priority within the programme. Monitoring is complete on the 100 kWp PV array integrated into rooflights on the Ford Motor Company Jaguar engine factory in Wales and a report on the performance will shortly be available. The performance of the ~70 kW PV system integrated into the Solar Office at Doxford has been monitored and recently reported (ETSU S/P2/00275/REP).

DEMONSTRATION SYSTEMS

There are an increasing number of examples of PV systems being used in the UK for a diversity of non-utility related applications. These include amongst others: telemetry systems, remote

telephone kiosks, navigational lights, parking meters, street lighting, and a wide range of consumer products.

A number of Design Studies for building integrated PV (BIPV) were commissioned under the DTI PV programme. These studies were carried out in parallel to designs of conventional (non-PV) buildings and allowed the real problems of designing BIPV to be tackled by expert multi-disciplinary teams but at a modest cost. In addition to the Design Studies, several real BIPV projects in the UK received DTI support for analysis of the design process in relation to the PV. The BIPV designs were produced by multi-disciplinary teams which included architects, electrical engineers, structural engineers, PV manufacturers and suppliers, quantity surveyors and other specialist consultants. In two of the four design studies the clients have been so impressed by the alternative PV designs that they are now seeking funding to include PV in the new buildings.

The experience of the Design Study teams and feedback from the designs of real BIPV buildings in the UK were discussed in a workshop hosted by Studio E Architects of London. The conclusions have been published in a compendium of UK BIPV projects (ETSU S/P2/00328/REP).

As part of BP's global project 'Plug in the Sun', 40 new BP service stations in the UK have each had an average of around 18 kWp of solar PV capacity installed. It is expected that all BP service stations in the UK will have thin film PV systems installed in the next few years as part of the worldwide rebranding. BP has also installed PV on its new offices at Sunbury, its refurbished Conference Centre in East London and on buildings at the Baglan Energy Park in Wales.

As well as PV module manufacturing, there are industrial interests in PV manufacturing equipment supply and BOS component supply. The main PV companies are BP SOLAREX (a result of the merger of BP and Amoco; it is now headquartered in the United States). BP Solar manufacture mono and polycrystalline modules, and thin film cadmium telluride and amorphous silicon, as well as a range of systems. BP Solar have established their World technology R&D centre in the UK with a particular focus on developments in crystalline technology. INTERSOLAR manufacture amorphous silicon modules and a wide range of professional and consumer product systems,. CRYSTALOX manufacture furnaces for silicon ingot manufacture and also produce polycrystalline ingot and blocks for the wafer market.. SOLAR CENTURY have installed systems on at least 12 domestic properties in the UK and on commercial buildings including those of Sainsbury and Orange. SIEMENS have installations in Hackney (residential) and on the Ballymena Eco Centre. A number of other companies also have interests in PV or act as agents for overseas manufacturers, and a number of companies are active consultants specialising in PV technologies.

INDUSTRY STATUS

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MARKET DEVELOPMENT INCENTIVES

As already noted, it is considered unlikely that photovoltaics will benefit from the new Renewables Obligation in the period up to 2010 mainly because the costs are too high.

UK PV Systems (kWp)

	Installed by end '99	Planned 2000 -2002
Stand alone industrial and residential	435	120
Grid connected BIPV	807	1 000
TOTAL	1 242	1 120

Note: these figures are best estimates and are subject to confirmation.

UNITED STATES

PV TECHNOLOGY STATUS AND PROSPECTS
WARD BOWER, SANDIA NATIONAL LABORATORIES,
ALBUQUERQUE, NEW MEXICO

GENERAL FRAMEWORK OF PHOTOVOLTAIC ACTIVITIES IN THE U.S.A.

The U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy directs the National PV Program through its Office of Solar Energy Technologies in the U.S.A. The U.S. Department of Energy was the leading funding source for PV research and development in 2000 and it offered the resources of the national laboratories to assist in the PV industry's applied research and development (R&D) activities. PV Program managers in the Office of Energy Efficiency and Renewable Energy, and in the national laboratories, 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 PV Program works with the PV industry through 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 2000. The U.S. Department of Energy web site (http://www.eren.doe.gov/pv/) provides information on and links to all aspects of the National PV Program. PV-related activities were balanced between PV cell and module development, manufacturing, system, and balance-of-system technologies.

