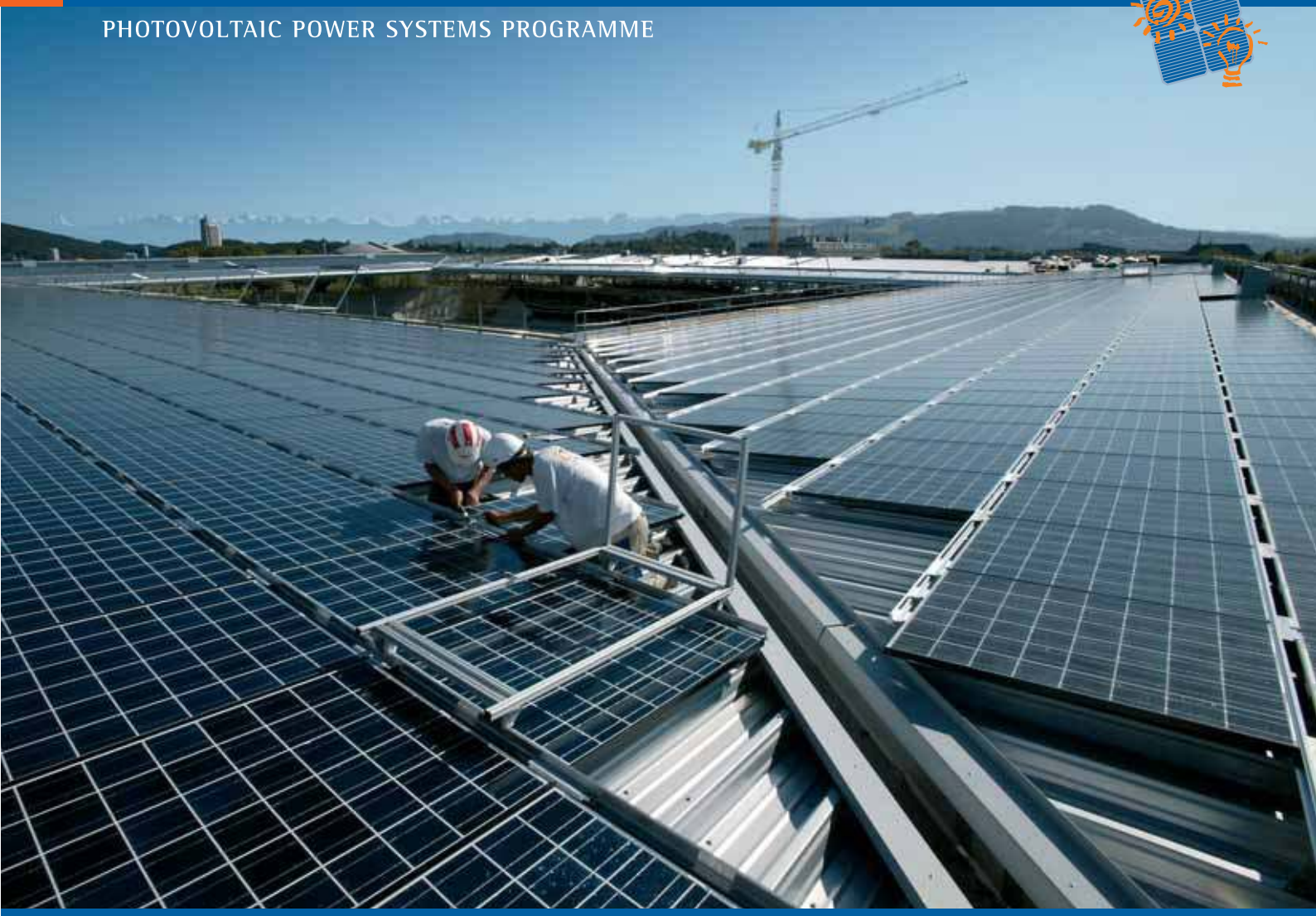
IEA INTERNATIONAL ENERGY AGENCY

PHOTOVOLTAIC POWER SYSTEMS PROGRAMME



PVPS

annual report 2004

IMPLEMENTING AGREEMENT
ON PHOTOVOLTAIC POWER SYSTEMS

PHOTOVOLTAIC POWER SYSTEMS PROGRAMME

ANNUAL REPORT 2004

PREFACE

In the year 2004, the ongoing work within the IEA Photovoltaic Power Systems Programme was characterised by a number of new initiatives and activities along the present strategic plan of IEA PVPS. Both on the Executive Committee level as well as on the Task level, the network was systematically extended towards new target groups, new members as well as new work items and accompanied by increased communication efforts.

After some years of absence from the Executive Committee, PVPS is pleased to have the renewed membership and support of Spain in the Programme. Similarly, Turkey has indicated an interest to revive its membership. Furthermore, China has been an observer at the 23rd PVPS Executive Committee Meeting and is presently exploring a membership within PVPS. Based on various contacts, interest in participation from a number of other countries can be observed. Finally, the European Photovoltaic Industry Association (EPIA) has confirmed its willingness to join the PVPS Programme as a sponsor member. The PVPS Executive Committee welcomes this initiative and intends to further intensify the relationship and co-operation with the photovoltaic industry.

On the Task level, increased co-operation and communication can be noted as follows:

- Led by Australia, Task 1 held a successful industry workshop at the 19th European Photovoltaic Solar Energy Conference in Paris;
- A new workplan was endorsed by the Executive Committee for Task 2 which thus entered into its third term. Task 2 was very successful in attracting new participation from 4 member countries and 1 observer. I am grateful to Germany which has accepted to continue leading this PVPS activity;
- Task 3 has accomplished its work programme with an impressive list of results and I am grateful to France which has led this activity since its very beginning;
- Task 8 is continuing its work under the leadership of Japan; a workshop on very large scale photovoltaic systems was held in Australia;
- Led by the United Kingdom, Task 9 is continuing its activities under the new name of "Photovoltaic Services for Developing Countries"; 4 events were organised by this Task in 2004;
- As the youngest of the PVPS activities, Task 10 started its work on urban scale photovoltaic applications in 2004. This activity is being led by the United States.

The following new activities are presently under discussion: As a follow-up of Task 3, a new Task on photovoltaic hybrid systems has received encouraging interest from a number of countries and their industry sectors. Another topic on the agenda is the subject of environmental issues related to photovoltaics. Due to the rapid global market expansion, it is felt that continuous analysis and communication on facts and figures is needed for this important subject.

The overall communication efforts were increased by different workshops, a new PVPS flyer, the dissemination of the PVPS newsletter and the PVPS website, www.iea-pvps.org. Moreover, a booth at the industry exhibition of the 19th European Photovoltaic Solar Energy Conference in Paris attracted a large number of visitors and interesting feedback on the programme activities.

With many new results from the various ongoing projects, 2004 was another productive year for PVPS. The detailed results are given in the Task reports of this annual report and all publications can be found at the PVPS website. I would like to congratulate all Tasks on their remarkable progress and achievements. The current status of photovoltaics in the PVPS member countries is described within the country section of this annual report.

A number of Executive Committee members and Operating Agents have left us during the year, heading for new responsibilities or horizons. In this respect, my particular thanks go to Harry Schaap who has always supported me and the Executive Committee as the Deputy Chairman over the past years. I will certainly miss Harry's always objective, concise and constructive proposals. With this, I take the opportunity to thank all Executive Committee members, Operating Agents and Task Experts who by their dedicated effort contribute to the collaborative work and success of PVPS.

Stefan Nowak
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 nine 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 2004, ten Tasks were established within the PVPS programme, of which one was completed in 1997 (Task 6), two were completed in 2001 (Task 5 and Task 7), one was completed in 2004 (Task 3) and one is not operational (Task 4). A new task began in 2004 (Task 10), which is a follow-up to Task 7.

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

IEA-PVPS MISSION

The mission of the IEA-PVPS programme is:
To enhance the international collaboration efforts which accelerate the development and deployment of photovoltaic solar energy as a significant and sustainable renewable energy option

The underlying assumption is that the market for PV systems is gradually expanding from the present niche markets of remote applications and consumer products, to the rapidly growing markets for building-integrated and other diffused and centralised PV generation systems.

This market expansion requires the availability of and access to reliable information on the performance of PV systems, technical and design guidelines, planning methods, financing, etc. to be shared with the various actors.

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: governments, utilities, energy service providers and other public and private users:

1. To stimulate activities that will lead to a cost reduction of PV power systems applications

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

2. To increase the awareness of their potential and value and thereby provide advice to decision makers from government, utilities and international organisations

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, policy and financing schemes, developments and standards.

3. To foster the removal of technical and non-technical barriers of PV power systems for the emerging applications in OECD countries

Over time, photovoltaic-based electricity supply can play a key role in urban-scale developments. Such developments should follow a holistic approach to maximise society's total energy efficiency and use of renewable energy opportunities. There is already increasing awareness of the principles of sustainable design and maximum use of (active) solar energy potential but this can be further expanded. PV power systems can play a key role in providing the reduced electrical energy services needs of houses and buildings and have the potential to become a major grid-connected electricity supply source. Through effective knowledge sharing, PVPS aims to enhance

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

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

OBJECTIVE	STRATEGIES	DELIVERABLES
1 – To stimulate activities that will lead to a cost reduction of 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.	• Objective information on the technical performance, reliability and cost structure of PV systems, in an accessible form; • Recommended practices for improved design, construction and operation and maintenance of PV systems and subsystems, in an accessible form; • Recommendations concerning remaining technical issues for 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 their potential and value and thereby provide advice to decision makers from government, utilities and international organizations.	• To collect and analyse information on key awareness issues, such as policies, markets, applications, experiences, 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; • To identify the most successful policy mechanisms leading to a self-sustained market growth; • To provide objective policy advice to governments, utilities and international organisations; • To encourage private and public sector investments that are required to bring PV Power systems into the main stream market.	• Continuous update of the web page content and accessibility to ensure that the information developed by PVPS is readily available for all stakeholders, at the website: www.iea-pvps.org; • PVPS fact sheets covering the development of key parameters and issues, e.g. industry shipments, installed capacity, potential, cost, etc. ; • The International Survey Report (ISR) intends to present and interpret year-to-year trends in both the PV systems and components being used in the utility sector, as well as the changing applications within that sector, in the context of business situations, policies and relevant non-technical factors in the reporting countries. The ISR is to present an accurate, comprehensive and useful description of the PV products, applications and markets in the reporting countries. The ISR is published in printed form on an annual basis; • The Annual Report, which describes the main outcomes of the PVPS programme, the status of each task, the concise description of the status and prospects of each participating country's PV programme. The Annual Report is published in printed form in the spring of the following year; • The PVPS Newsletter, published twice a year, informs the main target groups on the results of the collaborative work of the PVPS programme as well as on other important issues and initiatives regarding the deployment of PV power systems; • An overview of the activities, available information such as reports 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 is updated regularly; • International (executive) conferences are organised together with other national or international, private or public organisations. They are intended to provide information and enhance awareness on key issues for the deployment of PV power systems. The participants are carefully selected among important decision-makers in the different target groups in order to assure maximum benefit of the outcomes; • International workshops on important specific (technical and non-technical) issues are organised. They are intended to actively enhance the discussion and information exchange with participation from the concerned target groups; • Input to national workshops is provided by the participation of PVPS experts; • Summaries of the outcomes of the PVPS programme in national information networks and media are encouraged.
3 – To foster the removal of technical and non-technical barriers of PV power systems for the emerging applications in OECD countries.	• To develop a major education and awareness effort to remove informational barriers among key target audiences, including consumers, developers and utilities; • To conduct occupant surveys and gather key market data on targeted projects managed within participating countries; • To evaluate the inclusion of PV within the standard design and construction process in selected communities worldwide; • To assess the buildability, saleability, pricing and financing options for BIPV rooftop products and providing feedback to industry and manufacturers; • To assess the impact of BIPV rooftop products on the distribution network and other connection issues, particularly benefits dealing with time of day pricing and summer time demand side management; • To develop material that will assist in the development of standardised net metering contractual agreements between homeowners and utilities; • To address mortgage and insurance issues; • To identify steps in streamlining installation procedures and electrical inspections.	• Compilation of jurisdiction within participating countries where net billing and net metering has increased the accessibility; • Compilation of homebuilders providing solar home options to customers; • Overview of PV financing methods in OECD countries; • Planning methods to evaluate and maximise the benefits of grid-connected photovoltaic systems to the electric grid and to the customers; • Specific studies on important issues (e.g. non-technical barriers, financing, potential assessments, PV in competitive energy markets, etc.).
4 – To enhance co-operation with non-OECD countries and address both technical and non-technical issues of PV applications in those 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 identify opportunities and provide best practice for emerging applications (non-domestic systems, community systems, hybrids, mini-grids, weak grids); • To promote adequate measures for quality assurance and standards; • To identify the opportunities and conditions to implement adequate mechanisms of the Kyoto protocol as well as WSSD initiatives.	• Collation and analysis of relevant existing publications on PV in developing countries; • Guidance and documents to foster the successful introduction and expansion of PV systems drawing from past experiences and lessons learned from technology cooperation projects and programmes. These will be disseminated by appropriate means in selected developing countries; • A regular electronic newsletter containing an information update on the CDM process and latest news on Task 9 publications, workshops and other relevant events; • Staff workshops for multilateral and bilateral agencies; • Workshops in non-IEA countries, co-ordinated with bilateral and/or multilateral agencies and/or NGOs; • Active participation of target groups in selected developing countries; • Dialogue and contact point with staff of multilateral and bilateral agencies.

IEA PVPS Executive Committee, Paris, France, October 2004.

the opportunities for large-scale application of grid-connected photovoltaics in the urban environment as part of an integrated approach that maximises building energy efficiency, use of solar thermal and photovoltaics. There is a significant learning investment in many of the participating countries that have undertaken rooftop programmes and other sustainable community development initiatives.

4. To enhance co-operation with non-OECD countries and address both technical and non-technical issues of PV applications in those countries

PV power systems in non-OECD countries represent a fast growing market segment, both in remote areas for rural electrification as well as increasingly in urban environments of these countries. Applications of PV in those countries move gradually from domestic applications (typically solar home systems) to non-domestic applications, community systems, mini-grids and applications in weak grid areas. Depending on the local framework conditions, the infrastructure available as well as appropriate quality management, financing and capacity building schemes, such applications represent new opportunities where PV can increasingly provide the required energy service on a competitive basis. Some of the Kyoto mechanisms may in future provide additional opportunities for PV applications, in particular if they can be aggregated to larger volumes. The sustainable and large-scale introduction of PV is supported by bilateral and multilateral agencies and development banks. At the same time, this large-scale introduction is hampered by various barriers such as acceptable accessible financing structures, institutional and social barriers, infrastructure issues and sometimes technical problems. PVPS expertise can be instrumental to help overcome some of these barriers.

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 IEA PVPS the following Tasks have been established:

- Task 1. Exchange and dissemination of information on PV power systems;
- Task 2. Performance, reliability and analysis of photovoltaic systems;
- Task 3. Use of PV power systems in stand-alone and island applications (concluded in 2004);
- Task 4. Modelling of distributed PV power generation for grid support (not operational);
- Task 5. Grid interconnection of building integrated and other dispersed PV systems (concluded in 2001);
- Task 6. Design and operation of modular PV plants for large scale power generation (concluded in 1997);
- Task 7. PV power systems in the built environment (concluded in 2001);
- Task 8. Very large scale PV power generation systems;
- Task 9. PV services for developing countries;
- Task 10. Urban Scale PV Applications. Begun in 2004. Follow-up of Task 7.

The **Operating Agent** is the manager of his or her Task, and responsible for implementing, operating and managing the collaborative project. As such the Operating Agent compiles a status report, with results achieved in the last six months, as well as a work plan for the coming period. These are being discussed at the Executive Committee meeting, where all participating countries have a seat. Based on the work plan, the Executive Committee decides whether activities in the coming period should continue, or intensify, or stop. In case the Executive Committee decides to continue the activities within the Task, the participating countries in this Task commit their respective countries to an active involvement by national experts. In this way, a close co-operation can be achieved, whereas duplication of work is avoided.

TASK STATUS REPORTS

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

OVERALL OBJECTIVES

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 stakeholders and target audiences for the various Task 1 deliverables and establishing mechanisms for communication both within and outside the PVPS Programme. The public website www.iea-pvps.org will continue to be refined to reflect the requirements for information that are identified by Task 1 participants and others.

Task 1 activities are organized into the following subtasks:

SUBTASK 1.1: Status Survey Reports

A published report, Trends in Photovoltaic Applications, is compiled from the National Survey Reports (NSRs) produced annually by all countries participating in the IEA-PVPS Programme. The national reports can be found on the public website. The Trends report presents the current status and interprets trends relating to systems and components being used in the various PV power systems markets, the changing applications within those markets and aspects of the PV industry value chain. This is reported in the context of the business environment, policies and relevant non-technical factors mainly, but not exclusively, in the participating countries.

Trends 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 eight issues had been published by the end of 2004.

SUBTASK 1.2: Newsletter

A printed, colour newsletter, PVPower, is prepared and distributed to stakeholders by post and also via the website each six months to present 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.

Twenty one issues of the newsletter had been published by the end of 2004.

SUBTASK 1.3: Special Information Activities

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

IEA PVPS Website, Homepage.

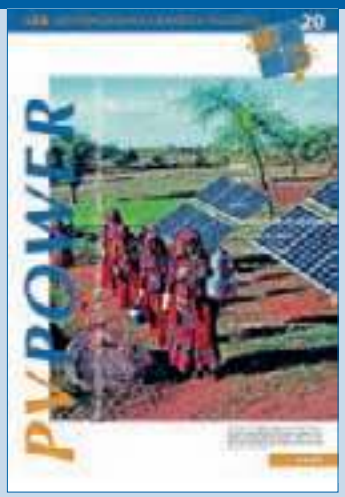
SUMMARY OF TASK 1 ACCOMPLISHMENTS FOR 2004

A key Task 1 priority is meeting the needs of the various stakeholders and target audiences, within the context of the objectives of the PVPS Programme. The public PVPS website enables PVPS information to be provided quickly and at a reasonable cost. The website remains a priority activity for Task 1, and its management is carried out within the framework of the guiding principles and agreed policy for the website. The website (and its various links) also provides other PVPS participants with valuable information on the programme as a whole, enhancing inter-task communication.

SUBTASK 1.1: Status Survey Reports

The 9th issue of the Trends in Photovoltaic Applications report was published in September 2004 and analyzed data collected between 1992 and the end of 2003. IEA-PVPS countries currently account for about 90 % of the total PV capacity installed worldwide, with this amount doubling around every two years, and more than 90 % of the PV production. In 2004 the report was prepared by a small Task 1 group on the basis of the National Survey Reports prepared by all Task 1 participants. All participating countries provided at least a basic level of information. About half of the countries can further improve their information exchange practices.

Trends in photovoltaic applications.
Survey report of selected IEA countries between 1992 and 2003.



Newsletter PV Power issues 20 and 21.

The National Survey Reports are funded by the participating countries and provide a wealth of information. They are available from the PVPS public website and are a key component of the collaborative work carried out within the PVPS Programme. Task 1 participants share information on how to most effectively gather data in their respective countries.

The Trends report is a 28 page colour publication with tables, figures and photographs that is funded by the PVPS Common Fund. Copies are distributed by post by Task 1 participants to their identified national target audiences and are provided at selected conferences and meetings. The report is also available on the public website, can be downloaded as a complete document, and figures and tables can be downloaded separately.

SUBTASK 1.2: Newsletter

Editorial policy for the newsletter continued to emphasize that projects and products - both PVPS and other - must be tangible to be included. The newsletter now contains a section highlighting interesting national developments in the participating countries.

Issue 20 of the newsletter was published in June 2004 and issue 21 was published in December 2004. Current and back issues of PVPower are available on the public website.

SUBTASK 1.3: Special Information Activities

During 2004, work continued at a low level on activities that fall under the umbrella of special information activities. An industry workshop was held in conjunction with the European PV conference in Paris in June 2004, and the presentations were made widely available via the website. Many topics of interests will benefit from working more closely with the industry associations, and include cost of energy from PV, value of PV business activity and the value chain of the PV industry.

Ideas for the PV Utility Forum were further refined, with the hope of making a useful contribution during 2005. The objectives are to openly share both positive and negative PV experiences, perceptions and ideas amongst electricity utilities internationally.

SUMMARY OF TASK 1 ACTIVITIES PLANNED FOR 2005

Task 1 activities will closely reflect the broader strategy for the PVPS Programme. The issue of market implementation is an important focus for PVPS activities, as is a close working relationship with the PV industry and other stakeholders.

SUBTASK 1.1: Status Survey Reports

The target date for publication of the 10th issue of the Trends in Photovoltaic Applications report is August 2005, with electronic versions of the information to be made available in July 2005. It is planned to broaden the report to include additional information from non-PVPS countries (in conjunction with Task 9), to further highlight industry development matters and to analyze market support efforts. National Survey Reports will be completed before the end of May 2005, based on the revised guidelines and data collection pro forma, so that the information can be incorporated in and analyzed for the Trends report. The definitions of "distributed" and "centralized" grid-connected systems have been refined to better reflect this rapidly evolving market.

SUBTASK 1.2: Newsletter

Task 1 participants will continue to review and update the target audiences within their countries, and to seek feedback regarding preferred format (e.g. electronic or printed) and content from these audiences. It is planned to develop strategies during 2005 to more fully capture the newsletter's full potential for PVPS information outreach.

PV Power Nos. 22 & 23 will be published in May 2005 and October 2005 respectively, both prior to major PV conferences, and maintaining current editorial policy.

SUBTASK 1.3: Special Information Activities

The matters of interest to Task 1 participants are increasingly being incorporated into existing activities - such as the newsletter, the survey reports, the website - and as input to other tasks except where dedicated activities, for example the PV Utility Forum and industry workshops can be supported. An industry workshop is being planned for the European PV Conference in Barcelona, possibly discussing life cycle analysis and recycling efforts. Task 1 interests will also benefit from a close working relationship with Task 10, particularly issues such as market transformation, and the added values of PV.

INDUSTRY INVOLVEMENT

Task 1 activities continue to rely on close co-operation with government agencies, PV industries, electricity utilities and other

LIST OF PARTICIPATING COUNTRIES, KEY TASK 1 PARTICIPANTS IN 2004 AND THEIR ORGANISATIONS

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

COUNTRY	NAME	ORGANISATION
Australia	Greg Watt	Australian PVPS Consortium
Austria	Roland Bruendlinger	Arsenal Research
Canada	Josef Ayoub	Natural Resources Canada
Denmark	Peter Ahm	PA Energy A/S
European Union	Rolf Öström	DG Research
Finland	Leena Grandell	MOTIVA
France	André Claverie	ADEME
Germany	Frank Stubenrauch	Forschungszentrum Jülich
Israel	Yona Siderer	The Ben-Gurion National Solar Energy Centre
Italy	Salvatore Guastella	CESI S.p.A.
Japan	Osamu Ikki	RTS Corporation
Korea	Kyung-Hoon Yoon	KIER
Mexico	Jaime Agredano Diaz	IIE
Netherlands	Job Swens	NOVEM
Norway	Fritjof Salvesen	KanEnergi AS
Portugal	Luis Silva	ADENE
Spain	Manuel Blasco	CENER
Sweden	Lars Stolt	Uppsala University
Switzerland	Pius Hüsser	Nova Energie GmbH
United Kingdom	Sarah Davidson	IT Power Ltd
USA	Ward Bower	Sandia National Laboratories

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

parties, both for collection and analysis of quality information and for dissemination of PVPS information to stakeholders and target audiences. This is achieved through the networks developed in each country by the Task 1 participants. While it is recognized that the target audience for PVPS information has broadened considerably, it is also appreciated that more effective means of attracting industry involvement in the PVPS programme should continue to be promoted. PVPS / industry workshops are seen as important ongoing activities.

KEY DELIVERABLES (2004 AND PLANNED)

The following were published and also made available on the public website during 2004:

Trends in photovoltaic applications in selected IEA countries between 1992 and 2003
Report IEA-PVPS T1-13: 2004;

Newsletter - PVPower issues 20 and 21.
Individual National Survey Reports are included each year under 'Country information' on the public website, with tables and graphs able to be downloaded. Guidelines and data collection pro forma for the NSRs are produced and updated each year.

During 2005 it is planned to produce the tenth issue of the Trends in Photovoltaic Applications report, PVPower issues 22 and 23, a broad range of country information, case studies and key topics on the website, to progress the PV Utility Forum and to organize a PVPS / industry workshop in conjunction with the European PV conference in Barcelona in June 2005.

MEETING SCHEDULE (2004 AND PLANNED 2005)

The 24th Task 1 participants' meeting was held in Daejeon City, Korea, 3-5 March 2004.
The 25th Task 1 participants' meeting was held in Port Macquarie, Australia, 8-10 September 2004.

The 26th Task 1 participants' meeting will be held in Lyon, France, 3-4 June 2005, immediately before the European PV Conference in Barcelona, Spain.

TASK 2 - PERFORMANCE, RELIABILITY AND ANALYSIS OF PHOTOVOLTAIC SYSTEMS

Fig. 1 - The Availability of Irradiation Data, IEA PVPS Task 2 Report, December 2004 & Country Reports on PV System Performance, IEA PVPS Task 2 Report, December 2004.

OVERALL OBJECTIVE

The overall objective of Task 2 is to improve the operation, sizing, electrical and economical output of photovoltaic power systems and subsystems by collecting, analyzing and disseminating information on their performance and reliability, providing a basis for their assessment, and developing practical recommendations.

The scope of Task 2 has concerned the information exchange about activities already in progress in the participants' national programmes. Technical and economic information on performance and long-term reliability are very important for an emerging technology such as PV. Task 2 aims to provide performance data for both general assessments of PV system technologies and improvements of system design and operation.

Task 2 officially started a new work programme in September 2004 for a period of three years, building on previous accomplishments in PV system performance analysis. Task 2 activities are organised into the following Subtasks:

SUBTASK 1: International Database

This is achieved through the development of the PV Performance Database, an international database containing information on the technical performance, reliability and costs of PV systems and subsystems located worldwide. The information is gathered and presented by means of standard data collection formats and definitions. The database user can select PV system data, present monitoring data and calculated results, and in addition export these data into spreadsheet programmes. A collection of such a variety of high quality operational data presents a unique tool for PV system performance analysis. The database is updated regularly, and can be downloaded from the website http://www.iea-pvps-task2.org.

SUBTASK 2: Analysis of Photovoltaic Systems

Participants analyse performance and maintenance data for photovoltaic power systems and components in their respective countries, both in order to ensure the quality and comparability of data entered in the database and to develop analytical reports on key issues such as operational performance, reliability, expected output and sizing of PV systems. Activities include the work on the availability of irradiation data, tools for checking the performance of PV systems, shading effects and temperature effects as well as long-term performance and reliability analysis.

SUBTASK 3: Measuring and Monitoring

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

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

SUBTASK 4: Improving PV System Performance

Participants develop 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. Subtask 4 was terminated during the second phase of Task 2.

SUMMARY OF TASK 2 ACCOMPLISHMENTS FOR 2004

During 2004, Task 2 focused on the completion of PV system performance analysis for the dissemination of Task 2 results and products within the previous working phase. The public Task website enables downloads and technical information to be provided quickly and cost-effective to the users. The volume of visitors to the Task website, their countries and sectors as well as the number of PVPS Task 2 products retrieved are being tracked to measure the extent to which the website is visited and the products are used (Figure 2).

Task 2 participants identified a need for additional work on aspects of PV system reliability, PV technology assessments, performance prediction and PV system cost analysis. A workplan for the extension of the Task was developed and the PVPS Executive Committee approved the new work programme in October 2004.

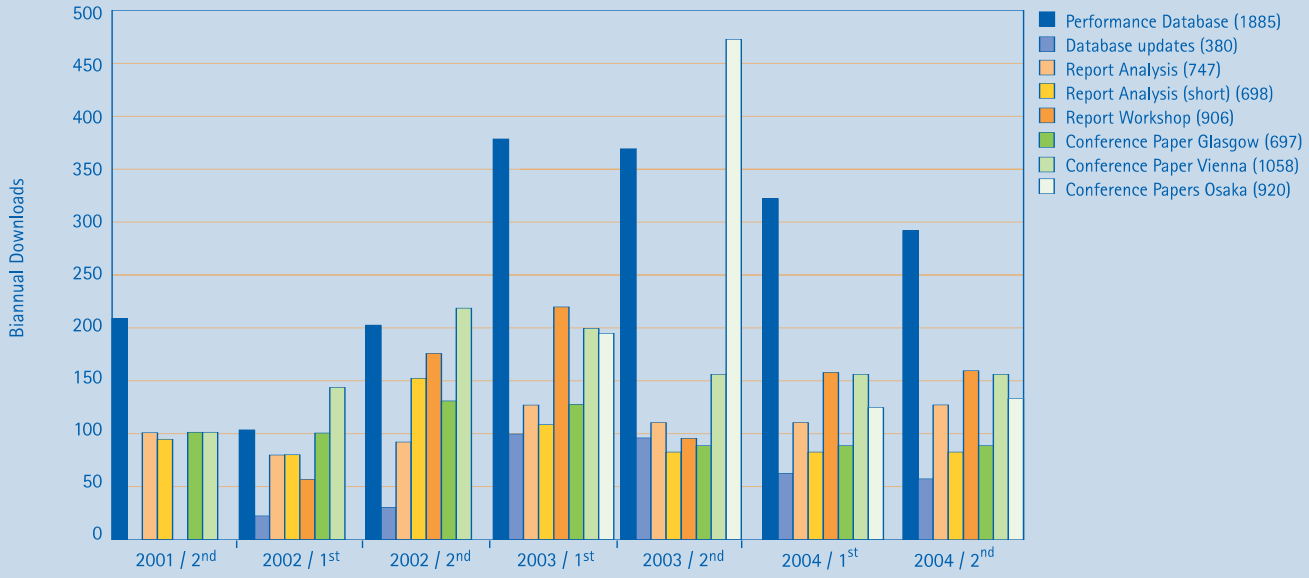


Fig. 2 – Statistics on information retrieval of different Task 2 products (database, reports, conference proceedings) from public Task 2 website "http://www.iea-pvps-task2.org."

SUBTASK 1: International Database

The **PV Performance Database** was updated and the programme was released in June 2004 as a tool for planning, sizing and improving PV systems with respect to operational performance and reliability. The new Performance Database contains high quality data of 414 PV systems of different system technologies, located in 21 countries. The update of June 2004 provides 14 580 monthly datasets from grid-connected and stand-alone PV systems of a total power of 12 MW. The Performance Database programme (47 MB) is available on CD-ROM (Figure 3) and can be downloaded from the Task website http://www.iea-pvps-task2.org.

Task 2 focused on the dissemination and promotion of the Task 2 database. This was achieved through the networks developed in each country by the Task participants and by presenting the database programme at PV conferences, seminars and in PV training courses. As a result, 2 596 database users from 77 different countries and a broad range of sectors are making best use of the Task 2 database for their applications in planning & consulting, education, production and research. In 2004, highest demand for the Performance Database came from the private sector and the engineering sector, followed by the education and industry sector.

SUBTASK 2: Analysis of Photovoltaic Systems

PV system performance analysis was continued and completed for the following activities:

- **The Availability of Irradiation Data** - This report provides information on the availability of irradiation data to be used to assess the performance of PV systems. Final draft report was reviewed and published in December 2004 (Figure 1).
- **Tools for Checking the Performance of PV Systems** - It will be finalized as internal working document.
- **Shadings Effects on PV System Performance** - not available.
- **Temperature Effects on PV System Performance** - Based on collected hourly data, temperature gains and losses were calculated for selected PV systems. An internal report was prepared and distributed in May 2004.
- **Long-Term Performance and Reliability Analysis of PV Systems** Case studies on long-term performance trends, on reduced yield analysis and on components failures were elaborated. A final draft report was reviewed and will be published in early 2005.
- **Country Reports on PV System Performance** - The country reports on Austrian, French, German, Italian, Japanese and Swiss systems gives an overview of the PV systems in each country. The report was finalized and published in December 2004 (Figure 1).

SUBTASK 4: Improving PV System Performance

Different documents on simulation tools have been collected and evaluated. The overview on simulation tools will be continued and improved. Regarding energy management strategies (EMS), a report on "Energy Management Strategies for Hybrid Energy Systems" was prepared in collaboration with Task 3. Case studies have been selected to initiate activities on "optimum operational conditions for stand-alone hybrid systems."

SUMMARY OF TASK 2 ACTIVITIES PLANNED FOR 2005

Task 2 activities for 2005 will focus on the new activities of the extended work programme running from September 2004 to August 2007: Subtask 5 will make technical assessments and identify technology trends of PV systems by broadening the previous work and by exploiting the wealth of existing data. Subtask 6 will collect and investigate performance and cost data of PV systems.

SUBTASK 1: International Database

The target date for publication of the fifth version of the PV Performance Database is June 2005. The updated Performance Database will be available for Internet downloads and on CD-ROM at the 20th European Photovoltaic Solar Energy Conference and Exhibition in Barcelona in June 2005. Furthermore, Task 2 will develop and review a web-based Performance Database using selected database information. The goal is to build up an online database on PV system performance and reliability during the coming two years.

Fig. 3 - IEA-PVPS Task 2 Performance Database programme: The fourth update available on CD-ROM and for Internet download was released in June 2004.

SUBTASK 2: Analysis of Photovoltaic Systems

The activities of PV system performance analysis will be completed, as follows:

- **Tools for Checking the Performance of PV Systems**
  Activity leader France will finalize the work and produce an internal report.
- **Long-Term Performance and Reliability Analysis of PV Systems**
  Activity leader Germany will review the recommendations and the results of the case studies and publish them in a public report.

SUBTASK 5: Technical Assessments and Trends of PV Systems

Task 2 analyses and validates expertise and performance results of PV systems, both in order to ensure the quality and comparability of information gathered in the Performance Database and to identify high performance products, technologies and design methodology. This will foster the development of maximum conversion efficiency and optimum integration of PV.

Planned activities include the work on performance, acceptance and standardisation of PV in the built environment, technological choices and strategies with respect to PV system reliability and the improvement of performance prediction with respect to both the solar resource and system performance.

SUBTASK 6: PV System Cost over Time

Task 2 will identify and evaluate the important elements, which are responsible for the life cycle economic performance of PV systems by investigating economic data for all key components of PV systems and by gathering information about real life costs of maintenance of PV systems. Furthermore, an Internet-based survey will be developed, reviewed and published in 2005 in order to gain additional economic data from global customers.

INDUSTRY INVOLVEMENT

PV industry, particularly, the European PV industry (EPIA) and the German Solar Industry Association, support Task 2 work and gain first-hand technical and non-technical information on performance and reliability issues. PVPS and industry workshops will be organized.

Task 2 benefits from its co-operation with PV industries, electricity utilities and other agencies, both for collection and analysis of PV system data and for dissemination of technical information to target audiences.

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

KEY DELIVERABLES (2004 AND PLANNED 2005)

- PVPS Task 2 Performance Database programme update with collected data from 414 PV systems, released in June 2004;
- The Availability of Irradiation Data: Report IEA-PVPS T2-04:2004 (Figure 1);
- Country Reports on PV System Performance: Report IEA-PVPS T2-05:2004 (Figure 1).

The following publications were prepared and presented at the 19th European PV Solar Energy Conference and Exhibition in Paris in June 2004:

- Oral presentation: U. Jahn, W. Nasse
  "ACHIEVEMENTS OF TASK 2 OF IEA PV POWER SYSTEMS PROGRAMME: FINAL RESULTS ON PV SYSTEM PERFORMANCE".
- Visual presentation: U. Jahn, W. Nasse
  "PERFORMANCE ANALYSIS, RELIABILITY AND SIZING OF PV SYSTEMS: TASK 2 OF THE IEA PHOTOVOLTAIC POWER SYSTEMS PROGRAMME."

During 2005 it is planned to produce and disseminate a fifth version of the Task 2 Performance Database to be released in June 2005, which will be available at the 20th European Photovoltaic Solar Energy Conference and Exhibition in Barcelona in June 2005. It is also planned to prepare and publish conference proceedings on Task 2 results, performance analysis & reliability and on global aspects of building-integrated PV, and to launch an internet-based survey on PV system and maintenance costs.

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

MEETING SCHEDULE (2004 AND PLANNED 2005)

The 10th Task 2 Participants' Meeting (phase 2) was held in Erlenbach, Switzerland, 22-24 March 2004.
The 1st Task 2 Participants' Meeting (phase 3) was held in Ispra, European Commission Joint Research Centre, 20-22 September 2004 (Figure 4).
The 2nd Task 2 Participants' Meeting will be held in Cocoa, USA, 28 February - 2 March 2005.
The 3rd Task 2 Participants' Meeting will be held in Hameln, Germany, 26-28 September 2005.

Fig. 4 - Task 2 Kick-Off Meeting, European Commission Joint Research Centre, Ispra, Italy, September 2004.

TABLE 1 - LIST OF PARTICIPATING COUNTRIES, TASK 2 PARTICIPANTS IN 2004 AND THEIR ORGANISATIONS

COUNTRY	PARTICIPANT	ORGANISATION
Austria	Stefan Mau	Arsenal Research, Vienna
Canada	Yves Poissant	CANMET Energy Technology Centre, Varennes
European Commission	Harald Scholz	DG Joint Research Centre (JRC), Ispra
France	Didier Mayer	Centre d' Energétique, Ecole Des Mines de Paris
Germany	Reinhard Dahl (OA) Ulrike Jahn (OA Alternate) Wolfgang Nasse	Projekttraeger Juelich (PTJ) Forschungszentrum Juelich, GmbH Institut für Solarenergieforschung GmbH Hameln / Emmerthal (ISFH) Solar Engineering Decker & Mack GmbH
Italy	Salvatore Castello	ENEA C.R. Casaccia
Japan (Until April 2004) (Since June 2004) (Until March 2004) (Since July 2004)	Koichi Sakuta Kenji Otani Tetsuo Yamaguchi Takeshi Igarashi	National Institute of Advanced Industrial Science and Technology (AIST) National Institute of Advanced Industrial Science and Technology (AIST) Japan Electrical Safety & Environment Technology Laboratories (JET) Japan Electrical Safety & Environment Technology Laboratories (JET)
Poland (Observer)	Tadeusz Zdanowicz	Wroclaw University of Technology
Sweden	Jonas Hedström	Energibanken AB, Stockholm
Switzerland	Thomas Nordmann Luzi Clavadetscher	TNC Consulting AG TNC Consulting AG
The United States of America	Andrew L. Rosenthal Kevin Lynn	Southwest Technology Development Institute (STDI), Florida Solar Energy Center (FSEC), Cocoa

Updated contact details for Task 2 participants can be found on the Task 2 website www.iea-pvps-task2.org.

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

OBJECTIVES AND WORK PROGRAMME

Task 3 was established in 1993 to stimulate collaboration between IEA countries in order to improve the technical quality and cost-effectiveness of photovoltaic systems in stand-alone and island applications.

When the first programme (1993-1999) was approved, the stand-alone photovoltaic sector was largely comprised of solar home systems for rural electrification, remote 'off-grid' homes in industrialised countries and PV consumer goods. PV hybrid systems and niche off grid applications such as PV powered bus shelters were also being introduced in certain countries.
As part of this programme, a number of documents were published as information about installed stand-alone PV systems worldwide. These included a lessons learned book featuring case studies from each country, as well as a survey of PV programmes in developing countries.

Some of the most pertinent problems of this phase were seen to be due to the many failures attributed to inappropriate system design and/or to a lack of a socially functional arrangement for system operation and management. Technical documents produced during this programme included studies on the charge controller and the lead acid battery.

Towards the end of the first Task 3 programme, the attention of the international PV community was increasingly focused on the quality issues of the stand-alone PV project. In addition, it was recognised that the storage of energy in a stand-alone PV system was a key component, and one which frequently led to systems' failure.

Task 3's second programme (1999-2004) was initiated against this background with the following overall objectives:

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

In this field, according to the objectives of the PV Power Systems programme, Task 3 aimed:

- To collect, analyse and disseminate information on the technical performance and cost structure of PV systems in these applications
- To share the knowledge and experience gained in monitoring selected national and international 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"

The main target audience of Task 3 activities were technical groups such as project developers, system designers, industrial manufacturers, installers, utilities, Quality organisations, training providers, end users.

The 1999-2004 work programme included the following subtasks and activities:

SUBTASK 1: Quality Assurance

Activity 11: Critical Review of Implementation of Quality Assurance Schemes

To develop quality assurance schemes that will lead to a warranty for all system installations at reasonable cost.

Activity 12: Technical Aspects of Performance Assessment on Field – Quality Management

To identify and establish practical performance assessment guidelines.

SUBTASK 2: Technical Issues

Activity 21: Hybrid Systems

To contribute to cost reduction through standardisation and modularity in order to facilitate large scale dissemination of PV hybrid systems.

Activity 22: Storage Function

To provide recommendations to decrease the cost of storage in PV and PV hybrid systems.

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

To provide a technical contribution to cost reduction by showing the cost efficiencies associated with effective load management and efficient appliance selection.

Collaborative activities had to develop knowledge based on project implementations, technological improvements from the equipment manufacturers, R&D programmes results, and feed-back coming from the field.

NATIONAL PARTICIPATION

Thirteen countries supported Task 3 activities:
Australia, Canada, France, Germany, Italy, Japan, Norway, Portugal, Spain, Sweden, Switzerland, the Netherlands, United Kingdom.

The Netherlands and Spain, due to national decisions during this period, halted their participation; respectively in 2001 and 2002.

ACTIVITIES

Activities were dedicated to produce technical reports and to disseminate information to the target audience through national workshops and international events.