PV-related manufacturers refined the "Industry Roadmap" in December 2000. The roadmap plan unifies the vision and long-term (2000-2020) strategies and goals for the PV industry. The vision provides the electrical/energy consumer competitive and environmentally friendly energy products and services from a thriving U.S.-based solar electric power industry. The National Photovoltaics Program Plan for 2000-2004 that was written in concert with the industry roadmap plan helps to guide the national program.

The National Center for Photovoltaics (NCPV), an alliance of organizations, serves as the focal point for the nation's capabilities in PV technologies and has proven to be an effective structure for planning and implementing the National PV Program. The National PV Program's R&D goals and strategies are formulated each year by its governing board in concert with the "Industry Roadmap" and through an all-encompassing annual operating plan.

PV technologies for both thin-film devices and crystalline devices continued partnership programs in 2000. The Thin-Film Partnership Program and the Crystalline Silicon Research Cooperative collaborated with manufacturers on technology issues that were common to all manufacturing processes and non-proprietary in nature to pool the nation's resources in order to maximize technology advancement. The U.S. Department of Energy also worked to reinforce the ongoing Million Solar Roofs Initiative with a goal to place one million PV and other solar energy systems on roofs by the year 2010.

The Visitors Center at Golden, CO hosts four Sunsine 300 AC PV Modules. Each AC module uses an Ascension Technology, Inc. micro-inverter attached to an ASE America large area PV module and is rated at 250 Wac. Photo courtesy of Holly Thomas (NREL).

THE NATIONAL PHOTOVOLTAICS (PV) PROGRAM

The National PV Program is managed by the U.S. Department of Energy with headquarters in Washington, DC, and by research centers at the National Renewable Energy Laboratory (NREL) and at Sandia National Laboratories (Sandia). The purpose of the U.S. Department of Energy PV Program was 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 was handled through printed reports, web sites, and conferences. The National PV Program shared the costs of pilot projects and applied research. The program's authorized funding was categorized into three areas for 2000.

Research and Development	52% of budget
Systems Engineering and Applications	24% of budget
Technology Development	24% of budget

The total FY2000 federal budget for the National PV Program was authorized at $60.5 million dollars. Additional support for PV-related projects came from state and local governments, the PV industry, and utilities. Total industry cost share for contracts in the U.S. Department of Energy National PV Program was expected to be more than 32.5% of the total budget while some elements of the program saw greater than 50% cost share.

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), and U.S. Department of Energy's Centers of Excellence in PV at the Georgia Institute of Technology and the University of Delaware (Institute of Energy Conversion). In addition, more than 180 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 around the country.

RESEARCH AND DEVELOPMENT

The national PV R&D effort included fundamental, advanced materials, device, and manufacturing R&D. Critical PV program contributions by the program 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.

Thin-film devices and materials development continued through the NCPV and 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 helps to commercialize this promising technology. Among this year's achievements were efficiency records, gains in cell and module processing techniques, and new commercial production facilities. Responding to sustained research efforts, the efficiency of thin-film devices is steadily rising. In 2000, commercially available amorphous silicon (a-Si) modules showed stable efficiencies that were more than 7.2%; cadmium telluride (CdTe) modules that were rated 10.6% efficient; and CIS-based modules that were rated at more than 10% efficient.

Research on amorphous silicon (a-Si)

Research has moved efficiencies of a-Si devices toward the national goal of 13% efficiency and methods for increasing the deposition rate of a-Si were successful. Research produced a record low-defect-density deposition rate as high as 83 angstroms per second. The method used for the high deposition rate was hot-wire chemical deposition.

The U.S. industrial capacity expanded to meet worldwide demand for a-Si products. United Solar Systems began construction of a new 25 MW manufacturing line in 2000. BP Solar now operates its 10-MW/year plant with enhanced throughput that produces tandem-junction, a-Si alloy modules in the 43 to 50-W range with glass-to-glass encapsulation.

Research on cadmium telluride (CdTe)

PV devices using CdTe can be manufactured using potentially low-cost techniques such as spraying, electrodeposition, and high-rate evaporation. Achieving high laboratory efficiencies using these low-cost techniques is an important objective of the National PV Program. To date, more than ten techniques have been used to grow CdTe layers resulting in cells operating at greater than 10%. Three of these methods are currently used in industry. BP Solar began production of a CdTe module with verified world-record aperture area efficiency of 10.6% and power output of 91.5 W. The changes in performance were the result of changes in the electro-deposition bath and a reduction in the thickness of the CdS film. The results also further the National PV Program 5-Year Plan milestone for a 10% CdTe-based module by 2004. First Solar, LLC has advanced its ultra-high-rate vapor transport deposition through collaboration with the National PV Program. First Solar now produces CdTe plates at the rate of 8 plates per minute in its new 100 MW per year plant.