TABLE 1 - TECHNICAL REPORTS PUBLISHED BY TASK 3 DURING THE PERIOD 1999-2004

TITLE	REFERENCE NUMBER
Survey of National and International Standards, Guidelines and Quality Assurance Procedures for Stand-Alone Photovoltaic Systems	IEA-PVPS T3-07:2000
Recommended Practices for Charge Controllers	IEA-PVPS T3-08:2000
Use of Appliances in Stand-Alone Photovoltaic Systems: Problems and Solutions	IEA-PVPS T3-09:2002
Management of Lead-Acid Batteries used in Stand-Alone Photovoltaic Power Systems	IEA-PVPS T3-10:2002
Testing of Lead-Acid Batteries used in Stand-Alone Photovoltaic Power Systems - Guidelines	IEA-PVPS T3-11:2002
Selecting Stand-Alone Photovoltaic Systems - Guidelines	IEA-PVPS T3-12:2002
Monitoring Stand-Alone Photovoltaic Systems: Methodology and Equipment - Recommended Practices	IEA-PVPS T3-13:2003
Protection Against the Effects of Lightning on Stand-Alone Photovoltaic Systems - Common Practices	IEA-PVPS T3-14:2003
Managing the Quality of Stand-Alone Photovoltaic Systems - Recommended Practices	IEA-PVPS T3-15:2003
Demand Side Management for Stand-Alone Photovoltaic Systems	IEA-PVPS T3-16:2003
Selecting Lead-Acid Batteries Used in Stand-Alone Photovoltaic Power Systems - Guidelines	IEA-PVPS T3-17:2004
Alternative to Lead-Acid Batteries in Stand-Alone Photovoltaic Systems	IEA-PVPS T3-18:2004

TABLE 2 - TIMETABLE AND LOCATION OF TASK 3 EXPERTS MEETINGS 1999-2004

HOST COUNTRY	1999		2000		2001		2002		2003		2004
	FEB	SEP	FEB	SEP	MAR	SEP	MAR	SEP	MAR	SEP	MAR
AUS											
CAN											
CHE											
DEU											
ESP											
FRA											
GBR											
ITA											
JPN											
NDL											
NOR											
PRT											
SWE											

PUBLICATIONS

Task 3 publications can be downloaded from the IEA PVPS website www.iea-pvps.org and are listed in Table 1.

MEETINGS

Two experts meetings per year took place during the programme. These meetings were dedicated to working sessions in order to review the technical reports, and in many cases, presented informative sessions relative to the national PV activities of the hosting country, and, additionally, participation in national or international workshops held in conjunction to the meetings.

TECHNICAL TOURS AND INFORMATION SESSIONS

Most of the meeting agendas included technical tours and national information sessions.
TABLE 3 - presents topics that were addressed during these sessions.

TABLE 3 - INFORMATION SESSIONS AND TECHNICAL TOURS HELD IN CONJUNCTION WITH TASK 3 MEETINGS

PERIOD	HOST COUNTRY	CONTENT
Feb 99	Australia	• Presentation on PV in Australia; Lessons Learned about Quality of Stand-Alone Systems, Installers Perspective on PV, Export Strategy • Technical tours to several PV, PV hybrid and mini-grid electrification systems for remote aboriginal communities near Alice Springs.
Sep 99	Sweden	• Technical presentation on PV application in Sweden. • Visit to the solar lab and activities of Vattenfall Utveckling AB , Älvkarleby • Visit to the thin film solar research group at the new Angström Laboratory, Uppsala.
Feb 00	Portugal	• Presentation on the Status of Renewable Energies in Madeira. • Technical tour to SAPV systems in a Natural Park located in San Lourenço island, near Madeira.
Sep 00	France	• Technical presentation of a study on PV lighting systems evaluation and rating methods. • Visit to the GENEC lab facilities, Cadarache.
Mar 01	Norway	• Visit to a local hydro power plant, near Lillehammer.
Sep 01	Canada	• "PV Horizon" Workshop.
Mar 02	Spain	• Visit to the SEBA company; in charge of operation and maintenance for over a hundred PV systems in the Aragon area. • Technical tour to PV and PV hybrid electrification systems in remote villages in Pyrenees, near Huesca.
Sep 02	Japan	• "Activity and Prospect of the Stand-Alone Generation Systems" Workshop. • Technical tour to the factory of the Japan Storage Battery Company, in Kyoto.
Mar 03	Switzerland	• Workshop with PV Swiss engineers and installers • Visit to the Demosite Exhibition Center for Photovoltaic Integration in the Built Environment. • Technical tour to the factory of the HCT Shaping Systems Company, Lausanne, world leader in the manufacturing of wire saw machines. • Visit to local SAPV systems.
Sep 03	Germany	• Information session on PV and PV R&D activities in Germany. • Visit to the ISET lab facilities in Kassel. • Technical tour to the factory of the SMA Company (inverters manufacturer).
Mar 04	Italy	• Information session on PV and distributed generation R&D activities at Catania University. • Technical tour to the Ginostra PV hybrid and mini-grid electrification system on the Stromboli Island.

PARTICIPATING COUNTRIES AND PARTICIPANTS

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

ACHIEVEMENTS AND BENEFITS

As a general overview, the main issues of Task 3 are contribution to the promotion of quality management processes, classification of systems types, production of guidelines for performance evaluation and management of both supply side and demand side.

To provide both end-users and programme managers with guidance on quality assurance of systems, projects and programmes, participants have been working on **methodological and practical aspects** concerning quality assurance.

To contribute to a better assessment of **performance of systems** recommendations were developed concerning **monitoring** of such systems.

As the **storage function** in stand-alone systems is a main factor of global life cycle cost, participants aimed to develop technical recommendations to optimise storage investments and to increase the reliability of batteries. In this field, effort has been more particularly made in developing advanced energy management recommendations.

Participants have also provided technical issues concerning load management and **cost efficient appliance management** strategies. In this topic, some recommendations for **technical design** for better efficiency and reliability of systems were achieved.

The network created by collaboration in the work programme benefits from a wide spread and far reaching extension due to the Task 3 dissemination activities. National activities rose from a broader base through the efforts of gathering news from well-known political, economical or neutral sources. National dissemination of Task 3 output also strengthens the national network.

SCOPE FOR FUTURE ACTIVITIES

A proposal was introduced at the 23rd IEA PVPS Executive Committee Meeting in Espoo, Finland, in May 2004.

The proposed new work programme objective is **to promote the role of PV technology as a technical relevant and competitive source in multi-sources power systems.**
It aims at enhancing the "know-how" about off-grid **multi-sources power generation** systems including PV **and associated distribution**. The systems to be studied are PV generators using photovoltaic technology combined with other electricity generating technologies and distribution equipment, **providing services either to single or multiple users.**

The expected results of the collaborative work are **technical recommendations that optimise the use of PV in a multi-sources electrification system.**

CONCLUSION

Through Task 3 activities, lessons learned as well as prospective aspects have been developed through the collaborative work of experts sharing their knowledge and experience. Technical contribution has been achieved for the PV community, for improvement of the design, construction and operation of stand-alone photovoltaic power systems.

These guidelines and recommended practices are relative to project management, systems and component design, use of applications and promises from emerging or maturing technologies.

After the present programme, some relationship within the group remains and further common activities could be organised to develop projects.

At a time where information is so easy to collect and disseminate via electronic media, direct contact and live exchange between people remain important, necessary, appreciated and productive. In addition to this fruitful sharing of expertise, this way of working creates sustainable and efficient links, based on friendship and collaborative activities from year to year.

DELIVERABLES - WHERE TO GET THEM?

All Task 3 reports are available for download at the IEA PVPS website: www.iea-pvps.org

CONTACT INFORMATION

For information contact the former Task 3 OA or visit the IEA PVPS website.

Former Task 3 Operating Agent:
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TASK 8 - STUDY ON VERY LARGE SCALE PHOTOVOLTAIC POWER GENERATION SYSTEM

OVERALL OBJECTIVES

The objective of Task 8 is to examine and evaluate the feasibility of Very Large Scale Photovoltaic Power Generation (VLS-PV) Systems on desert areas, which have a capacity ranging from over multi megawatt to gigawatt, and develop practical project proposals for demonstrative research toward realization of the VLS-PV Systems in the future (See Fig. 1).

For this purpose, in Phase I (1999-2002), key factors that enable VLS-PV systems feasibility were identified and the benefits of this system's applications for neighbouring regions were clarified as well as the potential contribution of system application to global environment protection and renewable energy utilization in the long term was clarified. Mid- and long term scenario options for making VLS-PV systems feasible in some given areas were also proposed.

In Phase II (2003-2005), case studies on VLS-PV systems are carried out in depth and practical proposals for demonstrative research projects on pilot PV systems suitable for selected regions, which enable sustainable growth into VLS-PV Systems in the future, and general instruction to propose practical projects for large-scale PV system are developed.

MEANS

To complete the overall objectives, participants carry out three subtasks in the second phase.

Subtask 2: Case studies for selected regions for installation of VLS-PV system in deserts
Subtask 4: Proposals of practical projects for sustainable development
Subtask 5: General instructions for project proposals to realize VLS-PV systems in the future

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

Objective

Employing the concepts of VLS-PV and the criteria and other results obtained in the first phase, case studies on VLS-PV systems for the selected regions are undertaken and the effects, benefits and environmental impact of VLS-PV systems are evaluated.

Major Activities

In addition to previous VLS-PV case study in Phase I, evaluation on the feasibility of various kinds of VLS-PV systems has been started. A comparative case study between the fixed array VLS-PV system and the tracking VLS-PV system is ongoing to evaluate generation cost. Technologies such as thin-film Si PV modules bifacial PV module have been investigated and researched to apply to the VLS-PV System. In order to find desert area suitable for large-scale PV installation, a new methodology to evaluate soil characteristics of deserts by using remote sensing technology has been developed.

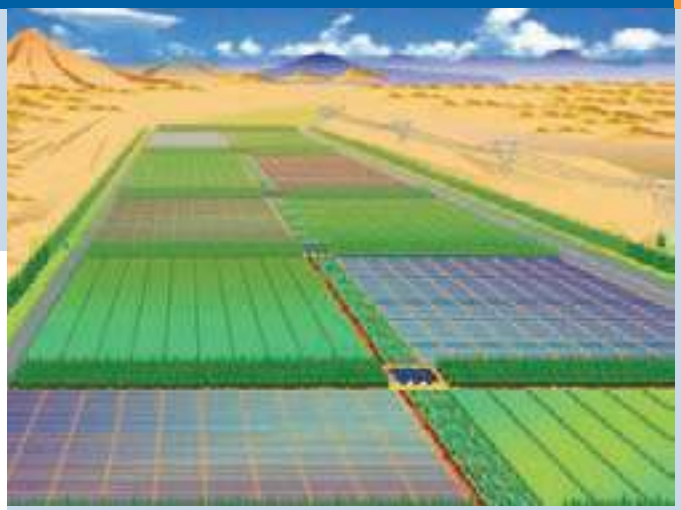


Fig. 1 - Image of a VLS-PV System in a Desert Area.

For this development, field surveys with GPS on the Gobi Desert, the Thar Desert and Western Australia were carried out, and the promising results were analyzed. This provided information of suitable land area for VLS-PV systems and the potential of electricity from VLS-PV systems installed in desert areas (see Fig. 2).

Fig. 2 - PV potential world map for selected six deserts (Total output would be four hundred PWh/year).

SUBTASK 4: PROPOSALS OF PRACTICAL PROJECTS FOR SUSTAINABLE DEVELOPMENT

Objectives

Practical project proposals for the initial stages of VLS-PV systems, which will enable sustainable growth of VLS-PV systems toward the future, are developed for some desert areas.

Major Activities

A project proposal on the Gobi Desert in Mongolia has been discussed as a first step toward the sustainable VLS-PV operation. One candidate site proposed is a surrounding area of Sainshand, which is located in eastern part of Mongolia. Sainshand has some advantageous infrastructures to start a VLS-PV project, such as a railway, utility grid, etc. The European team proposed that they would perform a feasibility study on the socio-economic background of different target sites in the Sahara or near-Mediterranean regions with respect to the

Fig. 3 - Full rainbow welcomed Task 8 Experts visiting the mega-watt scale PV system operated by the Arizona Public Service (APS) in Arizona.

application of VLS-PV in these countries. In addition, as a "Top-Down" approach, it was reported that the project proposal for the Middle-East region would show the advantages of the PV system for use in developing countries and desert areas, and that the project would analyze the criticism that data were often lacking with regard to comparisons with other renewable energy methods. Further, a new possibility of an Australian project has been also proposed.

SUBTASK 5: GENERAL INSTRUCTION FOR PROJECT PROPOSALS TO REALIZE VLS-PV SYSTEMS IN THE FUTURE

Objectives

By extracting essential knowledge from the Subtask 4, detailed practical instructions and a training kit for the development of other practical project proposals are developed to enable others to implement sustainable VLS-PV systems in the future.

Major Activities

For the future sustainable development and spread of knowledge base, a discussion to develop an instruction for realizing VLS-PV systems was started. Essential knowledge from Subtask 4 will be included in the instruction, as well as practical experiences and governmental, financial and economic requirements for large-scale energy development projects will be considered.

OTHER ACTIVITIES

Special Seminar on VLS-PV in Western Australia

In conjunction with the 10th expert meeting, a special seminar on VLS-PV in Western Australia took place on February 2, 2004, at the Murdoch University in Perth. This seminar was organized by the Consortium for VLS-PV Western Australia, and approximately 50 participants including Task members joined in. Summary booklet of "Energy from the Desert" was distributed to the participants. Task members introduced the results of the Phase I activities and a status of the Phase II. A panel discussion was held on "How to Realize VLS-PV in Western Australia."

Technical Report

A technical report based on the Phase II activities will be published in spring, 2006. A purpose of the report is to reveal virtual proposals of practical projects suitable for selected regions, which enable sustainable growth of VLS-PV in the near future, and general instructions to propose practical projects for realizing VLS-PV system in the future.

DELIVERABLES

Internal Publications

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

External Publications

Book: "ENERGY FROM THE DESERT", James and James, 2003 (ISBN 1 902916 417)
Report: "Summary - ENERGY FROM THE DESERT", 2003

MEETING SCHEDULE

Meetings Held

1st June 28-29, 1999, Paris (France)
2nd December 1-2, 1999, Utrecht (The Netherlands)
3rd April 30, 2000, Glasgow (UK)
4th September 15-16, 2000, Sacramento (USA)
5th June 9-10, 2001, Cheju Is. (Korea)
6th September 2-4, 2001, Ulan Bator (Mongolia)
7th February 27-March 1, 2002, Utrecht (The Netherlands)
8th September 12-13, 2002, Warsaw (Poland)
9th June 30-July 1, 2003, Lens (France)
10th February 2-5, 2004, Perth (Australia)
11th June 5-6, 2004, Paris (France)
12th January 9-11, 2005, Scottsdale (USA)

Meetings Planned

13th June, 2005, Leipzig (Germany)

Fig.4 - 12th meeting's technical visit to PV system test site, APS Star Center.

LIST OF TASK 8 PARTICIPANTS

COUNTRY	PARTICIPANT	ORGANISATION
Canada	Mr. John S MacDonald	Day4 Energy Inc.
Germany	Mr. Claus Beneking Mr. Matthias Ermer	ErSol Solar Energy Shell Solar GmbH
Israel	Mr. David Faiman	Ben-Gurion University of the Negev
Italy	Mr. Fabrizio Paletta Mr. Angelo Sarno	CESI SFR-REI ENEA
Japan	Mr. Kosuke Kurokawa Mr. Masakazu Ito Mr. Kazuhiko Kato (OA) Mr. Kenji Otani Mr. Keiichi Komoto Mr. Masanori Ishimura (secretary)	Tokyo University of Agriculture and Technology (TUAT) Tokyo University of Agriculture and Technology (TUAT) The National Institute of Advanced Industrial Science and Technology (AIST) The National Institute of Advanced Industrial Science and Technology (AIST) Mizuho Information & Research Institute (MHIR) Photovoltaic Power Generation Technology Research Association (PVTEC)
Korea	Mr. Jinsoo Song	Korea Institute of Energy Research (KIER)
The Netherlands	Mr. Leendert Verhoef Mr. Peter van der Vleuten	New-Energy-Works Free Energy International bv
Spain	no participation	
USA	no participation	
Mongolia (observer)	Mr. Namjil Enebish	Ministry of Infrastructure

TASK 9 - PHOTOVOLTAIC SERVICES FOR DEVELOPING COUNTRIES

Fig. 1 - PVSDC publications.

RATIONALE AND OBJECTIVE

There are around 2 billion people in the world who do not have access to adequate clean water supplies, electric lighting, primary health care, education and other basic services. At the Millennium Assembly of the United Nations in 2000, the international community adopted the eight Millennium Development Goals (MDGs), and set clear and ambitious targets for improving the conditions of these disadvantaged people. The focus of the programmes of the world's development assistance agencies (bilateral and multilateral donors, development banks, NGOs) are now clearly aimed at poverty alleviation in general, and at achieving the MDG targets in particular.

PV is uniquely attractive as an energy source to provide basic services, such as lighting, drinking water and power for income-generating work, for the people without access to electricity. After five years of work, PVPS Task 9 (PVSDC) has adopted the primary mission of Increasing the sustainable use of PV in developing countries in support of meeting the targets of the Millennium Development Goals.

The objective of PVSDC is to increase the rate of successful deployment of PV systems (i.e. the rate of rural electrification) in developing countries. This is being promoted through enhanced co-operation and flow of information between the IEA PVPS Programme and the other international development stakeholders. PVSDC has drawn upon the experience of the participating countries aid and technical assistance programmes, as well as the work of agencies, such as the Global Environment Facility (GEF), World Bank and United National Development Programme (UNDP). By this means, objective and impartial information is published and disseminated through workshops and seminars. PVSDC's work with PV also takes account of other renewable energy technologies, such as micro-hydro and wind. The team advocates use of the most appropriate technology in particular circumstances and does not simply promote PV.

ACHIEVEMENTS IN 2004

Task 9 has been operational since May 1999. The Phase One Workplan, which comprised three subtasks, concluded in April 2004.

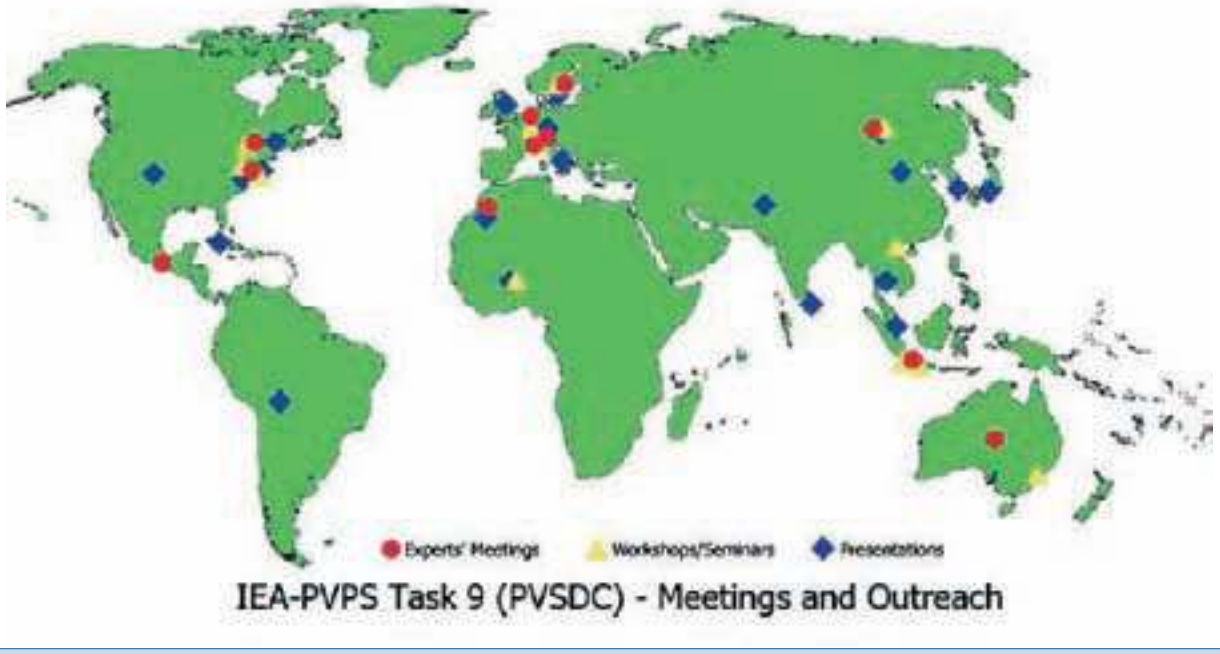
SUBTASK 10: Deployment Infrastructure: This work contributes to overcoming the critical barriers to widespread PV deployment and implementation through the development, dissemination and application of a series of guideline documents to promote the necessary infrastructure requirements in developing countries. The aim has been to develop and disseminate a coherent series of guideline documents to promote the necessary infrastructure requirements in developing countries to help overcome the critical barriers to widespread PV deployment and implementation. The Recommended Practice Guides (RPGs) published by Task 9 are shown in Figure 1.

The overview document of issues for photovoltaics in developing countries "*Photovoltaics for Development: The Key to Success*", previously anticipated for publication in early 2004 is the only outstanding deliverable from Phase One. The document will present a short overview of PV deployment in developing countries and the key points and messages of Task 9, as previously indicated. However, it is also being realigned to emphasise the linkages to the Millennium Development Goals and the International Action Programme that emerged from the conference, Renewables 2004, held in Bonn in June. This document is now expected to be published in early 2005.

Five Recommended Practice Guides (RPGs) were published during 2002 and 2003. New, extended Executive Summaries for each of the RPGs were written towards the end of 2004. It is anticipated that these will be translated into a number of different languages. The RPG's have been promoted at a number of Workshops (see below), and are all available for download from the main IEA-PVPS website.

SUBTASK 20: Support and Co-operation: PVSDC stimulates awareness and interest amongst the multi- and bilateral agencies, NGOs and other target sectors on the technical and economic potential and opportunities arising from energy / PV. This enables decision-makers to obtain the expertise and knowledge that is required for the appropriate PV system deployment. Task 9's global outreach is illustrated in Figure 2.