Commercial production of CdTe products progressed in 2000 as BP Solar, a participant in the Thin Film PV Partnership, fabricated modules made of thin-film CdTe material in its plant which was designed to produce up to 7 MW of CdTe modules per year.

Research on Copper Indium Diselenide (CIS) and Copper-Indium-Gallium-Selenide (CIGS)

Two major goals for CIS research are to transfer years of government-sponsored research on the technology to industry for pilot-scale manufacturing and to produce commercial modules with 10% efficiency. NREL scientists achieved replicable CIGS cells with efficiencies between 18.1 and 18.8% using a special plasma vapor depo

PV Powers This Monastery of Christ in the Desert Where 15 Computers Provide Web Site Designs Worldwide. (Photo Courtesy of Siemens Solar Industries)

sition technique to sputter molybdenum onto the substrate used for CIGS deposition. Industry explored new deposition systems for large-area CIS devices. Co-evaporation of CdS/Cu(In,Ga)Se2 at the Institute of Energy Conversion produced solar cells with 14.9% efficiency. Two companies are now planning to use co-evaporation processes to produce CIS modules.

Commercial products, using CIS alloys, were sold by Siemens Solar Industries (SSI) and by Global Solar in 2000. SSI produced 5- to 40-W PV modules made of CIS alloys that were more than 10% efficient. Global Solar produced flexible modules for a variety of field applications. SSI developed the new products using copper-indium-gallium-sulfur-selenide (CIGSS) under contract to the Thin-film PV Partnership Program. Global Solar developed increased throughput of its CIGS modules via new high-speed scribing, integrated ink-jet hardware and high CIGS deposition rates.

Research on crystalline silicon (c-Si) PV

Because more than 90% of PV power systems sold today are made of crystalline silicon (c-Si), improvements to this technology have the potential for quick advancement to the marketplace. Fundamental research for scientific advances through the Crystalline Silicon Research Cooperative and other programs in crystalline silicon technologies continued in 2000. The program sponsored the 10th Workshop on Crystalline Silicon Materials and Processes to effectively communicate research results. In light of industry interest, a Cooperative Research and Development Agreement was established in 2000 to develop new direct-writing approaches to contact metalizations. The industry has set high priorities to the understanding ofhydrogen passivation of impurities and defects to better control processes for high-efficiency c-Si modules. Researchers at Sandia continue to investigate plasma texturization of multi-crystalline cells.

Research and Development of the Balance-of-System

Research within the industry and the national laboratories has explored improved solid-state switching methodologies for inverters, new balance-of-system hardware designs, and entire PV systems that are cost effective. Some significant improvements in balance-of-system components developed in 2000 included new utility-interactive, stand-alone and micro-inverters that are listed for safety and code compliant for installation. Other inverter improvements include higher efficiency, reduced operating losses, lowered cost, improved quality control, and smaller size. 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 PV Program.

Research on High Performance and Concentrating PV

The National PV Program plan 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 begun in 2000. The NCPV and Spectrolab are collaborating toward a goal of a 40% cell under concentrated sunlight. ENTECH Corporation produced a 28% efficient mini-module using a triple-junction, high-performance solar cell. Work continues on several fronts to develop materials that will perform well at very high concentrations of sunlight.

MANUFACTURING AND IMPLEMENTATION

ndustry Roadmap

Success of the National PV 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 National PV Program worked in concert with the industry to finalize the draft of an "Industry Roadmap" to support work that focused on the roadmap's vision and strategies to provide competitive PV products and services.

Photovoltaic Manufacturing

A major goal of the PV manufacturing project has been to help the U.S. PV industry improve manufacturing processes and equipment; accelerate manufacturing cost reductions for modules, balance-of-system components, and integrated systems; and enhance the investment opportunities for substantial scale-ups of U.S.-based manufacturing capacities. The PVMaT program transitioned existing and prototype production into advanced and improved manufacturing technology and processing for the industry through R&D. PVMaT was a major undertaking for the PV industry as well as for the U.S. Department of Energy. Approximately $90M in contract money has been invested through 2000 where the industry provided another $70M (more than 43.3% of the total) as cost share. PVMaT began with a problem identification phase. It then progressed to improvement of processes, reduction of costs, and improvement of performance of PV modules. Solving generic manufacturing problems was a specialized effort. PVMaT then addressed areas of R&D related to cost-effective PV end-products, including module manufacturing, flexible manufacturing approaches, system integration, and balance-of-system. The latest partnerships in PVMaT include 14 cost-shared contracts placed with industrial partners in 1998. They were two- and three-year contracts for PV system and component technology and PV module manufacturing technology and some continued into 2000. New manufacturing facilities, production lines, and processes will take advantage of the improvements resulting from the PVMaT cost-shared work. Manufacturing and performance of systems and components were also advanced with PVMaT.

A new solicitation for letters of interest in performing PV manufacturing R&D was released in August 2000. The solicitation was entitled "PV Manufacturing R&D – In-line Diagnostics and Intelligent Processing in Scale-up Manufacturing." It solicited interest from individual or teamed U.S. PV and related industries in addressing topics related to manufacturing PV modules, components and systems. The primary focus is to address approaches for intelligent processing and larger-scale manufacturing as identified in the PV Industry Roadmap. The solicitation is intended to be a first step toward more accelerated growth in the capability of the U.S. industry to produce cost-effective products.

Systems Research and Development

A systems engineering program that included a balance-of-system program continued this year with Sandia leading efforts to fund evolutionary changes to power processing hardware resulting in improved reliability and performance. The reliability of switchgear, ground-fault detection and interruption equipment, and component safety certification programs were also funded. Sandia continued working with industry in 2000 to improve "Total Quality

Management" programs in the manufacturing and assembly areas. Sandia also assisted industry in "Highly Accelerated Life Tests (HALT™)" and "Highly Accelerated Stress Screens (HASS™)" to improve quality and reliability of hardware. The U.S. Department of Energy's PV Program test facilities at Sandia and NREL continue to contribute significantly to all of the programs.

MARKET DEVELOPMENT

The Utility PhotoVoltaic Group (UPVG) reorganized in 2000 and is now the Solar Electric Power Association whose membership is more than 160 electric service providers, utilities and related organizations from eight countries. The UPVG Technology Experience to Accelerate Markets in Utility Photovoltaics (TEAM-UP) program included grid-connected and small-scale grid-independent applications of PV energy. TEAM-UP now has a total of 36 ventures with more than 140 partners in 40 states and connected to 80 different distribution grids. They have installed a total of 7.2 MW generating capacity. The performance data on some of these installations are available on their web site at http://www.ttcorp.com/upvg.

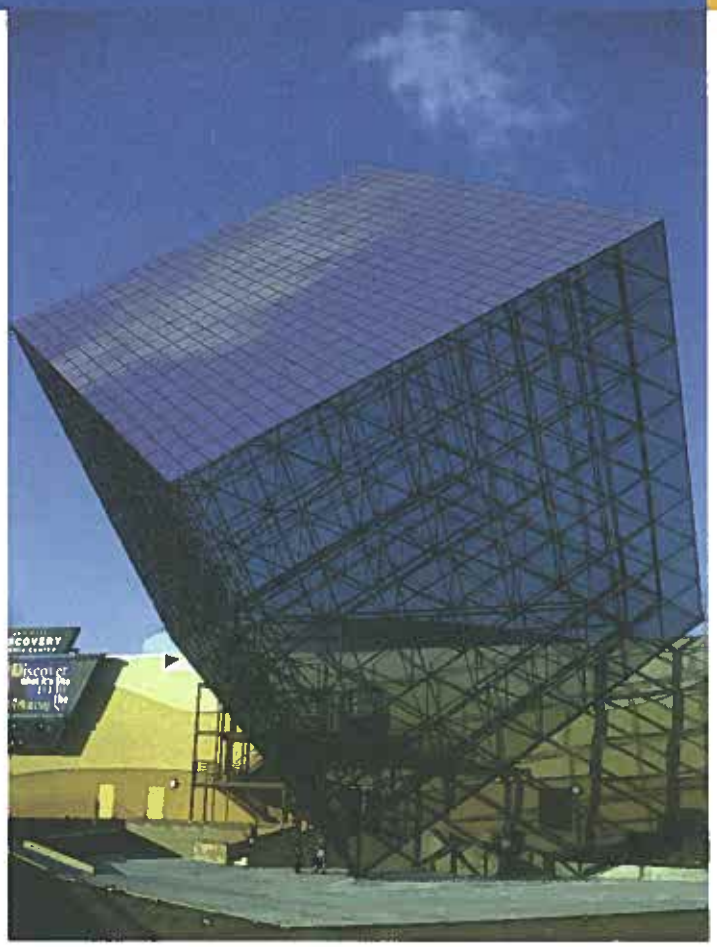
The National PV Program provided continuing support for state-supported PV applications using assistance through the Interstate Renewable Energy Council. Much of this work provided PV applications and education for parks and public spaces through the Photovoltaics for Utilities (PV4U) program. This approach to removing barriers to PV for utilities is a network of 15 state working groups that promote PV. For example, the PV4U consumer project works to educate and assist state-appointed consumer representatives about PV issues. Installation, metering, and utility interconnection of small-scale PV systems remains a high priority for this group.