A seminar and three workshops were organised in 2004. The seminar took place in March for the Swedish International Development Co-operation Agency (SIDA) and other Swedish stakeholders. A major two-day workshop, *From Projects to Markets*: *Perspectives for Private Sector Participation*, was held for the German Development Bank, KfW, and the German Technical Co-operation Agency, GTZ at the GTZ Headquarters in Eschborn in March. Two half-day workshops were organised for Francophone stakeholders: *The Role of Photovoltaics in Rural Electrification Programmes* was an integral part of the



workshop of the "Club of Rural Electrification Agencies" held in Ouagadougou, Burkina Faso in May. In June a workshop was held at the Direction des Relations Économiques Exterieures (DREE) of the French Ministry of Finance in Paris, to coincide with the European PVSEC. Task 9 held discussions with the World Bank on possible future joint workshops and information dissemination.

The work of Task 9 was also presented at several conferences and seminars in developed and developing countries including PVSEC-14 in Bangkok, (January), Renewables 2004 in Bonn (May), 19th EPVSEC in Paris (June), WREC-VIII in Denver (September) and at a joint meeting with Task 1 for Australian stakeholders in Sydney (September 2004).

The Norwegian Development Agency, NORAD, continues to show interest in joining PVSDC in the future and a seminar, similar to that organised by SIDA (see above) and earlier for the Canadian International Development Agency (CIDA), has been offered.

Task 9 has established linkages with organisations such as the Global Village Energy Partnership (GVEP), the Renewable Energy & Energy Efficiency Partnership (REEEP) and the EU Energy Initiative (EUEI). The immediate priority is to ensure that these (& other relevant) groups are aware of IEA-PVSDC activities and network.

This activity aims to ensure that Task 9 is meeting the expectations of its target audience, as well as increasing the dissemination of Task 9 materials. All Task 9 reports are available for download from the main PVPS website. Some additional materials, such as workshop presentations are made available via Task 9's website.

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

The guide, entitled "PV for Rural Electrification in Developing Countries - Programme Design, Planning and Implementation", was published in September 2003. A new draft of the document Financing PV Deployment in Developing Countries was approved by the ExCo in March 2004. The report is available from the PVPS main website.

Phase 2 Workplan

The workplan for a Second Phase, continuing some of the work from Phase One and introducing a number of new elements, was approved by the Executive Committee in May 2004. In order to achieve the ongoing and new objectives, the collaborative work under Phase Two is organised into four Subtasks.

Preparatory work and planning of three new subtasks has been undertaken during 2004. The activities will commence in earnest in 2005.

SUBTASK 20: SUPPORT AND CO-OPERATION

This is a continuation and expansion of the outreach work of phase 1.

SUBTASK 40: PV ENERGY SERVICES FOR RURAL ELECTRIFICATION AND POVERTY ALLEVIATION

This work reviews and investigates the techno-economic aspects and potential of PV systems for provision of rural services and poverty alleviation. This focuses on the role of PV in the provision of water, health, education and Information & Communication Technologies (ICT) services, PV battery charging stations, hybrids and village mini-grids. The approach is to collate information from topical PV case studies and use the information to develop review documents and guides.

Fig. 2 - Car batteries are often charged at a central station (PV, hydro or diesel) and used in unelectrified homes for lighting and TV (Cambodia).

Fig. 3 - Car radios are increasingly adapted into products specifically for home use, powered by PV (China).

There are five main activities:

- Economic Assessment of PV Energy Services
- PV Based Energy for Water Services
- PV in Health, Education and ICT
- Battery Charging Stations and PV Hybrids and Mini-grids
- Role of PV in the Alleviation of Poverty
- Internal working groups and internet are being established to identify information gaps and to define most appropriate work areas for subtask 40.

SUBTASK 50: MARKET PENETRATION ACTIVITIES

This investigates technical and economic aspects of PV power packs and large-scale (~ 1 MWp) grid-connected PV plants. There are many locations in the developing world where electricity demand is growing rapidly and lack of capacity frequently results in power cuts or 'brown-outs' caused by indiscriminate load shedding. This Subtask will collate relevant case studies and review situations in developing countries where network capacity and/or generation capacity needs to be increased and where it is cost-effective to install PV (or PV hybrids) as an alternative. The work will also examine emerging grid-connected or grid-support applications for PV in developing countries. The objective is to evaluate the techno-economic aspects of small PV Power Packs (which provide back-up power supply to customers when grid supplies are cut) and Grid support applications in developing countries.

The main outputs will be review documents and a number of relevant case studies.

Australia will lead the work for subtask 50, commencing with a review of grid-connected systems for developing countries. This internal report will be completed early in 2005 and will establish the baseline for further work.

SUBTASK 60: PV AND THE KYOTO MECHANISMS

This work collates and disseminates information from the Clean Development Mechanism (CDM) process which may become relevant to the deployment of PV systems in developing countries. Many developing countries are looking to the CDM to help leverage funding to achieve sustainable economic development, through investment in renewable energy and end-use efficiency projects which fit with their developmental needs. This Subtask will provide updated information on the opportunities for PV project developers and governments in developing countries arising from the CDM process.

The Experts appointed to the Task cover a broad range of experience, including technical PV experts, development economists and sociologists, and other renewable energy technologists. Representatives from developing countries also participate. Work includes dissemination of information on the development of the CDM process in relation to PV projects in developing countries. Outputs will be a newsletter providing regular updates on developments in the CDM process, a review of bundling PV projects for CDM new baselines and pilot projects.

Subtask 60 will commence with a review and short commentary for internal discussion on the relevance of CDM for PV projects in developing countries. Task 9 will maintain a watching brief for future developments.

Plan for 2005

The first Task 9 meeting of 2005 will be held at the World Bank in Washington DC, to coincide with *Energy Week*. This is an important gathering of stakeholders concerned with energy in the developing world. This also includes a number of other events, including a meeting of the Renewable Energy Financing and Policy Network Forum, which is a World Bank input to the Renewable Energy Global Policy Network (REGPN), which was a key outcome of the *Renewables 2004* conference in Bonn. Task 9 will participate in Energy Week and the associated events and will make a presentation in the session entitled Energy and the Millennium Development Goals.

Now that the European Photovoltaic Industries Association (EPIA) has become a member of PVPS, Task 9 will co-operate with the EPIA *Catapult project*, which promotes rural electrification in developing countries. Task 9 and EPIA will co-operate to organise a workshop at the 20th European Photovoltaic Solar Energy Conference in Barcelona in June.

Task 9 representatives will also participate in an ASEAN Regional PV Standards Harmonisation Workshop in Laos in March.

Swedish participation in Task 9 will in 2005 expand to bring experts from Tanzania and Zambia to join the team. This recognises the new emphasis on support for Africa, where there is a very large potential for PV but impact has been far less than, for example, in Asian countries. The World Bank and GEF have announced that they will

increase support for projects in Africa, and this topic will be on the agenda of the G8, which will be chaired by the UK. An invitation has been received to plan a future meeting in Uganda.

MEETING SCHEDULE (2004 AND PLANNED 2005)

2004 meetings:

10th Experts' Meeting, 8-10 March 2004, Stockolm, Sweden.
11th Experts' Meeting, 13-15 September 2004, Alice Springs, Australia.

2005 meetings:

12th Experts' Meeting, 14-17 March 2005, Washington, USA (to coincide with World Bank Energy Week).
13th Experts' Meeting, 10-14 October 2005, Shanghai, China (to coincide with PVTEC -15).

TASK 9 PARTICIPANTS

COUNTRY	NAME	AFFILIATION
Australia	Geoff Stapleton	GSES
Canada	Fayez Malek	CIDA
Denmark	Peter Ahm Jean Paul Laude	PA Energy A/S DANIDA
France	Bernard Chabot Anjali Shanker Lara Bertarelli	ADEME IED IED
Germany	Rolf Posorski	GTZ
Italy	Francesco Groppi	CESI
Japan	Takayuki Nakajima Tetsuzou Kobayashi Takahito Ilma	JPEA Showa-Shell Shikoku Electric Power Co. Inc
Switzerland	Alex Arter	ENTEC
Sweden	Anders Arvidson	Stockholm Environment Institute
United Kingdom	Bernard McNelis Paul Cowley	IT Power
USA	Mark Fitzgerald Wendy Parker	ISP ISP

Fig. 4 - Small home lighting systems can also be powered by pico-hydro (Ecuador). PVSDC also investigates other renewable energy technologies, as well as PV.

PVPS AND THE MILLENNIUM DEVELOPMENT GOALS

Delivering a real contribution towards achieving the Millennium Development Goals (MDGs) is one of the strong driving principles behind PVSDC.

Neither access to modern energy services in general, nor provision of electricity are recognised as specific goals in themselves. Nevertheless they can play a central role in poverty alleviation, through impacts on education, health and local enterprise, as well as access to modern telecommunications and information technology resources.

The MDGs and some of the roles for PV are:

1. **Eradicate extreme poverty and hunger** - Lighting allows increased income generation and reliable electricity encour ages enterprise development, energy for water supplies for cooking and drinking and water for irrigation increases food production.
2. **Achieve universal primary education** - Electricity enables access to educational media and communications, energy helps create a more child-friendly environment and reduces school drop-out rates and lighting in schools allows evening classes and helps retain teachers.
3. **Promote gender equality and empower women** - Availability of modern energy means that women do not have to carry out survival activities, good quality lighting permits home study and reliable energy services offer scope for women's enterprises to develop.
4. **Reduce child mortality** - Electricity can bring about less indoor air pollution, increased safety, free up more time to be spent on child care and provide pumped water and purification.
5. **Improve maternal health** - Energy services provide access to better medical facilities (vaccine refrigeration, equipment sterilization, operating theatres). Provision of cooked food and space-heating contribute to better health.
6. **Combat HIV/AIDS, malaria and other diseases** - Energy services provide better medical facilities, and energy can help produce and distribute sex education literature and contraceptives.
7. **Ensure environmental sustainability** - Traditional fuel use contributes to erosion, reduced soil fertility and desertification, energy can be used to pump and purify clean ground water.
8. **Develop a global partnership for development** - Energy supply can contribute to the development of information and communication technologies in remote / rural areas.

TASK 10 – URBAN SCALE PV APPLICATIONS

Fig. 1 - Task 10 2nd Technical Experts Meeting, Florence, Italy, October 2004.

OBJECTIVE

The objective of Task 10 is to enhance the opportunities for wide-scale, solution-oriented application of PV in the urban environment as part of an integrated approach that maximizes building energy efficiency and solar thermal and photovoltaics usage. Value analysis, policy incentives, analysis tools as well as system design and integration that have proven successful in the participating countries will be developed to the extent possible into a uniform international set of tools for the global market. This will be accomplished through:

- making connections between the building design and development industry;
- deriving recommendations for stakeholders to remove barriers to mass market uptake of photovoltaics;
- developing system components, design and applications with the largest global market penetration potential, including aesthetic values as well as the mechanical and energy related values;
- expanding successful tools (models, roadmaps, guides, system integration, etc.) and analysis relevant to the needs of the emerging global markets;
- identifying gaps in currently available information and developing products to fill those gaps;
- developing materials and holding events targeted at meeting the needs of specific groups of stakeholders; and
- providing continuous communication, promotion and education throughout the period of the task.

In line with the objectives, the short term goal (5 years post) of the Task is to have a clear definition of the global market and all associated values, resulting in stakeholders considering urban scale PV in their respective spheres of activities. The Task's long term goal (10 years post) is for urban-scale PV to be a desirable and commonplace feature of the urban environment in IEA PVPS member countries.

Task 10 work initiated in January 2004. The task will require a 5 year period to complete.

APPROACH

There will be four subtasks in Task 10. The total range of deliverables has been designed comprehensively to include and meet the various needs of the stakeholders who have been identified as having value systems which contribute to urban-scale PV. The deliverables are designed to optimise usefulness to the stakeholders and have multiple communication and promotion scenarios. Although each of the deliverables is a separate product which can be developed independently from all the other deliverables, the relationship between deliverables will be cross-referenced or data based as appropriate. Through developing and producing these deliverables, Task 10 will contribute to achieving the vision of mainstreaming urban-scale PV. The comprehensive list of targeted stakeholders is:

- **Building Sector:** builders and developers, urban planners, architects, engineers, permit and code authorities;
- **End-Users:** residential and commercial building owners;
- **Government:** supporting, regulatory and housing agencies;
- Finance and Insurance Sector: banks, insurance companies, loan for houses
- **PV Industry:** system manufacturers, PV system supply chain, retail sector;
- **Electricity Sector:** network and retail utilities; and
- **Education Sector.**

SUBTASK 1: Economics and Institutional Factors

This subtask seeks to provide opportunities for stakeholders to look beyond a single-ownership scenario to the larger multiple stakeholder value. In this way, utility tariffs, community policy, and industry deployment strategy can be used to create scenarios which combine all stakeholder values to the PV system investor through sustained policy-related market drivers. Australia leads this subtask. Activities will include:

Activity 1.1: Value Analysis

This activity will develop a value matrix of stakeholders by the extended value stream beyond the economic market drivers (the market drivers will be included), allowing individual stakeholders to realise a full set of values. Australia leads this activity.

Progress includes a stakeholder value survey developed and implemented with the participating technical experts as well as other interested countries. The results of the survey will be presented in a paper at the PVSEC conference in Barcelona, Spain in June 2005. Additionally, the US has developed analysis on government stakeholder economic values such as emissions, health care cost and water consumption reductions, jobs, gross regional product, and household incomes.

Activity 1.2: Barriers Resolution

Recommendations to stakeholders will be developed for removing barriers to mass market uptake of PV. Australia leads this activity.

Progress includes the development of a barriers survey which will be implemented in 2005.

Activity 1.3: Market Drivers

Building upon existing lessons learned with financing, policy, environmental and rate structure issues this activity will analyse the economic contribution of these market drivers and developing best practice scenarios. Australia leads this activity.

Progress includes the collection of individual country's analysis. The surveys in activities 1.1 and 1.2 will be used to determine priorities for the global analysis.

Activity 1.4: Market Roadmaps

Using participating country industry roadmaps, either a global market roadmap or a roadmap of global markets will be developed. Either product will serve as a guide for roadmap development. The United States leads this activity.

Progress on this activity includes analysis of the European Industries Association Roadmap, the US Industry Roadmap and the Australian Industry Roadmap.

SUBTASK 2: Urban Planning, Design and Development

This subtask focuses on infrastructure planning and design issues needed to achieve the vision of a significantly increased uptake of PV in the urban environment. The subtask will integrate PV with standard community building practices.

Activity 2.1: Integrating PV Development and Design Practices

This activity will develop guidance for integrating PV into standard whole building design models, rating tools, and building development practices. Emphasis will be placed on the building integration properties of PV for efficiency gains.

Activity 2.2: Urban Planning

A guide will be developed for integrating PV and the whole community energy infrastructure element into urban planning practices through a guide providing processes and approach for setting quantifiable urban-PV goals and objectives in the planning process. Architectural considerations such as building aesthetics, land use, shading, and urban renewal opportunities for BIPV will be included as planning elements. Additionally, community energy use forecast and planning impacts related to the whole building approach and coordinated utility or community system load control to increase demand reduction and increase PV capacity value. The US leads this activity.

Progress on this activity includes analysis of 12 US communities that have taken steps to renewable and efficiency technologies into urban planning. The analysis will be presented at the PVSEC in Barcelona Spain, June 2005, and is developing an input template for the other participating countries to collect similar data.

SUBTASK 3: Technical Factors

This subtask concentrates on technical development factors for mainstream urban-scale PV. Large-scaled urban integration of BIPV systems faces technical challenges related to synergetic use as building material and for energy supply purposes. Other challenges involve the potentially negative impact on the grid and obstacles posed by the regulatory framework. The aim of this subtask is to demonstrate best practices and to advocate overcoming those barriers associated with extensive penetration of BIPV systems on urban scale. The deliverables focus on the broad set of stakeholders required to achieve the vision such as the building product industry, builders, utilities and PV industry.

Activity 3.1: Building Industry/BIPV Products and Projects

By identifying the building material and energy use synergies of PV and of BOS as well as updating the existing Task 7 database of products and projects for BIPV, guidance will be developed for mainstreaming these products in the building industry . A major aspect of the building integration will be building energy management integration and coordinating energy use with lighting and HVAC systems to assure demand reduction and capacity value. Canada is the lead for this activity.

Progress includes the development of a detailed workplan entitled "Residential Urban BIPV in the Mainstream Building Industry" presented at the October technical experts meeting for critique and input. Additionally, Malaysia presented the Country's BIPV development program plan, which could potentially serve as a guide for other countries as well as communities program development.

Activity 3.2: Codes and Standards

Existing codes and standards applicable to urban scale PV and the needs for developing new codes and standards will be evaluated. Both electrical and structural codes will be evaluated as related to buildings. Network codes and standards will be evaluated in a separate activity. This work will build upon work initiated in Tasks 5 & 7.

Activity 3.3: Electricity Networks

This activity will analyse electricity network effects, benefits, impacts, and issues. Interconnection, operational effects, and market issues will be included.

Progress includes the collection of analysis of PV's contribution to peak load reduction in both Australia and the US.

Activity 3.4: Market Driven Approach

The US developed systems driven approach to research and development will be expanded to the global market by i) establishing a benchmark of current system component cost and market penetration relationships; ii) testing benchmark relationships with existing and potential future system designs, applications, building integration and operational economics; and iii) documenting relationship between research investment in system component development and market penetration.

Progress is the initiation of work on a Canadian contribution focusing on the Mass Customising Photovoltaic Solar Homes in Subdivision Development.

Activity 3.5: Certification Practices

Certification practices will be reviewed and standard test procedures harmonized and transferred to the relevant stakeholders and standard committees.

SUBTASK 4: Targeted Information Development and Dissemination

This subtask will carry out the information dissemination of all deliverables produced in Task 10. As activities develop in other subtasks, subtask 4 will review to assure the results are useful to the targeted stakeholders. Participating countries will be encouraged to translate documents and workshop materials. This task will also organise countries to host technical development and education workshops. The subtask will also prepare mass/multi-market promotional material about urban-scale PV and will update existing

TABLE 1 LIST OF PARTICIPANTS AND THEIR ORGANISATIONS

COUNTRY	PARTICIPANT	ORGANISATION
Australia	Mrs. Georgine Duncan	Origin Energy
Austria	Mr. Reinhard Haas Mrs. Assun Lopez-Polo	Institute of Power Systems and Energy Economics Energy Economics Group Vienna University of Technology
Canada	Mr. David Elzinga Mr. Masa Noguchi	Arise Technologies Corporation NRCan/CANMET Energy Technology Centre - Varennes
Denmark	Mr. Kenn Frederiksen	Energimidt Erhverv A/S
France	Mr. Marc Jedliczka Mr. Bruno Gaiddon	HESPUL
Italy	Mr. Francesco Groppi Mr. Gianluca Tondi	CESI S.p.A. ETA Renewable Energies
Korea	Mr. Suk-Hyung Lee	Daegu City Gas Co., Ltd.
Malaysia	Mr. Ahmad Hadri Harris	Malaysia Energy Center, PTM
Portugal	Mrs. Maria Joâo Rodrigues	Center for Innovation Technology and Policy Research Instituto Superior Têcnico (Technical University of Lisbon)
Spain	Mrs. Estefanía Caamaño Martín Mrs. Ana Rosa Lagunas	INSTITUTO DE ENERGÍA SOLAR E.T.S.I. Telecomunicación, Ciudad Universitaria s/n Centro Nacional de Energias Renovables CENER
Sweden	Mr. Mats Andersson	Energibanken AB
Switzerland	Mr. Peter Toggweiler Mr. Daniel Ruoss	Enecolo AG Enecolo AG
USA	Ms. Christy Herig	Segue Energy Consulting/Subcontractor to National Renewable Energy Laboratory

PV education tools. An innovative deliverable will involve holding a competition for urban-scale PV with the winner of the competition announced at a forum on PV for the venture capital sector. Market research for the purpose of understanding and targeting stakeholder perceptions will also be part of this subtask. Finally, this task will be responsible for continuous outreach to stakeholders for input and participation in the task.
France is the Subtask leader.

Activity 4.1: Educational Tools

Sweden leads this activity.
This activity will include a best practices web site which will include templates for tender documents, sales contracts, consumer guides, as well as best practices, detailed real project development information.

Progress has been made through the collection of templates and the Swedish web site Sol Cell.Nu has been identified as the host for this information.

Activity 4.2: Competition

Progress will occur in March of 2005 when Portugal will launch the Lisbon Ideas Challenge - Designing with Photovoltaics: New Energy Concepts for the Built Environment.

Activity 4.5: Continuous Communication

France leads this activity.

Progress includes three 2004 workshops, a task 10 brochure and a fully active website.

INDUSTRY INVOLVEMENT

An integrated multidisciplinary approach involving all stakeholders will be used in carrying out the work in Task 10. The PVPS Programme will be the managing Implementing Agreement for the Task, but to assure the results contribute effectively to wider whole-of-building integrated urban-scale efforts, the Task will actively coordinate with several IEA Implementing Agreements. The approach recognizes that optimising good design and solar thermal and PV potential and maximizing their synergies will require cooperation of a number of the Implementing Agreements (particularly the Photovoltaic Power Systems Programme, the Solar Heating and Cooling Programme, and the Energy Conservation in Buildings and Community Systems Programme). To assure coordination, implementing agreement liaisons will be established in order to participate in Tasks and Subtasks (and potentially activity level endeavours) contained in other implementing agreements.

KEY DELIVERABLES (PLANNED 2004)

- 2nd International Symposium, Photovoltaic-Electricity From the Sun, February 11, 2004, Vienna - Austria.
- Oral Paper Mainstreaming PV in the Urban Landscape - Activities of the New Task 10 IEA PVPS Implementing Agreement, 19th PVSEC, Paris, France, June 2004.
- Architects and Builders workshop for French stakeholders during the 19th PVSEC, Paris, France, June 2004.
- Brochure/flyer for outreach to stakeholders.
- Task 10 website with front end for stakeholder outreach and Task 10 participants' password accessible working platform.
- Italian Stakeholders Workshop, PV integration in urban areas, October 6, 2004 Florence, Italy.

(PLANNED 2005)

- Workshop targeted at all building sectors, Photovoltaics in Buildings: Opportunities for Building Product Differentiation, Lisbon, Portugal March 16th, 2005.
- Workshop targeted at government stakeholders, Washington DC, October, 2005.
- 2 abstracts submitted to the ISES conference in Orlando, Florida, USA, August 2005.
- 2 abstracts submitted to the 20th PVSEC, Barcelona Spain, June 2005.
- Best practises website.

TABLE 2 – MEETING SCHEDULE (2004 AND 2005 PLANNED)

TASK 10 MEETING	DATE	PLACE
1st Task 10 Technical Experts	Feb. 4-5, 2004	Vienna, Austria
2nd Task 10 Technical Experts	Oct. 4-5, 2004	Florence, Italy
3rd Task 10 Technical Experts	March 17-18, 2005	Lisbon Portugal
Combined 26th Task 1 and 4th Task 10	June 1-3, 2005	Lyon, France
5th Task 10 Technical Experts	October 6-7, 2005	Washington, DC, USA

AUSTRALIA

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS
DR MURIEL WATT, CENTRE FOR PV ENGINEERING,
UNIVERSITY OF NSW

GENERAL FRAMEWORK

The use of photovoltaic power systems (PV) in Australia continues to grow moderately, with installed capacity increasing by 16,6 % (almost identical to the previous year) to reach a total installed capacity of 45 630 kW by the start of 2004. Although not the main focus of government support programmes, off-grid non-domestic applications continue to dominate Australia's cumulative installed capacity (about 57 % by 2004, which is one percentage point lower than the previous year and down from about 75 % in the mid 1990's), with an annual growth rate that decreased slightly during 2003 to 14,6 % (compared with 18,6 % in 2002, 12 % in 2001 and 4 % in 2000). Off-grid domestic applications have enjoyed strong growth over the last decade and continue to benefit from the government support programmes aimed at increasing the use of BIPV and replacing diesel use with renewables. These applications accounted for almost 30 % of the cumulative installed capacity by 2004, again slightly lower than the figures for the previous years. Total off-grid cumulative installed capacity accounts for close to 87 % of PV installed in Australia.

The amount of PV that was connected to the grid has doubled each year over the past two years and the grid-connected market segment now exceeds 13 % of the total installed capacity compared with less than 1 % about seven years ago. The national BIPV support programme (which initially commenced in 2000) and, to a lesser extent, the mandatory renewable energy target (MRET) for electricity retailers and major energy users (implemented in 2001 and recently reviewed), which are both discussed later in this report, are widely perceived as the key factors behind this market growth. The Australian PV Industry Roadmap, launched in August 2004, identifies enhanced feed-in tariffs (a measure not implemented in Australia to date, although similar to MRET) as an important component amongst a suite of measures for promoting grid-connected PV in Australia.

The Australian electricity industry continues to play a role in both remote area power supply and grid-connected PV, although the degree of interest varies between businesses. This interest lies with both the retailing and network businesses and is largely stimulated by issues of customer contestability, the operation of greenhouse gas reduction agreements or licence conditions in a number of states and, more recently, as a means of reducing peak demand on mini grids and for selected substations.

The public is generally supportive of PV and interested in its use - however, even with rebates, PV investments for grid-connected households and community applications are difficult to justify on economic grounds because of Australia's relatively low electricity tariffs.

NATIONAL PROGRAMME

The Australian Government has initiated a number of measures over recent years to support renewable energy in general and, in some cases, PV in particular. These include:

Fig. 1 - Australian cell line (photo BP Solar).

Mandatory renewable energy target - this target seeks to increase the contribution of renewable energy sources in Australia's electricity mix by 9 500 GWh per year by 2010, with that target continuing until 2020. Since 1 April 2001, electricity retailers and large energy users (known as liable parties) must purchase increasing amounts of electricity from renewable sources. A trade in Renewable Energy Certificates (RECs) and financial penalties for non-compliance are features of this scheme. A major review of the scheme - *Renewable Opportunities:* A Review of the Operation of the *Renewable Energy (Electricity)* Act 2000 - was published in January 2004. With respect to PV, the recommendations of the review that have been supported by the Government during 2004 include: extending the deeming provisions for small PV systems from 5 to 15 years and increasing the deeming threshold from 10 to 100 kW. These changed provisions are expected to pass through Parliament in early 2005. This could equate to an effective 5-10% reduction in the system price based on current RECs value, since deemed systems can claim their RECs when installed, rather than on the basis of actual annual output.

Supporting the use of renewable energy for remote power generation (RRPGP) - this programme commenced in 2000 and is expected to make available around 200 million Australian dollars over nine years

Fig. 2 - Aerial view of Kings Canyon (photo Advanced Energy Systems).

for the conversion of remote area power supplies (including public generators and mini-grids) from diesel to renewable energy sources, and for new renewable installations that would otherwise have been fueled by diesel. The RRPGP provides up to 50 % of the capital value of the replacement or new renewable generation for off-grid users of diesel-based power systems. Recent changes to the terms of the grants mean that from 2005 fringe-of-grid will also fall under RRPGP, grants will now be available for other fossil-fuel replacement (not just diesel), and that energy efficiency and solar water heaters will also qualify. The programme is administered by and is different in each State and Territory: Western Australia's Remote Area Power Supply (RAPS) sub-programme, targeting indigenous communities, isolated households and commercial operations such as pastoral properties and tourist and mining operations; Western Australia's Renewable Energy Water Pumping (REWP) sub-programme; Northern Territory's Renewable Energy Rebate Programme (RERP), targeting small and large communities, households, commercial and industrial operations; Queensland's Working Property Rebate Scheme (WPRS) targeting family owned working properties; Queensland's Renewable Energy Diesel Replacement Scheme (REDRS) targeting indigenous communities, households and businesses; Tasmania's Residential Remote Area Power Supply Sub-programme and RRPGP sub-programmes in NSW and South Australia. Bushlight (Indigenous Renewable Energy Services Project) is a national sub-programme which aims to both increase industry capacity to service indigenous communities and to build greater understanding of renewable energy issues within communities, and RESLab is a renewable energy systems test centre, also supported under industry support components of the RRPGP.

Supporting the use of solar photovoltaic electricity on residential and community buildings, the PV Rebate Programme (PVRP) - this programme commenced at the beginning of 2000, initially with 31 million Australian dollars available over four years, and then extended until early 2005 with a further 5,8 million Australian dollars made available. Funding is provided by the Australian Government, with administration by the State Governments, and provides rebates to householders or community building owners who install grid-connected or stand-alone photovoltaic power systems. Under the currently operating extension, householders are eligible for a rebate of 4 AUD/W capped at 4 000 AUD per residential system. Smaller rebates are also paid for extensions to an existing system. Community buildings attract the same rebate but have a higher cap of 8 000 AUD. The Australian Government has also made available one million Australian dollars to fund projects by residential housing developers, through a competitive bidding process.

In June 2004, an Energy White Paper "Securing Australia's Energy Future" was released by the Australian Government. It includes a number of new measures targeting renewables:

Solar Cities trials - 75 million Australian dollars have been allocated over 5 years to demonstrate high penetration uptake of solar technologies, energy efficiency, smart metering and other options aimed at improving the market for distributed generation and demand side energy solutions. Tenders have been called for consortia to install PV and other distributed generation options in four urban sites, with detailed monitoring and associated tariffs, marketing and financing also being supported.

Commercialisation of renewable energy technologies - 100 million Australian dollars have been allocated over seven years to promote strategic development of renewable energy technologies, systems and processes that have commercial potential. A further 20 million Australian dollars will be provided to support development of advanced electricity storage technologies, including batteries, electro-mechanical and chemical storage.

Market Leader Technologies - PV and Remote Area Power Systems have been identified as technologies of strategic importance for Australia and for which Australia has a clear technological advantage internationally. This will be reflected in priorities for Government R&D funding.

State government policies also support PV market growth. For example, the New South Wales Government has set a state-wide benchmark of reducing greenhouse gas emissions. The parties who are required to meet targets for greenhouse gas emissions must reduce the average

Fig. 3 - Pennant Hills 1,5 kWp PV tiles with skylight (photo PV Solar Tiles).

Fig. 4 - Solomon Islands 600T Sun Mill (photo Solar Energy Systems).

emissions of greenhouse gases from the electricity they supply or consume to the pre-set individual benchmark level (or they pay a penalty). To achieve the required reduction in greenhouse gas emissions, benchmark participants purchase and surrender certificates called NSW Greenhouse Abatement Certificates (NGACs) which may be created by any eligible measures which reduce the average greenhouse intensity of electricity generation. In theory, this includes grid-connected PV systems, though in practice the relatively low penalty (buy-out) favours already economic or nearly-economic demand-side measures.

A number of key agencies at both Federal (the Australian Greenhouse Office) and State (the NSW Sustainable Energy Authority) levels have been restructured and their functions absorbed within broader departments. The likely impacts of these changes are not clear at this time, though for the time being most PV-related programmes are continuing in line with existing plans.

R&D, D

Australian Government annual funding for PV R&D, D (including market incentives) was about 29,2 million Australian dollars during 2003 (compared with 20,3, 16,7 and 24,6 million Australian dollars for the three previous years). Funding from the state governments for the same period was around 0,9 million Australian dollars, significantly more than for the previous year.

A new Centre of Excellence in Advanced Silicon Photovoltaics and Photonics has been established at the Centre for PV Engineering, University of NSW. Research streams are focused on short (1st generation), medium (2nd generation) and long term (3rd generation) technology needs. 1st generation work includes continued improvement of the buried contact cell, the use of phosphorous doping in place of boron, and fabrication on thinner wafers. 2nd generation research includes support for commercialising crystalline silicon on glass technology, as well as research into improved silicon deposition quality and grain size, manufacturing cost reduction and non-metal contacts. 3rd generation technology is expected to be both high efficiency and thin film, with research focusing on all-silicon tandem cells based on bandgap-engineering, silicon light emitting devices and lasers, and light trapping. Other researchers at the University of NSW are working on GaAs solar cells.

BP Solar Australia significantly increased both its mono and poly silicon cell efficiencies by installation of new plasma enhanced chemical vapour deposition (PECVD) Silicon Nitride systems on its production lines. BP Solar continues its development of automated production equipment.

CSG Solar (formerly Pacific Solar) is developing and commercialising a thin film PV technology called Crystalline Silicon on Glass based on initial research at the University of NSW. In addition to its PV module R&D, Pacific Solar developed and commercialised its own module inverters and roof mounting systems which have now been sold as a separate business.

Origin Energy is commercialising the "Sliver cell" PV technology developed by the Australian National University. The technology promises crystalline Si cell performance with significantly lower wafer requirements. The ANU team is also developing parabolic trough and paraboloidal dish PV concentrator systems, and associated concentrator cells, trackers, controllers and mirrors, as well as a Combined Heat and Power Solar System. It is also undertaking research into thermochemical storage and phase change energy storage materials.

Sustainable Technologies International (STI) continued pilot production and further development of its titania dye sensitized solar tiles and panels, with the installation of several demonstration systems.

Solar Systems Ltd. continues development and commercialisation of its PV tracking concentrator dishes for off-grid community power supplies or end of grid applications. Current systems achieve 500 times concentration and use air or water cooling. System efficiencies of 20 % have been achieved. The systems are currently based on silicon cells, but work is continuing on development of non-silicon devices, which are expected to achieve 40 % efficiency.

PV Solar Energy has developed a building integrated PV Solar Tile™ product which can now be used with a PV AirFlow™ ventilation or heat extraction system. The tile itself can be used as a weatherproof roofing material, with good thermal performance characteristics, while the airflow system allows air to flow behind the PV panels and into the roof cavity, whence it can be externally vented in summer (or used for other purposes) or internally vented in winter.

Fig. 5 - Technician Training in Sri Lanka (photo GSES).
Fig. 6 - Telstra installation (photo BP Solar).

Other PV research undertaken at Australian universities include:

- Flinders University - improved dye sensitised solar cells.
- University of Queensland - semiconductor biopolymers
- Newcastle University - nanoscale polymer devices.

IMPLEMENTATION

Annual PV installations in Australia rose to 6,5 MW in the year up to the beginning of 2004 (up from 5,5 MW the previous year) and the figures for total installed capacity continue to be dominated by the off-grid market for agricultural/industrial uses (particularly telecommunications systems, shipping, rail and road signalling, water pumping, cathodic protection, billboards and electric fences) and private dwellings.

More than 3 MW in over 2 000 household / community building PV systems have been connected to the grid as a result of five years of operation of the PVRP. The programme has also resulted in about 3,5 MW and over 3 500 off-grid installations during the same period. This programme is scheduled to end in mid 2005, although extensions are being considered.

The off-grid market is also helped by the RRPGP sub-programmes, with funding available for possibly a further five years. Although it is not PV specific, 2,13 MW of PV has been installed in small projects and 280 kW in larger mini-grid systems under this programme to end 2003. Almost all small systems include some PV and PV makes up about 90 % of installed capacity in small systems. Major PV projects supported by the RRPGP include a 55 kW system at an indigenous community and a 222 kW system at a tourist resort. Three concentrator dish PV systems, with a total capacity of 720 kW are under construction for indigenous communities in the Northern Territory. However, a recent government decision to remove diesel excise for stationary applications is likely to significantly affect the economics for diesel-replacement, which is a key driver for off-grid PV investments.

Green Power sales from the twelve Green Power retailers were recorded at about 131 GWh (year to date) in the third quarter of 2004 (a similar level to the previous year). While the Green Power market in its early stages was a strong driver for PV projects, PV electricity now accounts for less than 0,12 % of total green electricity purchased by the retailers - and is becoming relatively less significant each year. Only one third of the available Green Power products contain PV, with energy retailer EnergyAustralia's PureEnergy product accounting for about half of the Green Power PV electricity sourced nationally.

As for Green Power, the generic market based approach to renewable energy implementation under the MRET scheme has done little to stimulate the PV market. In 2003 about 0,15 % of renewable energy certificates (each equivalent to 1 MWh of generation) created under MRET were generated from PV systems. The modifications to PV deeming provisions mentioned earlier may increase interest in PV for MRET.

Although maintaining a general interest in PV, only a small number of electricity businesses are currently installing PV systems. Some retailers own and operate systems installed during the 1990's. There is some electricity business interest in using PV to achieve peak load reduction in diesel power stations. Electricity businesses will be involved with the four Solar Cities trials.

INDUSTRY STATUS

BP Solar remains the major PV manufacturer in Australia carrying out cell fabrication from imported wafers, through to module fabrication as well as total system production. BP Solar's cell production rose to over 26 MW during 2003 - about 80 % of production capacity. 64 % of cells produced in Australia during 2003 were exported. 9 MW of modules were manufactured, about half of which were exported. Cell production capacity is expanding. BP Solar's module ratings continued to increase, with typical modules now rated at 160 W.

Sustainable Technologies International is manufacturing Titania Dye Sensitized products (first phase capacity of 500 kW) with in-house manufacturing of all the key materials for DSC technology: titania paste, dye, electrolytes, catalytic paste, interconnecting material and internal sealants. The product is aimed primarily at façade integration.

CSG Solar (formerly Pacific Solar) will continue research on its thin-film CSG product in Australia, but will begin manufacture in Germany and has sold its Plug&Power™ ac module business.

Solar Systems is continuing to expand the installation of its successful CS500 solar concentrator PV dishes in remote communities. These parabolic solar tracking dishes consist of 112 mirrors concentrating to the equivalent of 500 suns onto 24 kW water-cooled upgradeable receiving modules.

Origin Energy will open its pilot line in 2005 in Adelaide, which is designed to commercially demonstrate the potential of the Slivers™ technology.

Fig. 7 - Train signalling in the Australian countryside (photo BCSE).

Fig. 8 - Water pumping for stock (photo Solar Sales).

PV Solar Energy Pty Ltd has developed and demonstrated a new PV roof tile, based upon a versatile extruded aluminium frame. The tile uses a new low cost pluggable PV junction box, developed by Tyco Electronics and monocrystalline solar cell laminates.

There are several Australian manufacturers of inverters, controllers, batteries and other components, as well as of specialized end use products, such as water pumps, electric fences, lights and hybrid power supplies. The inverters and controllers cover both grid and off-grid markets, several new products have been introduced and prices fell markedly in 2003, after being relatively stable for some years. This will have significant positive impacts on the overall cost of PV systems.

MARKET DEVELOPMENT

Growth in the local Australian market saw annual sales expanding by 17 % during 2003, down from the 27 % growth experienced the previous year. Imported cells, modules and BOS components are increasingly being used in the Australian market.

Australia's vast size and sparse population have made effective remote area telecommunications, power supplies, water pumping, navigation aids and transport route signaling critical and expensive. PV continues to provide an important commercial alternative to diesel and central grid supplies for such applications. The telecommunications market sector is likely to remain strong over coming years. The water pumping market is also performing strongly. Increased interest and activity are also evident in the medium sized centralised system market for supply to "mini-grids" for off-grid communities and commercial enterprises. Installations include flat plate and concentrator systems for aboriginal communities and for tourist facilities. The off-grid diesel replacement market for PV will however be adversely effected by a Government decision to remove fuel excise from off road diesel usage by 2012.

With its relatively low electricity tariffs, PV remains an expensive option for grid applications in Australia and with government grants for grid-connected systems scheduled to cease during 2005, there is a strong concern that this market sector may well stall.

The MRET review noted that further consideration should be given to special assistance measures that would support the development of the PV industry in Australia, including measures to support increased installation of systems. The PV Industry Roadmap, developed by the Australian Business Council for Sustainable Energy, has outlined a two part policy framework to drive investment in PV and Australian production. Firstly there are the broad-based industry and market development initiatives - market stimulation and support, removal of regulatory barriers and stimulation of industry capacity and capability. Secondly are measures focusing on specific PV markets - 150 000 grid-connected roof-top programme (underpinned by feed-in tariffs), diesel fuel replacement programme and export market initiatives. Targets for installed PV capacity of 350 MW and 6 740 MW by 2010 and 2020 respectively have been identified.

FUTURE OUTLOOK

The Australian PV Industry Roadmap suggests that PV in Australia is at a crossroads. The mid-term outlook for PV applications remains reasonably healthy, but the near-term may present challenges, especially for grid-connected applications. Green Power schemes and MRET are not delivering their initially anticipated levels of investment in PV. There continues to be a lack of PV installations for grid support or other distributed system benefits and it remains a challenge in Australia to promote the real value of distributed generation sources such as PV through appropriate regulation and market mechanisms. Recent state government building energy standards, such as the NSW BASIX scheme which gives credit to PV, may assist in the development of the BiPV market. In addition, consistent planning processes and guidelines, which typically operate at local government level, are needed in order to streamline building approvals and to guarantee solar access. Nevertheless, the installation of PV systems up to 10 kW is becoming more of a straightforward and accepted practice in Australia and work has been carried out on uniform installation and connection guidelines, and straightforward contracts. Interest and initiatives are in evidence at all levels in the community, but public funding support remains critical for the forseeable future.

AUSTRIA

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

HUBERT FECHNER AND ROLAND BRUENDLINGER, ARSENAL RESEARCH

Fig. 1 - Trop - Furniture warehouse St.Johann/ Tirol (photo ATB Becker).

GENERAL FRAMEWORK AND NATIONAL PROGRAMME

The public support schemes in Austria for the new renewable electricity sources from PV, wind and bioenergy and are mainly characterised by discontinuity. After several years where the support for PV was governed by local and regional schemes of the federal states the commencement of the National Green Electricity Act (GEA) on 1.1.2003, provided a fundamental change. From this date, the legislative authority changed from the provincial to the federal level and thus, most of the regional incentives by the federal states were disbanded. The GEA governs not only the support for green electricity but also for electricity from combined heat and power generation. The GEA supplements the Austrian Electricity Law (ELWOG, 2000) which defines the basic framework for the liberalised electricity market.

The overall aim of the GEA is to increase the share of electricity from Renewables to more than 78 % in 2010, based on the obligations of the Renewable Electricity directive of the EU. For this purpose the GEA sets a target to meet 4 % (about 2,3 TWh/a) as well as 9 % (about 5,2 TWh/a) of the public national electricity demand with electricity generated from "new" renewable energy sources (RES) and small hydropower by 2008, respectively. Those "new" RES are suported mainly via long-term guaranteed feed-in tariffs as well as additional investment subsidies to achieve the above mentioned political target quotas. The feed in tariffs are stated by the Federal Ministry of Economics and financed by a supplementary charge on the net price and a fixed price purchase obligation for electricity dealers.