Successful advances from the PV Building Opportunities in the U.S. (PV:BONUS) program to assist U.S. industry in exploring the potential market for building-integrated PV were used in 2000. PV on buildings or integrated into buildings to replace windows, skylights and walls, while generating electricity, were installed in 2000.

No major national demonstration programs were active during 2000. Study programs were sponsored by various sectors of the PV program, state governments and utilities, but most of those programs were implemented because the target PV system was cost effective or because the sponsor was developing PV applications or training programs. Deregulation of the electric utilities has spurred several state programs that require installation of PV energy systems.

ELECTRICAL AND PERSONNEL SAFETY THROUGH CODES AND STANDARDS

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 PV 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 34 changes in Article 690 of the NEC for the upcoming 2002 National Electrical Code and most of those proposed changes have now been approved.



This Discover Science Center Cube located in Santa Ana, CA towers 12 stories high. The PV System consists of Solarex Millennia PV modules rated at 20kWdc. The utility-interactive system was designed, engineered, installed and commissioned by Solar Design Associates. Photo courtesy of Steve Strong (SDA)

The IEEE Standards Coordinating Committee (SCC21) made excellent progress in publishing a utility interconnect guideline for PV systems. The new IEEE929-2000 standard was published in January. NREL headed up the IEEE PV standards activities and also actively participated in theInternational Electrotechnical Commission activities for PV-related international standards. Underwriters Laboratories finalized 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. Coordination with the NEC and IEEE interconnect guidelines was essential for finalizing the UL1741 standard.

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/IEC1215 or IEEE1262/IEC1646 qualification standards since the work began in 1996. Additionally, the PTL has tested many module types to the UL1703 PV module standard to determine their suitability for listing and now has a reciprocity arrangement with European testing organizations.

MARKET DEVELOPMENT INCENTIVES

International work included the Mexico Renewable Energy Program that was sponsored by the U.S. Agency for International Development (USAID) and supported by the U.S. Department of Energy to institutionalize the use of renewable energy technologies. This program has 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. This program has led to loans by the World Bank and Global Environmental Facility that has contributed to a $31 M renewable energy for agriculture program. Other National PV Program pilot projects and cooperative programs are underway in Africa, China, India, and Russia. Additional work through Winrock International, NREL, Sandia, and non-governmental agencies provides collaborative PV efforts in other countries such as Brazil, China, Central America, Ghana, Indonesia, Kenya, Philippines, the Dominican Republic, Russia, South Africa, and Venezuela.

First Solar-powered BP Gas Station in the US in Downtown Atlanta.

FUTURE OUTLOOK

The U.S. Department of Energy, in partnership with its national laboratories will continue with a strong National PV Program well into the next century. The "Industry Roadmap" and a the National PV Program 5-year Plan will guide the work. 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, and hardware certification will remain vital elements in the program.

The Million Solar Roofs Initiative promotes the use of solar thermal and PV to reduce the energy demands of buildings. It enables businesses and communities to install solar systems on one million rooftops across the United States by 2010. The U.S. Department of Energy 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. In 2000, the Department of Energy had fifty partners that had made commitments for one million solar roofs by the year 2010. The Florida Energy Office, the Florida Department of Community Affairs and the U.S. Department of Energy through Sandia, the PV industry, the Florida Solar Energy Center and nine end-user groups have committed to contributing 20 000 of the nations million solar roofs. Photovoltaic systems installed in 2000 included 750 different systems amounting to approximately 3 MW peak rating.

ANNEX A

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COLOPHON

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