During the first 2 year period of the law which ended in December 2004, it has been above all wind installations which benefited from this law leading to more than 800 MW approved capacity (more than 600 MW already installed) by the end of 2004. However, the role of PV in this law was limited from the very beginning. Although the feed-in tariff stated in the GEA has been supportive for PV with 0,6 EUR per kWh for installations up to 20 kW and 0,47 EUR per kWh for larger systems the framework has a crucial drawback: a 15 MW cap. With the limited availability of the support in mind, a run for permissions for the 8 MW of remaining PV-capacity took place in the first weeks of 2003. Already in mid January the limit was reached and until the end of 2003 the granted capacity was installed. Since then the PV market in Austria has been stagnating and only a few regional authorities have again reintroduced a PV support to overcome the lack of federal incentives.

Since a revision of the GEA has been foreseen for early 2005, the negotiations have started already at the beginning of last year and several drafts have been produced. The current draft for the revised GEA for the first time defines a specific share for each energy source with about 70 % of the support dedicated to biomass. The remaining 30 % are reserved for other sources, support for wind is planned to be phased out during the coming years. Although PV still plays a minor role in the revised draft, small support will probably lead to 3-4 MW of new installations per year. However, this draft of the law revision finally received no consensus in parliament, which leads to a further prolongation of the unfavourable situation with no federal PV support. New negotiations are expected to take place in early spring 2005.

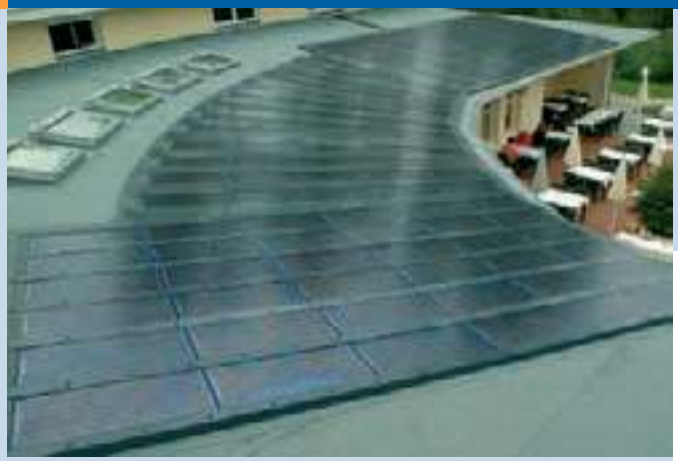


Fig. 2 - Schwedenschanze: Photovoltaic construction of the Rheindelta Motorboat and Sailing Club (photo stromaufwärts, courtesy of Fotostudio Christine Kees).

RESEARCH AND DEVELOPMENT

Austrian PV research activities are mostly focused on national and international project bases: The involved research organisations and companies are participating in various national and European projects as well as in different tasks of the IEA-PVPS Programme. The RTD development and approach is widespread located and decentralised orientated.

The national programme "Energysystems of Tomorrow," successfully initiated by the Ministry of Transport, Innovation and Technology is a quite broad research programme on energy technologies. Although research is not directly related to PV, distributed generation with many aspects relevant for PV is of high priority within this programme.

On a European level, the ongoing initiatives to increase the coherence of European PV RTD programming (PV-ERA-NET) are actively supported by the Austrian ministry of transport, innovation and technology.

Some principal descriptions of these projects highlight the general RTD trend of photovoltaics in Austria:

- Organic Solar Cells based on thin plastic films have been intensively investigated during the last 10 years, at the Kepler University of Linz, terminated recently but leading to the foundation of a local branch of an U.S. PV producer in Linz.
- Socio-economic research concerning the integration of PV is internationally well positioned at the Technical University of Vienna.
- Other areas of institutional and academic research include the improvement of photovoltaic solar cells made from lower purity or multi-crystalline silicon. Recently, a novel front contact grid for multi-crystalline solar cells was patented which reduces the influence of the defects at grain boundaries on the solar cell efficiency.
- Besides crystalline technologies, thin layers of fine polycrystalline silicon deposited at very low temperatures are investigated in order to develop a new type of thin film solar cell. Most recently the work was extended to thin film solar cells prepared from microcrystalline silicon.
- Grid-interconnection, not exclusively related to PV but more to Distributed Generation from RES in general, is the main focus of several EU financed projects, which are jointly carried out by research institutions, industry and utilities.
- Cost reduction and optimization of new solutions for building integrated PV are addressed within several EU projects.
- Other recent activities, mainly in the framework of European projects include studies for the development of combined PV-Thermal collectors.
- In the area of system technology, new activities for quality assurance, certification and testing of PV modules were initiated. Since autumn 2003, arsenal research, an Austrian research & testing institution, is officially accredited to qualify crystalline silicon PV modules according to the EN/IEC 61215 standard.

IMPLEMENTATION & MARKET DEVELOPMENT

Due to the ceasing of the PV support with the 15 MW cap reached in 2003, a serious decline in newly installed capacity to a level of 3-5 MW is expected; less than 50 % of the capacity installed during 2003.

Only in few regions, local incentives have alleviated the unfavourable situation and provide limited support in form of investment subsidies or grants.

The main applications for PV in Austria are grid connected distributed systems, representing more than 90 % of the total capacity. Grid-connected centralised systems in form of PV-Power plants play a minor role with about 1,2 MW installed. Building integration is an important issue and several remarkable installations were realised. Besides on-grid applications, off-grid systems are widely used to provide electricity to technical systems or for domestic use in Alpine households or mountain huts lying far away from the grid. But not exclusively in remote areas, also on urban sites PV is an increasing option to supply infrastructure systems. PV is also becoming more and more visible on Austrian highways supplying the increasing numbers of screens which are informing the drivers with actual information about the traffic situation.

Some provincial governments have built PV-demonstration plants on municipal buildings in order to create public awareness for PV.

INDUSTRY STATUS

Despite an unclear and unsatisfactory situation with almost no national market for PV, the Austrian PV industry could still expand their activities during 2004, focussing on the export of their products to the booming German market.

PVT Austria, the first manufacturer of PV modules in Austria, produces standard and tailored modules from imported crystalline silicon cells. The company successfully increased their output taking profit of the German PV market.

SED manufactures modules specially designed for integration into PV-roof tiles. The custom laminates produced are directly stuck into

Fig. 3 - PV inverter production in Fronius, Wels, Austria.

standard format tiles made of recycled plastic and can easily replace conventional roofing materials.

RKG Photovoltaik, a new company located in the province of Carinthia recently started the production of PV modules from scratch in 2004. The company is closely linked to GREENoneTEC, European's market leader in solar thermal collectors.

Besides PV-Module production, various other companies are manufacturing components for modules and BOS-components like batteries, inverters, or mounting systems.

FRONIUS INTERNATIONAL has been engaged in solar-electronics and is now Europe's second largest manufacturer of inverters for grid connected PV systems.

SIEMENS AUSTRIA started large-scale manufacturing and development of string-inverters in the range of 1,5 kW to 4,6 kW for grid connected applications in 2004.

ISOVOLTA AG is the world market leader for flexible composite materials used for encapsulation of solar cells. The ICOSOLAR back sheet laminates are available in various colours and are used by many module manufacturers in the world.

BANNER BATTERIES is an important manufacturer of lead-acid batteries for off-grid PV applications.

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

MARKET DEVELOPMENT

The long time existing National Photovoltaic Association which has restarted in spring 2003 has expanded its activities by creating a national network for dissemination of information on PV and initiating awareness raising activities. By fostering the political contacts and intensive political lobbying work for PV, the association is aiming at changing the legislative frame conditions for PV by introducing stable and supportive PV market incentives preferably based on feed in tariffs.

About 30 companies involved in the PV business are currently members of the Association. Besides political lobbying, the association has recently issued the "Austrian PV Roadmap," a PV marketing Concept for Austria and also awards the biannual "Youth Solar Award."

A national PV-network "PVPS.NET" was created, funded by the Ministry of Transport Innovation and Technology, aiming at supporting the implementation of PV in the building sector. The PV installers and module producers together with architects are preparing tools for the architects and the building industry to integrate PV more and more, as part of buildings. It has been recognized that it is not only the costs, but often very practical reasons, which prevent architects from integrating PV into their building concepts, or the lack of arguments to convince the building owner to implement PV. Addressing these topics, various tools for argumentation and education in PV building integration were developed, which are available at the web site of the Austrian PV Association. (http://www.bv-pv.at). National PV conferences are taking place on a regular basis focussing on national developments and international aspects of the national PVPS participation.

FUTURE OUTLOOK

While waiting for the further negotiation concerning the GEA, the situation of PV is currently unclear and unsatisfactory. If no significant and stable support mechanisms which can provide long and promising perspective for a national PV industry development are introduced, the market will remain limited relying on regional incentives which will only partly support the market.

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

The level of the public know-how concerning the potential and perspectives of PV is still insignificant but continuously growing. Several renewable energy education courses are already implemented and some new courses are currently under development. All of them include PV as an essential part of the future energy strategy. The importance of proper education for installers and planners of PV systems will increase, depending on the market situation. However, the National PV Association is just about to initiate a national "Certified PV Training" for installers and planners in order to keep the quality of the installed systems at a high level. It can be expected that the recently empowered National PV Association will significantly promote the topic in Austria. The small PV industry, currently taking advantage of the strong German market is very much interested in creating a home market for PV, and furthermore, is waiting for an improvement in the economic frame conditions.

CANADA

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

JOSEF AYOUB AND LISA DIGNARD BAILEY, CANMET ENERGY TECHNOLOGY CENTRE - VARENNES, NATURAL RESOURCES CANADA

Fig. 1 - The Toronto Hydro Energy Services high-visibility pilot project in Downtown Toronto will generate 36 kilowatts of electricity. The provincial utility is providing Torontonians with an opportunity to see commercial installations in operation (photo Phantom Electron Corporation).

GENERAL FRAMEWORK

The federal Department of Natural Resources Canada (NRCan) is responsible for energy policies and energy R&D in Canada. The CANMET Energy Technology Centre-Varennes (CETC-Varennes) is one of NRCan's three energy research and innovation centres[1]. Established in 1992, CETC-Varennes' mission is to encourage targeted sectors of the Canadian economy to reduce their greenhouse gas (GHG) emissions, use energy more sustainably, and improve their innovation capabilities. CETC-Varennes is responsible for the management of the federal photovoltaic R&D and technology transfer programmes. Other Centre activities focus on: buildings, refrigeration, industry and RETScreen™ development[2].

The Government of Canada is signatory to the Kyoto Protocol to the United Nations Framework Convention on Climate Change. It has invested more than 3,7 billion CAD in climate change programs and to the development of leading edge technologies over the past six years, including 2 billion CAD in its federal Budget 2003 alone The CCPC is a five-year national programme based on extensive consultations with provincial and territorial governments, industry, environmental organizations and individual Canadians. It sets out the strategy by which all Canadians and all sectors can work together to meet Canada's Kyoto commitment to reduce (GHG) to an average of six per cent below 1990 levels during the period 2008-2012.

The CCPC allocated 250 MCAD towards the Technology and Innovation (T&I) Initiative, which is contributing to advancing promising GHG technologies through R&D, demonstration and early adoption initiatives to achieve long-term GHG reductions and strengthen Canada's technology capacity in five key areas: decentralized energy production; advance energy end use in buildings and communities, industry and in transportation; cleaner fossil fuels; biotechnology; and, the hydrogen economy. PV and related activities have been included in the implementation plans of the first two T&I R&D technology areas. Technology Early Action Measures (TEAM)[4] is another initiative that has been renewed under the CCPC with injection of new funding for technology demonstration. TEAM is an interdepartmental technology investment programme that supports projects that are designed to develop technologies that mitigate (GHG) emissions nationally and internationally, and that sustain economic and social development. TEAM is funding several partnerships between federal partners, the PV industry and regional stakeholders to demonstrate projects to raise the awareness of this emerging technology, as well as contributing to their improvement and cost reduction targets.

In 2004, a multi-stakeholder partnership between the solar industry, home developers and builders, renewable energy associations, energy research centers and academia joined forces to launch the Net-Zero Energy Home (NZEH) Coalition[5] with the aim to establish Canada and Canadian Industry as a world leader in competitive, innovative and sustainable residential building construction for the 21st century. The Coalition envisions all new home construction in Canada to meet net-zero energy standards by 2030, by combining onsite solar and other renewable energy generation technologies and energy efficiency applications and devices. The Coalition builds upon Canada's pioneering work in energy efficient home construction, embodied in the R2000[6] standards by adding residential-scale renewable energy production for household needs and additional energy conservation technologies.

The Government of Canada continued its efforts to work with multi-stakeholder groups in Canada to raise awareness of building-integrated photovoltaics with the next generation of architects and building engineers. It collaborated with the Royal Architectural Institute of Canada's (RAIC), a voluntary national association representing more than 3 000 members, to deliver a full-day professional development course on building-integrated photovoltaics to 135 Canadian architects in five Canadian cities. The workshops were designed to dispel the myths surrounding building-integrated photovoltaics and to heighten the architectural community's understanding this emerging and exciting renewable energy technology in Canadian buildings of the future.

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 11years in Canada. The installed power capacity has reached an estimated 14 MW in 2004, compared to 11,67 MW in 2003 (see Table 1). This is an unsubsidized market that is growing because PV technology is meeting the remote power needs of Canadian customers particularly for transport route signaling, navigational aids, remote homes, telecommunication, and remote sensing and monitoring.

NATIONAL PROGRAM

Within the framework of NRCan's Renewable Energy Strategy, CETC-Varennes is responsible for the photovoltaic R&D and technology transfer programme. In collaboration with Canadian industry and universities, as well as international energy research organizations, the Center undertakes R&D activities and fosters information exchanges to promote the adoption of PV technologies. CETC-Varennes' coordination role keeps policy makers and Canadian industry abreast of developments in the rest of the world.

The strategies of the Canadian photovoltaic programme are to:

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

R&D PROGRAM

The Canadian R&D programme 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. In 2004, it has initiated a four-year programme to effectively address technical, institutional and regulatory barriers and to promote the grid integration of decentralized energy resources (PV, wind, distributed generation)[7]. This work is conducted in collaboration with the industry at CETC-Varennes, a National research facility located near Montréal in the Province of Québec. On-going projects include:

- R&D for the integration of PV-thermal systems in buildings;
- Optimization strategies for Zero Energy Solar Homes;
- Evaluation on the use of small PV-hybrid systems in off-grid applications;
- Integration of renewable energy technologies in off-grid residences in Canadian climatic condition;
- Evaluating the energy performance of novel PV modules operating in Canadian climatic conditions;
- Assessing the performance of PV products designed for building applications;
- Collaboration with Measurement Canada on net-metering to address the regulatory issues;
- Simulation studies on the impact of inverter-based systems and utility interconnected PV systems;
- Championing the development of a national guideline for the interconnection of small distributed generation systems; and,
- Supporting the development and adoption of performance and safety standards for use in Canada, including participation in the International Electrotechnical Commission working groups that aim to develop international standards.

DEMONSTRATION PROJECTS

Largest Pilot Photovoltaic Project in Toronto Reflects Utility Commitment to Energy Alternatives

Toronto Hydro-Electric System Ltd., a subsidiary of Toronto Hydro Corporation, recently installed the largest industrial grid-connected solar power generation system in the city (Figure 1). The photovoltaic system will produce 36 kilowatts of clean, non-polluting electricity for Toronto Hydro's service centre at the company's office in downtown Toronto - a high profile location chosen to increase public awareness of the potential for green power in an urban environment. This is the second green power system to be launched by Toronto Hydro in the past two years, following the downtown wind turbine at the Canadian National Exhibition. The PV system includes

TABLE 1: CUMULATIVE PV POWER CAPACITY INSTALLED IN CANADA

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
PV power (MW)	1,24	1,51	1,86	2,56	3,338	4,47	5,83	7,15	8,83	10	11,67 MW	14 est.

Data - Natural Resources Canada

Fig. 2 - "Blue Vine"; H 70cm, W 45cm; art glass panel created in 2 layers; interior - screen printed and air-brushed with fired glass enamels; exterior - photovoltaic cells integrated into the glass. Here is an opportunity to integrate emerging energy technology and stained glass art in the buildings of the future (photo Sarah Hall Studio).

189 Sanyo HIT 190 watt solar modules, and is utilizing a Xantrex 30 kilowatt grid-tie inverter. The PV system generates sufficient electricity to displace annual emission of 38 tonnes of carbon dioxide and provide 12 % of the lighting load at the centre, which houses 800 staff and equipment in a 12-acre building. The installation showcases the utility's commitment to alternative energy sources.

Government Embraces Onsite Solar Power Generation
The Government of Canada is committed to climate change reduction efforts through efficient use of energy and the use of energy from renewable sources. Under funding from the Government of Canada's On-Site Generation at Federal Facilities initiative, nine federal departments and agencies are demonstrating PV, wind and micro hydro technologies on seventeen federal facilities throughout Canada. Of the seventeen projects, thirteen are grid-tied PV applications totaling 100 kilowatts nominal capacity. For example, the Royal Canadian Mounted Police are using PV power supply systems for their border detachment facilities across Canada, Health Canada is demonstrating PV power generation on native health clinics under their jurisdiction, Environment Canada is demonstrating roof mounted systems on its National Centre for Inland Waters research facility in Ontario, and Parks Canada is also demonstrating a roof-mounted systems on its Ecologic/Education Building in its St. Lawrence National Park also in Ontario. In the western Province of British Columbia, the Department of Fisheries and Oceans and the National Research Council are also demonstrating roof-mounted systems on their Institute of Ocean Sciences and the Herzberg Institute of Astrophysics. In 2005, the Customs and Revenue Agency Customs will be demonstrating two building-integrated PV projects on their border crossing facilities in the provinces of Quebec in eastern Canada and British Columbia in the west. The initiative provided total subsidies of 850 KCAD to leverage about 2 MCAD of total project costs to realize about 850 kilowatts of total nominal generating capacity, expected by the planned completion of this initiative in 2005. These results far exceed the planned target of 125 kilowatts from PV, wind and micro hydro generating sources.

Arts Fellowship Supports Energetic Exploration in Glass
Noted Canadian glass artist Sarah Hall was recently awarded an Arts Fellowship from the Canadian-based Chalmers Foundation to support her innovative work in photovoltaic art glass. This technique, which uses solar cells in the glass to generate electricity, adds an exciting new dimension to the relationship between a building and its windows. As she integrates these systems into her art glass windows, Sarah Hall will explore the connections between light, colour, imagery and energy and her own deep concerns for our natural world and our future. Her proposal for the Chalmers Foundation was for six new major works that integrate original, expressive designs with working photovoltaic systems over the next year (Figure 2). One of her current projects involves contributing to the Canadian entry in the USDOE-sponsored Solar Decathlon, a competition for energy-efficient housing design, in Washington, DC this September. Since establishing the studio in 1980, Sarah Hall has built an international reputation for her technical and artistic exploration. She has collaborated with world-renowned German architect Dr. Ingo Hagemann, Saint Gobain Glass in Aachen, and with Mr. Wilhelm Peters of Glasmalerei Peters to develop and demonstrate artistic applications of stained glass and PV, and she will be working with them on these demonstration projects in Canada. Her work has garnered Honor Awards from the American Institute of Architects, the Allied Arts Award from the Ontario Association of Architects, and election to the Royal Canadian Academy of Art.

IMPLEMENTATION

Canada has developed and approved a number of climate change mitigation schemes in support of its National Implementation Strategy to enable it to meet its commitments under the Kyoto Protocol. Support for collaborative public and private sector efforts are provided through some of the following initiatives:

Federal Leadership through Federal House in Order Initiative & On-Site Generation at Federal Facilities.
In 2000, the Government of Canada launched the Federal House in Order (FHIO)[8] initiative with Natural Resources Canada and Environment Canada as the lead departments. The FHIO initiative is the Government of Canada's plan for reducing greenhouse gas (GHG) emissions within its own operations. FHIO recognizes that the Government of Canada's operations produce GHG emissions and, as a result, must meet their share of the responsibility for honouring the Kyoto commitment. Through the FHIO initiative, the Government of Canada is demonstrating that it is taking a leadership role in getting its own "house in order." Reducing its own emissions may ultimately encourage others to do their part in addressing the issue of climate change. An investment of 44,2 MCAD million has been allocated to federal operations, including $ 30 million for the purchase of electricity from renewable resources and 1,2 MCAD for on-site electricity generation demonstration projects in federal buildings using PV, wind and micro-hydro technologies. Through these initiatives the Government of Canada developed a target for reducing GHG emissions within its own operations.

Fig. 3 - Innovative PV technology at Solar Spheral™ Power (a division of ATS Automation Tooling Systems Inc.), Cambridge, Ontario. Coloured silicon spheres appeal to architectural applications (photo ATS Automation Tooling Systems, Inc.).

Federal Investments in Technology-To-Market Support

Through continued support to *TEAM*, now in its third phase of funding (2003-2008), The federal government is continuing to provide financing for the late stage development and first demonstration of new technology with strategic partnering through the zone between R&D and market implementation. TEAM is an interdepartmental technology investment program established under the federal government's Climate Change Action Plan. TEAM supports projects that are designed to develop technologies that mitigate GHG emissions nationally and internationally, and that sustain economic and social development. TEAM's unique approach brings together industry, community, and international partners to encourage additional investment in innovative technology. TEAM's position in the technology innovation process has enabled the Government of Canada to support a wide range of technology options and paths for mitigating greenhouse gases. To-date there are about 98 projects that are being funded by TEAM in consort with federal departments totaling some 960 MCAD of which the federal share is 20 % of the total cost.

Technology Partnerships Canada (TPC)[10] is a special operating agency of Industry Canada with a mandate to provide funding support for strategic research and development, and demonstration projects that will produce economic, social and environmental benefits to Canadians. TPC's main R&D program is geared to pre-competitive projects across a wide spectrum of technological development. The program focuses on key technology areas such as Environmental Technologies, Aerospace and Defence Technologies and Enabling Technologies, which includes biotechnology and health related applications, as well as manufacturing technologies. TPC and TEAM are funding the development and commercialisation of Solar Spheral™ technology.

Sustainable Development Technology Canada (SDTC)[11] is a foundation created by the Government of Canada that operates a 550 MCAD fund to support the development and demonstration of clean technologies - solutions that address issues of climate change, clean air, water quality and soil remediation to deliver environmental, economic and health benefits to Canadians. An arm's length, not-for-profit corporation, SDTC fills the void in the innovation chain between R&D and commercialization - helping clean technology developers move through the development and demonstration phases, in preparation for commercialization. In 2002 SDTC has awarded 500 KCAD to a consortium lead by Carmanah Technologies Corporation, Vancouver, British Columbia, to demonstrate and adapt solar powered LED technology to edge-lit signage, which will lead to the development of a more diverse and robust solar industry in Canada. This project is enabling solar powered lighting to enter mainstream applications.

Net Metering Initiative

Deregulation of the Canadian electric utility industry is creating opportunities for distributed power generation to occupy a significant share of the electricity markets of the future. PV has an important role to play in this market, and appropriate policies to promote investments in PV are being pursued. One such area is to compensate system owners feeding power to the grid through net metering and net billing practices. This is relatively a new policy area for Canadian power utilities to consider and nascent activities are happening across Canada. To date, approximately eight Canadian utilities have policies in place that allow small renewable energy generators to be compensated at the retail rate and another seven utilities provide below retail compensation. The federal government is leading a working group composed of stakeholders from the electricity industry (manufacturers and utility) and federal regulatory branches to identify and eliminate barriers to the introduction of net metering in the electricity sector[12].

INDUSTRY STATUS

There are over 150 companies and organizations promoting PV power in Canada and may are active in the Canadian Industry Association and Energie Solaire Quebec[13]. The Canadian Solar Industry Association released a "Solar Plan for Canada" at its annual meeting in November 2004. It aims to insure a solar future for Canada and targets 25 million megawatt-hours by 2025[14].

The Canadian PV manufacturing sector has grown significantly in the last three years to serve both the domestic and export market. In 2004 significant investment in the manufacturing sector were announced. In June 23rd, 2004, ATS Automation Tooling Systems Inc. opened Canada's first fully integrated 20-megawatt Spheral Solar Technology manufacturing plant in Cambridge Ontario. It now employs approximately 200 people and has been developing innovative products using its flexible, lightweight solar technology[15] (Figure 3).

Xantrex Technology Inc.[16] is a world leading manufacturer of innovative power electronic product interfaces with its headquarter in Burnaby, British Columbia. Xantrex has developed a platform for advanced multi-energy control for hybrid power systems that are being demonstrated at six sites in Canada. It has also initiated a project for a new integrated variable-speed drive system for larger wind turbines in 2004.

Carmanah Technologies Corporation[17] continued to expand its innovative solar powered LED lighting solutions for marine, aviation, transit, roadway, railway and mining markets. Since 1997, it has sold more than 80 000 units in 110 countries.

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

MARKET

Canada has seen a sustained domestic market growth that has averaged 24 % over the last 11 years. It is estimated that the Canadian PV installed capacity will reach 14 Megawatts in 2004. In 2003, the annual PV installed based was 1,67 Megawatts, mostly for off-grid applications (1,59 MW). It is estimated that the Canadian PV industry generated revenues over 100 million CAD and employed approximately 625 people in 2004.

FUTURE OUTLOOK

Several Canadian PV companies have invested significantly in both the development and promotion of solar PV power systems in Canada. This is reflected by steady growth in the installed base, as well as the significant private-sector investment in manufacturing. Both the Canadian Solar Industries Association and Énergie Solaire Québec have continued their promotional and marketing activities in Canada. However, more significant effort will be required to encourage the development of the grid-connected market sector in Canada. The Net-Zero Energy Home Coalition is calling for leveraged support from the federal and provincial governments to participate in a project to construct 1500 net-zero energy homes across 5 or more regions in Canada within 3 to 5-years period as a pilot demonstration of the concept. This pilot phase would be followed by a full scale, incentive-based, early-adopters deployment program. This is a first step to enable the Coalition to reach the target by 2030 that all newly built homes in Canada meet Net Zero Energy standards.

Footnotes with relevant web sites:

1 *CETC-Varennes: http://cetc-varennes.nrcan.gc.ca/eng/accueil.html*
2 *RETScreen International Clean Energy Decision Support Centre http://www.retscreen.net/*
3 *Climate change: http://www.climatechange.gc.ca/english/publications/announcement/climatechange_investment.html*
4 *Technology Early Action Measures (TEAM): http://www.climatechange.gc.ca/english/team_2004*
5 *Net Zero Energy Home Coalition: http://www.associations.cc/nzeh/aboutthecoalition.htm*
6 *R2000 Program: http://oee.nrcan.gc.ca/r-2000/english/public/index.cfm*
7 *CETC-Varennes DER: http://cetc-varennes.nrcan.gc.ca/en/er_re/inter_red.html*
8 *Federal House in Order: http://fhio.gc.ca/default.asp?lang=En&n=A78D906F-11*
9 *Technology early Action Measures: http://www.climatechange.gc.ca/english/team_2004/*
10 *Technology Partnerships Canada: http://tpc-ptc.ic.gc.ca/epic/internet/intpc-ptc.nsf/en/Home*
11 *Sustainable Development Technology Canada: http://www.sdtc.ca/en/index.htm*
12 *Net-Metering Project: http://www.micropowerconnect.org/NetMeteringProject/index.htm*
13 *Canadian Solar Industries Association: http://www.cansia.ca; Énergie Solaire Québec: http://www.esq.qc.ca/*
14 *PDF report available from the CanSIA website: http://www.cansia.ca/downloads/sunnydaysahead%20V1.5.pdf*
15 *Spheral Solar Power Inc.: http://www.spheralsolar.com/*
16 *Xantrex Technology Inc.: http://www.xantrex.com/*
17 *Carmanah Technologies Corporation: http://www.carmanah.com/*

DENMARK

PV TECHNOLOGY STATUS AND PROSPECTS

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

Fig. 1 - The Tjornehojskolen School, Copenhagen. A fully integrated PV system of 17,4 kWp.

GENERAL FRAMEWORK

Denmark has presently no national energy plan, but the government's energy policy builds on a vision of a fully liberalised energy market supported by a framework, which underpins high consumer and environment protection, energy efficiency, subdued development in energy prices and high security of supply both in the short and long term. The vision focuses inter alia on the ongoing development of efficient energy technologies both nationally and in the EU, and the government wish to strengthen the research community and the development of new and promising energy solutions. In late 2004, the government announced its intention to present a more comprehensive energy initiative or energy plan around March 2005.

The Kyoto protocol and the consequent EU agreement on GHG reduction targets has lead to a Danish commitment to reduce GHG emissions by 21 % in the period 2008-2012, compared the base year 1990. The market for CO2 certificates is seen as the most cost-effective way to reach this target.

Renewable energy is not only a future option, but very much a present and considerable element in the energy supply: by the end of 2004, more than 25 % of the national electricity consumption is expected to be generated by renewable energy sources. Ongoing research, development and demonstration of new energy solutions including renewable energy sources have high priority in the vision, the two main objectives being the development of a future environmental benign energy system and a high degree of security in the energy supply many years ahead.

Photovoltaic technology (PV) is not specifically mentioned in the government's energy policy, but in early 2004, the Danish Energy Authority (EA) in collaboration with the electricity sector, the industry and other key stakeholders, finalized a national strategy on PV after a public hearing. This PV strategy includes the fields of research, development and demonstration. Deployment activities in support of the PV strategy are expected to be developed in the coming years and an overall framework for the coordination of PV development and deployment in Denmark is thus expected to be in place within a few years.

Key actors have been identified as: utilities - carrying out small and large R&D and in particular demonstration projects; network operators - identifying potentials and unresolved issues related to PV in a large network; universities and institutions - carrying out R&D activities on PV technology and its application & integration; professional consultants - catalysing a broad range of PV projects; industry - developing and manufacturing PV components and systems; NGO's - disseminating information and the general public exhibiting steadily increasing interest in and willingness to buy PVs.

NATIONAL PROGRAMME

Denmark has no unified national PV programme, but a number of projects supported mainly by the Danish Energy Authority and via the Public Service Obligation (PSO) of Danish network operators.

PVs have been included in the action plan of the Danish Energy Authority (EA) since 1992 and have received increasing attention in the consecutive three-year Solar Energy Action Plans. Since 1992, the Renewable Energy Development Programme of the EA has supported about 125 PV projects, and by the end of 2004 about 2,3 MW have been installed in the context of projects and demonstrations plants. A 300 roof-top project including 750 kWp was launched early 1998 and was completed by end of 2001. A 1000 roof-top programme was launched late 2001 as a follow up. This programme targets a mix of general cost reductions, increase in end-user payment and promotion of small roof-tops. Only a few weeks after the announcement of the programme, the SOL 1000, more than 3 000 house owners had registered their interest. However, uncertainty about the programme due to change of government and increased demand for end-user payment have introduced a delay of almost a year in the programme implementation. By the end of 2002 the programme reported a portfolio of some 1 300 house owners expressing firm interest in the programme and by end 2004 about 470 kW have been implemented, stimulated by an investment subsidy of 40 % of the turnkey system cost; the average turnkey system cost being 4,50 EUR/W.

A special support programme for PV applications in the commercial sector, funded by the CO2 tax on electricity, was set up in early 1998. The support includes a subsidy of up to 40 % for the turnkey system costs. The calculation of the actual subsidy will be in favour of high yield installations. This programme has so far not been very successful, as the commercial sector seems to regard an incentive of 40 % as inadequate, and during the last few years no projects have been implemented using this support mechanism.

Net-metering for privately owned PV systems was established in mid 1998 for a pilot-period of four years. In late 2002, the net-metering scheme was extended another four years up to the end of 2006. Net-metering has proved to be a cheap, easy to administrate and effective way of stimulating the deployment of PV in Denmark; however the relative short time window of the arrangement has so far prevented it from reaching its full potential. A small project has been launched to identify the best possible institutional arrangements around PV systems on multi-family buildings and housing, and the draft report was sent into hearing to key stakeholders, late 2004.

RESEARCH AND DEVELOPMENT, DEMONSTRATION

During 2003, the government has announced additional financial support to the new R&D programme started in 2002. Over a 3-5 year period more than 150 MDKK are allocated to renewables; however it is still too early to say to which extent PVs can benefit from the programme. In 2004, the government increased the PSO allocation for R&D into environmentally benign generating technologies from 100 MDKK per year to 130 MDKK per year. However, due to an ongoing merging of the two network operators into one new state-owned venture, this extra funding has not yet materialized.

In 2004, the EA became part of the new EU supported PV RTD network PV-ERA-NET focussing on EU level and national level coordination and optimization of PV RTD programmes.

R&D activities into PEC cells (Grätzel type cells) are ongoing at the Danish Institute of Technology. This activity has been supported in 2002-2003 by the PSO of the Danish network operators. This R&D activity has now attracted commercial finance and a new company has been formed. The Risoe National Laboratory, basic research into polymer based PV cells is ongoing.

In mid-1995, the Photovoltaic System Laboratory (PVSyslab) was established in collaboration between Risoe National Laboratory and the Danish Institute of Technology. The main function of PVSyslab is to certify the quality of PV systems and their installation and to help industry develop better products. The PVSyslab is also engaged in PV system monitoring and in the upkeep of a national knowledge base on applied PV technology. The PVSyslab has ongoing activities in the field of technology cooperation with developing countries; in particular, in the setting up of local quality assurance schemes and test laboratories.

IMPLEMENTATION

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

The SOL 1000 programme run by the utility EnergiMidt, which as mentioned above intends to demonstrate low cost and architectural acceptable integration of PV technology primarily on existing single family houses, had implemented about 470 kW in total, by the end of 2004. The same project focuses on the gradual increase of end-user payment, thus paving the way to a commercial market with no investment subsidy. A third objective is to disseminate information and experience on PV roof-top deployment to the Danish distribution utilities. Several projects for building integrated PV systems including commercial buildings, apartment buildings and schools have been implemented, typically in the range of 2-15 kWp.

Fig. 2 - Danish housing project where the idea is to develop standard solutions for houses with PV.

The aim of the project is to develop integrated PV solutions for standard houses. This implies the development of an integration method in the design phase, which makes the PV system a functional and architectonic element of the standard house. The PV system will be promoted as an aesthetic, green and prestigious element of standard houses.

By developing the PV system with standard modules as a functional and aesthetic part of a standard house one obtain the following advantages and at the same time promote PV technology and renewable energy production.

- Compared to PV-systems applied to existing buildings, a reduction of cost is gained by integrating PV as a regular element of standard houses.
- Developing the standard house with a PV-system from the beginning creates possibilities in aesthetics and design, research and developing of integration concepts and the choice of materials used.
- When the PV system is a regular part of the standard house it also enters into the financing, which diminish the actual cost of the PV system.
- The electrical installations can be optimized and adjusted to obtain a more efficient use of the PV production.

The final result of this project of integrating PV as a regular element of standard houses will be realized in full scale as a demonstration house. The project will show the way for future PV systems on standard houses and at the same time focus on the possibilities for reducing the price of integrated PV-system on standard houses.

The designs of future PV systems are of vital importance in promoting building integrated PV to constructors of standard houses. It has to be both economically and visually attractive to integrate PV as a regular element of standard houses.

A new utility initiative has been launched in 2003 by Copenhagen Electric: the sale of certified PV produced electricity without any subsidies or other external support. The utility contracts to buy all electricity from new PV systems for the next 20 years at commercial terms, and tries to sell the same electricity to the consumers in small standard packages including a certificate. Even though the end-user cost of the certified PV electricity is 3-4 times that of standard electricity - ironically partly because of the present tax and duty structure - the scheme reports a small but growing success.

INDUSTRY STATUS

R&D efforts are beginning to show commercial results in terms of export. The company Topsil, which uses a float-zone technique produces high purity Silicon (Si) ingots for the semiconductor industry, announced in 2002 their intention of developing a low-cost float-zone manufacturing technology, that would enable the company to offer high purity Si to the PV industry. It is now (2004) seeing the first commercial results of its R&D into low-cost float-zone processing and is presently supplying SunPower in the USA, with float-zone Si for high efficiency PV cells.

Inverter technologies has been R&D'd for some years for both fuel cell and PV applications. For the latter, a commercial breakthrough was also announced in 2003 by the Danfoss related company Powerlynx, which reports in 2004 to have underpinned and significantly strengthened the commercial breakthrough announced in 2003.

PV Si cell production stopped in Denmark in 1996. A single Danish module manufacturer (Gaia Solar) with an annual capacity of about 0,25 MWp per shift has existed since 1996. A few other companies producing tailor-made modules such as window-integrated PV cells can be found.

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

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

A few companies develop and produce power electronics for PVs, mainly for stand-alone systems for the remote-professional market sector such as telecoms, navigational aids, vaccine refrigeration and telemetry.

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

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

MARKET DEVELOPMENT

Market development incentives already in place are mentioned above, under the National Programme section.

Total PV business volume in 2004 is very difficult to estimate with any degree of accuracy primo 2005, due to the commercial secrecy surrounding the above mentioned new business developments in the fields of Si feed stock and inverters. However, a rather sharp increase from 10 mill in 2002 to 25 MEUR in 2004 is a "best guess."

The cumulative installed PV capacity in Denmark (including Greenland) was estimated to be about 2,3 MWp by the end of 2004, an increase of about 20 % compared to 2003.

FUTURE OUTLOOK

The increasing government funds allocated to R&D into renewables are expected to give a boost also to the PV sector, but - if left alone - may lead to an imbalance between R&D efforts and demonstration, as the eventual R&D results need support to be demonstrated and reach the market. However, it is the hope, that the earlier mentioned effort to establish a national PV strategy and consequent deployment schemes may succeed in creating a more coordinated and unified approach to PV in Denmark.

The SOL 1000 project targeting building integrated PVs mainly on single family houses but also addressing apartment houses and institutions, is also expected to lead to ongoing availability of government funds for PV demonstration and deployment, e.g. a SOL 5000 initiative is under development. It is certain that without funding and a clear public support to PVs for yet some years to come, the sector will quickly diminish.

However, the trend towards commercial sustainability for PVs is seen as ongoing and with the objective, realistically within reach. Projections and scenarios now under study seem to indicate, that with the continued global technical and economic development of the PV technology, with a more permanent net-metering scheme in Denmark and with the unchanged development of the Danish end-users increasing willingness to invest in PVs, a market for PV roof-tops in Denmark without any investment subsidy will emerge around 2011-2012.

EUROPEAN COMMISSION

RESEARCH, DEVELOPMENT AND DEMONSTRATION ON PHOTOVOLTAICS SUPPORTED BY THE EUROPEAN COMMISSION
ROLF ÖSTRÖM, SCIENTIFIC OFFICER, EUROPEAN COMMISSION, DG RESEARCH
PIETRO MENNA, RESPONSIBLE FOR SOLAR SECTOR, EUROPEAN COMMISSION, DG ENERGY AND TRANSPORT

The policy objectives of the programme of research into sustainable energy systems include reducing greenhouse gases and pollutant emissions, increasing the security of energy supplies, improving energy efficiency and increasing the use of renewable energy.
In addressing these objectives, a differentiation is made between research activities having the potential for exploitation in the short to medium term and those which are expected to have an impact in the medium to longer term. Through a series of RTD framework programmes (FP), the European Commission has been supporting research and development in the Photovoltaic sector in Europe for more than 20 years, and has been instrumental in providing a framework within which researchers and industrialists can work together to develop new applications for the Photovoltaic technology. Through a series of RTD framework programmes (FP), the Commission has maintained long term support for the development of the full range of PV devices, including crystalline and thin film solar cells, PV modules and balance of systems.

5TH FRAMEWORK PROGRAMME (1998-2002)

In total more than 100 projects were started between 1999 and 2003 in the Photovoltaic sector within the 5th Framework Programme. In the short to medium term timeframe, 40 projects have been launched in Europe, for a total cost of more than 150 MEUR and an EC contribution close to 45 MEUR. The lion's share of the resources (51 %) has been dedicated to projects aimed at demonstrating the economies of scale which are achievable for grid-connected PV systems when developers, utilities and building industry work together with the public authorities, from the planning phase of the project. The second most important component (more than 19 %) has been for demonstrating innovative concepts for better integration of PV into the built environment. Large, MW size grid connected plants, and balance of system developments absorbed almost 17 % and 9 %, respectively while supporting actions for education, dissemination and studies took almost 4 % of the contribution.

The activities with an expected impact in the medium to long term correspond to more than 60 projects with over a 65 MEUR contribution. The main areas of medium to long term PV research were: Low-cost and high-quality silicon feedstock; Optimisation of crystalline silicon process technologies, with particular emphasis on cost and efficiency of wafer cell production; Thin-film technologies: highly efficient mass production plus an understanding of material limitations, aimed at reducing costs; Innovative concepts for PV cells and modules which have a potential for large cost reductions); Research on reducing the cost of other new and innovative components and systems.

6TH FRAMEWORK PROGRAMME (2003-2006)

Photovoltaics development continues to be supported in FP6 through both research and demonstration actions. Under this programme, the focus has been put on the development and demonstration of integrated approaches for new system design options and concepts, with a stronger emphasis on cost reduction. In the short to medium term, priority has been given to: Innovative production concepts for high efficiency cells/modules to be integrated into larger scale photovoltaic production facilities to lower the cost; and including low cost integrated components or devices for grid connected or stand alone PV generators; Support actions aimed at kick-starting Si-feedstock production by EU industries to secure a reliable and affordable supply for fostering PV cell cost reductions; Transfer to industrial scale of a new generation of PV technologies/products to facilitate the integration of innovative solutions at lower costs; Large area, low cost photovoltaic modules for building integrated PV and autonomous solar electricity generation systems in industrialised and developing countries; Integration of photovoltaic installations in generation schemes to feed local distribution grids, closer to the point of use and development of new devices and systems to manage these installations.

At the same time the medium to long term part of the programme has focused at: Innovative concepts and fundamental materials research for the next generation of PV technologies; Thin film PV technology (development of cost-effective PV cells and modules based on new and improved technologies and materials); PV processing and automated manufacturing technologies (to reduce the costs and improve materials usage in the manufacture of PV cells and modules); PV components and systems - balance of systems (research into components and their integration into the overall system) and the research for innovative applications of PV in buildings and the built environment (to develop integrated PV module systems which are configured for ease of mounting on building roofs and facades, hybrid PV/heating systems).

From the proposals received under the first FP6 Call, nine new PV projects have been launched, for a total cost of 78 MEUR and an EC contribution of nearly 42 MEUR. Among them, PV MIPS, in the short to medium term programme, is an integrated project aimed at the development and demonstration of a new generation of PV modules with integrated power conversion system, to reduce the cost of the electricity generated by grid connected systems The project outcome embraces the high-voltage module with integrated inverter without transformer. This approach offers tremendous advantages when used with high-voltage thin-film modules. For crystalline silicon modules an integrated, two-stage inverter is also being developed and demonstrated within the same project The research will have a strong focus on building integrated PV, because the potential for these applications is especially high in the dense populated areas of Europe. For the medium to long term programme it is well justified to specifically mention the two integrated projects CRYSTAL CLEAR and FULLSPECTRUM. CRYSTAL CLEAR deals with crystalline silicon photovoltaics, and the objectives are: research, development, and integration of innovative manufacturing technologies which allow solar modules to be produced at a cost of 1 EUR/Wp in next generation plants; improvement of the environmental profile of solar modules by the reduction of materials consumption, replacement of materials and designing for recycling; enhancement of the applicability of modules and strengthening of the competitive

position of photovoltaics by tailoring to customer needs and improving product lifetime and reliability. The aim of the project is to enable a price reduction of grid connected systems to a level of 3 EUR/Wp or even less, which roughly corresponds to electricity generation costs of 15 to 30 eurocents per kWh, depending on location in the EU. This is an improvement of 50 % over the present situation.

The project FULLSPECTRUM pursues a better exploitation of the FULL solar SPECTRUM by further developing concepts already scientifically proven but not yet developed and by trying to prove new ones in the search for a breakthrough in PV technology. More specific objectives are the development of: III-V multijunction cells (MJC); Solar Thermo-photovoltaic (TPV) converters; Intermediate band (IB) materials and cells (IBC); Molecular-based concepts (MBC) for full PV utilisation of the solar spectrum; Manufacturing Technologies (MFG) for novel concepts including assembling. Much of the research in this project is long term, but some is medium term with commercial results possibly visible at the end of the project. The final aim is making PV cost competitive with prevalent electricity.

TECHNOLOGY PLATFORM ON PHOTOVOLTAICS

A Conference for preparing the launch of the Technology Platform on Photovoltaics and to discuss the report A Vision for Photovoltaic Technology was held in Brussels on Sept 28, 2004. A technology platform is an instrument which the Commission has devised to stimulate public-private partnerships between the research community, industry and policy makers with the aim of mobilising greater research and innovation effort. The elaboration of the Strategic Research Agenda is an essential part of the Vision report prepared by the Advisory Council2. The setting up of the Steering Committee for the PV Technology Platform is now under way. The expected impacts of the platform include:

- raise overall RTD investment;
- identify and address obstacles to deployment at EU, national and regional levels;
- facilitate and accelerate the market penetration of PV technologies.

Footnotes:

[1] *The word "research" used in the general sense refers to research, technological development and demonstration activities.*

[2] *A Vision for Photovoltaic Technology for 2030 and Beyond, preliminary report prepared by the Photovoltaic Technology Research Advisory Council (PV-TRAC), available on line at: http://europa.eu.int/comm/research/energy/nn/nn_rt/nn_rt_pv/article_1265_en.htm*

FRANCE

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS IN FRANCE

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GENERAL FRAMEWORK

The French Agency for Environment and Energy Management (ADEME) is a public organization responsible, under French government supervision, for the national sustainable policy in the five following intervention areas: energy management, waste management, conservation of soils and air quality. The energy management aspect involves energy efficiency and renewable energies. Solar photovoltaic electricity is one of the activity lines covered in this policy.
A new framework law on energy is going to be submitted to the Parliament during the year 2005. The text of the law is focusing on energy efficiency and the promotion of renewables: the use of bio-resources and the recourse to thermal solar energy will be high on the agenda. Photovoltaic solar electricity (PV) will come under the research section of the law, similar to hydrogen and carbon dioxide sequestration.

Fig.1 - PV-STARLET project, Nattages Charmont (Ain): 4 kW BIPV (photo courtesy of Imerys Toiture/Hespul).

ADEME is the only public establishment with a promotion role in photovoltaics at the national level. ADEME co-finances research and technological development projects and allocates grants designed to facilitate the opening up of the market for photovoltaic applications. In order to implement its market opening policy, ADEME participates in the operations in cooperation with regional agencies (regional councils) and the European Commission's structural funds. Since some of these regional councils are very active, this allows some French regions to be better equipped with solar systems than some others. And it is from a local initiative that the idea of creating a solar energy institute (INES) at Chambéry was born. The preliminary studies for this new research and solar energy promotion tool were performed during the year 2004. The French Atomic Energy Commissariat (CEA) and the National Council for Scientific Research (CNRS) are very present in the development of this project, and plan to bring together a large part of their PV research teams within the INES.

NATIONAL PV PROGRAMME

ADEME's photovoltaic promotion programme is structured around two action lines. The research and technological development programme and the programme for stimulating the building integrated PV (BIPV) market. Both programmes are led by ADEME's Renewable Energies Department (ADEME/DER) at the Sophia-Antipolis Centre, while it is up to the 26 ADEME regional delegations to manage the procedures for investment grants.

ADEME is also a body in charge of information dissemination (www.ademe.fr) and training: training of installers and PV project managers and the training of young engineers through research. That's why ADEME/DER is running four annual training sessions on photovoltaic systems at the Sophia-Antipolis centre. Two sessions are particularly dedicated to photovoltaic grid-connected systems. Concerning training through research, ADEME finances Ph.D. students; grant-holders who for three years participate in the applied research projects carried out in public or industrial research laboratories. ADEME is also involved in several types of international cooperation.

For example, in 2004, two of its managers have contributed to high-level PV-TRAC working group under the aegis of the European Commission (DG Research). The aim was to define a development strategy for photovoltaics in Europe. The excellent study report, "A Vision for Photovoltaic Technology for 2030 and Beyond," was presented in Brussels on 28 September 2004 (http://europa.eu.int/comm/research/energy/photovoltaics/). ADEME is also a partner in the new European project which was launched October 2004. This project, named PV-ERA-NET, brings together the national and regional coordinators of photovoltaic programmes. With the aim of bringing consistency in the different policies and research actions conducted by the Member and Associate States. ADEME is also active in the International Energy Agency (IEA) Photovoltaic Power Systems Programme (www.iea-pvps.org) through a direct or subcontracted participation in task working groups n° 1, 2, 3, 9 and 10. Regarding the standard aspects, ADEME contributes through its various partners to studies carried out by the International Electrotechnical Commission (IEC, Technical committee 82, www.iec.ch).

ADEME is also sponsoring events with international exposure, such as the 19th European Photovoltaics Exhibition and Conference held in Paris from 7 to 11 June 2004. This event broke every attendance record, with 1 800 people registered.

RESEARCH AND DEVELOPMENT

Two industrial technologies have been selected by ADEME for RTD activity: bulk crystalline silicon and thin film Cu-In-Ga-Se. In 2004, three new projects which are important due to their ambitious undertakings, were implemented in the crystalline silicon field for the 2004-2009 period.

The RÉDUCOP project, which is conducted by the manufacturer Photowatt International, is aiming at a 25 % cut in the direct manufacturing costs of the photovoltaic modules within 4 years. This industrial project benefits from partnerships forged by public research bodies such as CEA and CNRS.

Fig. 2 - PV STARLET project, "SUNSAT" PV tile (photo courtesy of Imerys Toiture/Hespul).

The second project, SiNERGIES, is carried out by the CEA/GENEC laboratory of Grenoble, in cooperation with the CNRS. The project seeks to demonstrate the feasibility of photovoltaic conversion efficiencies of 20 % on large crystalline silicon cells (up to 20 cm x 20 cm) with cost-competitive processes that can be transferred to the industry. It is based on the RESTAURE technology platform installed in Grenoble during the year 2003.

The third project concerns feedstock silicon. The PHOTOSIL project brings together two companies, Invensil and Apollon Solar, as well as the CEA. The project is aimed at building a pilot for the manufacturing of solar photovoltaic grade silicon (capacity of 200 tonnes per year). The metallurgical route associated to inductive plasma purification should allow developing feedstock silicon at the production cost of 15 EUR/kg. The pilot will be installed at Savoie Technolac (near Chambéry). This project comes under the future INES Institute mentioned earlier.

The second technology sector that has been selected is the thin film approach based on polycrystalline Cu-In-Ga-Se compounds. An electrodeposition process on glass substrate has been chosen for its low-cost potential. The RTD project named CISEL is led by EDF R&D. Among the partners are the CNRS/LECA and glass manufacturer Saint-Gobain Research. A new technology platform that brings together the research teams of EDF and the CNRS has been opened in Chatou, and the IRDEP (R&D institute on photovoltaic energy) has been instituted in early 2005 by combining the interests of the various partners. In 2004, a PV cell with a conversion efficiency of 11,4 % was elaborated through the novel electro-deposition process. The third phase of this project will go on over the 2005-2007 period with the demonstration on the feasibility of 30 cm x 30 cm PV modules at a manufacturing cost below 0,7 EUR/W.

In the balance of system components sector, financial efforts made by ADEME are focusing on studies on ageing of storage electrochemical batteries and their management of the charge/discharge protocols. The SAFT Company and the CEA/GENEC have launched a study in 2004, with the objective of demonstrating that lithium-ion batteries could be of technical, as well as of economical interest in photovoltaic applications.

The RTD effort was increased in photovoltaic materials meant for the construction industry associated with larger involvement from construction and photovoltaic professionals under the aegis of the ADEME-Ministry of Equipment Programme, "Buildings by 2010." The selected projects of this programme are under realization and concern the following themes: integrated photovoltaic roofing for southern France regions (Apex BP Solar, Lafarge); curtain wall and photovoltaic glass roofs (Apex BP Solar, Kawneer Europe and Costic); integration of large-sized photovoltaic glass roofs to buildings (Solarte, Genec and Anglade structure bois); development of a PV-Th module with a compact light heat-exchanging medium (CEA/GREThE, CSTB and Photowatt) and finally a "solar steel" for the construction industry (Sunland 21, Arcelor, Total Energie, CSTB and Insavalor).

The scientific community gathers once a year at the ADEME Centre of Sophia Antipolis. 130 people have thus been able to get acquainted with the ongoing PV RTD projects on the occasion of this seminar co-hosted by ADEME, the CNRS and the CEA on 15-17 November 2004.

IMPLEMENTATION

Over the year 2004, ADEME has maintained its investment grant programme designed for the building integrated grid-connected PV (BIPV) systems by mobilizing complementary public funds from the regional councils. The two new contracts that have been approved in 2003 by the Energy Regulation Commission (CRE) - the connection contract and the distributor purchasing contract - have allowed launching PV projects with enhanced efficiency. Regarding the private individuals that are willing to install a grid-connected PV generator, ADEME has limited their PV system power to 5 kW while pointing out the benefits of a global energy-efficiency based approach. For more ambitious projects, ADEME has given priority to solutions with integration into the built shell associated to architectural quality. Public subsidies in 2004 amounted on average to 4,6 EUR per watt of which 3 EUR granted by ADEME and 1,6 EUR by the regional councils. Partnerships forged with the local communities have facilitated the appearance of new quality projects namely in regions such as Rhône-Alpes, Provence - Alpes - Côte d'Azur, Languedoc-Roussillon and Pays-de-la-Loire.

In December 2004, the Finance Law has modified the income tax allowance for private individuals willing to install a photovoltaic system in their home. This income tax allowance amounts to 40 % (previously was 15 %) of the investment cost, outside installation expenses, within the limits of 16 000 EUR per household. ADEME has consequently revised downwards its grants for 2005.

The Construction Industry Scientific and Engineering Centre (CSTB) has implemented the technical approvals procedures (ATex and ATec) that are to be met by the photovoltaic modules meant to be integrated into the built environment. To date the Apex-BP Solar Company has been involved in this approach.

European projects benefiting from ADEME funds have continued over the year 2004. The PV-STARLET project, in partnership with the Hespul Association and Imerys Toiture Company, plans to install 420 kW of photovoltaic systems based on 'SUNSAT' PV tiles over some 200 homes: late 2004, 72 projects were completed for 162 kW (see Figures 1 and 2). The UNIVERSOL project coordinated in France by Hespul plans the installation of 345 kW over 15 buildings of educational type, 8 installations (128 kW) have already seen the light of day (see Figure 2).

The "Photovoltaic Architecture Day in France," was held in parallel with the 19th European Photovoltaic Conference, in Paris, June 2004, and has enabled many of the attending players to exchange their experiences and participate in the debates.

INDUSTRY STATUS

The Photowatt International Company has produced 28 MW of photovoltaic cells in 2004; a significant increase over last year. Photowatt introduced automation in the production tools and improved the manufacturing processes. Improvements and innovations achieved are derived from the results of RTD projects carried out with public research partners and supported by ADEME (see new RÉDUCOP project described above). Photowatt holds the PV GAP quality label (www.pvgap.org) for its photovoltaic crystalline silicon modules certified according to the International Standard IEC 61215 with a 20-year warranty. In 2004, Photowatt, traditionally the sole PV modules supplier, made a foray into the PV market by offering standardized PV systems of 1,6 kW, 3,2 kW and 4,8 kW.

Emix Company has just begun the production of multicrystalline silicon ingots using a continuous electromagnetic cold crucible casting. Products made by this new production tool are currently undergoing validation with the company's customers.
Invensil and Apollon Solar companies have launched the construction of a manufacturing pilot of feedstock photovoltaic grade silicon (capacity of 200 tonnes per year) and should be operational in 2007.
Total Energie Company has announced in 2004, the construction of a photovoltaic modules production unit in Toulouse, based on crystalline silicon with a capacity of 15 MW per year. Production could start in April 2005 in rented premises, with the plant opening planned for early 2006.

In the field of photovoltaic components destined for the construction industry, Imerys Toiture Company has presented its new solar tile, which is marketed in the form of a complete 1 kW kit (inverter, cabling and modules), on the occasion of the 19th European PV exhibition. Interestingly, partnerships that have been forged within photovoltaic and construction industries and which were still in their infancy in 2003, became more and more extensive in 2004. Some of the partnerships and products are described in the Research and Development section above.

MARKET DEVELOPMENT

The year 2004 was marked in France by a fair growth in grid-connected PV installations and a decrease in off-grid domestic applications. The total power of the grid-connected PV systems funded by ADEME and its partners in 2004 is six times the power of the off-grid systems for rural electrification (professional off-grid applications of the telecommunication relays type are excluded from these statistics). The power of some grid-connected photovoltaic applications (public establishments, technical centres, etc.) has evolved towards higher power: for the first time in France two PV installations of over 100 kW were funded.

In 2004, the power of the grid-connected photovoltaic systems was of about 4,2 MW equally distributed over mainland France and the overseas "departements." Public grants to investment amounted globally to 15,7 MEUR for these sole operations. Investment grants

Fig. 3 - UNIVERSOL project, Lycée du Grésivaudan, Meylan (Isère): 45 kW BIPV (photo courtesy of Pienergies/Hespul).

allocated by ADEME, the regional councils and the European Commission can reach 80 % of the installed cost of the investment. In 2004, grants allocated were on average of 4,6 EUR per watt. Purchasing prices of PV solar energy electricity were set for 2004 at 0,14 EUR/kWh in mainland France and 0,28 EUR/kWh in the overseas "departements" and Corsica. For the 20 year purchasing contract, prices remain constant. In contrast, these purchasing prices decrease by 5 % a year inflation adjusted.

Off-grid domestic applications which up to now accounted for an important part of the market have shown an average annual decrease of about 30 % per year since 2002. This decrease was attributed to the saturation of the market in the overseas "departements." These installations benefited from grants that could reach up to 95 % of the installed cost. However, regarding the overseas "departements," installations benefiting from tax exemption measures for investments were subsidized up to 7,68 EUR per watt in 2004 (6,17 EUR/W in 2005, covered by EDF, ADEME and the regional councils).
These measures have allowed financing in France, in 2004, for some 600 kW of off-grid domestic photovoltaic systems (outside professional applications of the telecommunication relays type which account for up to 1 500 kW per year).

FUTURE OUTLOOK

In the field of research and technological development, ADEME continues to support targeted projects undertaken by consortia of industrial and public partners. Three new RTD projects on materials, processes on silicon photovoltaic cells have been implemented in 2004 and will last four years. A new phase in the development of thin film copper-indium-diselenide cells will start in 2005.
Concerning the off-grid PV systems for rural electrification, the slowdown noticed in 2003 and 2004 should be confirmed all the more now that the grants allocated to the installations benefiting from tax exemption measures are decreasing.

Regarding the building integrated grid-connected PV installations, the regional councils and the European Commission have contributed to financing 5,1 MW, in 2004, which is a significant increase when compared with the previous year.

In 2005, ADEME has reduced its system of investment grants to 1 EUR/W for taking into account the new income tax allowance for private individuals (40 % of the equipment investment cost). Regional councils will continue co-financing operations with variable grant amounts. This new measure constitutes a turning point in the development of the grid-connected BIPV market and it is difficult to predict its future evolution. For the BIPV systems installed by private companies and public operators not eligible for the income tax allowance, ADEME will maintain an investment grant scheme by contributing 2,8 EUR/W to operations with good visibility and considered to be particularly exemplary, with regard to architectural integration and the rational use of energy.

Footnote:

[1] *France means mainland France, Corsica and the four overseas départements: Guadeloupe, Martinique, Réunion and Guyane.*

GERMANY

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS
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Fig. 1 - 5 MW System at Espenhain near Leipzig.

GENERAL FRAMEWORK

The reduction of emissions of greenhouse gases is an important goal of environmental policies in Germany. The Federal Government explicitly formulated the target of doubling the share of renewable energies in gross energy consumption from 2000 until 2010. Accordingly, for the electricity production an increase from 6,3 % (2000) to 12,5 % (2010) is expected. For 2020 a share of 20 % is envisaged. The monitoring of measures taken shows good progress. In 2003 a share of roughly 8 % in electricity production was reached. For the first six months of 2004, already 10 % could be projected.

Photovoltaic (PV) contributes to this development. With currently a 0,8 % share of the renewable power generated one can expected an increasing importance of PV in the long term. Therefore, research and development as well as market introduction of PV are supported from several sides, especially the Federal Government, the Federal States, local authorities and utilities.

NATIONAL PROGRAMME

The responsibility for renewable energies within the German Federal Government is with the Federal Ministry of Environment (BMU). Research and Development (R&D) is conducted under the 4th Programme on Energy Research and Energy Technology. The main parts of this programme are managed by the Project Management Organisation PTJ. In addition to this initiative, there are other sources for the support of R&D: The Federal Ministry of Education and Research (BMBF) conducts a programme aiming for the support of renewable energies related networks. Moreover, the funding of renewable energies at national institutes is partly covered by their institutional funding provided by the Federal Government and the Federal States. Finally, some of the Federal States carry out their own R&D programmes.

From January 1999 until end of 2003 the so called, "100 000 Rooftops Solar Electricity Programme," provided soft loans for the installation of grid connected PV systems. Designed for the support of 300 MW, it turned out that at the end of 2003, approximately 65 700 systems with a total capacity of 345,5 MW were granted. Overall, this marks a clear success of the programme.

With the termination of the "100 000 Rooftops Solar Electricity Programme" the Renewable Energy Sources Act (EEG) guaranteeing a favourable feed in tariff was adjusted accordingly. From 2004 on, there is a basic tariff of 0,457 EUR per kWh. On top of this, there are boni for small systems and building integration. The rates are guaranteed for an operation period of 20 years. As before, they will decease by 5 % annually for newly installed systems.

The amended EEG provides now reasonable feed in tariffs for ground mounted systems in the MW class. Consequently, there is a movement towards large PV power stations. For example in September 2004, two large systems went into operation.

In Merseburg, a 4 MW system was built at the site a former oil company. Another plant of 5 MW was erected near Leipzig on an old coal dust deposit (Fig 1).

R, D & D

Overview

With the start of the 4th Federal Programme on Energy Research and Energy Technology in 1996 the so-called, "Way Paving Programme Photovoltaic 2005," was formulated. In early 2004 it seemed to be necessary to reformulate this sub programme taking the development of the recent years into consideration. As a result, in June 2004, the concept "Photovoltaic Research 2004-2008" was published. It puts emphasis on:

- the consequent utilization of R&D results in the production,
- a further reduction of costs for PV-cells, modules and systems by decreasing production costs and by increasing the overall system efficiency and
- the consideration of environmental issues related to the production and usage of PV systems.

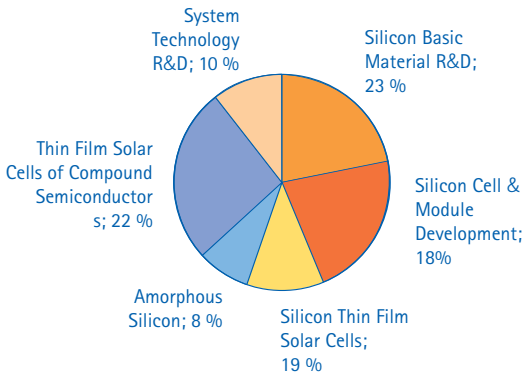

Fig. 2 – Funding of R&D 2004 by BMU (24,4 Mio. EUR in total).

Together with this new research concept an additional kind of cooperative research, so-called "Cluster Projects", was launched. Cluster Projects start from a common technology oriented problem formulated by two or more PV related companies. These companies

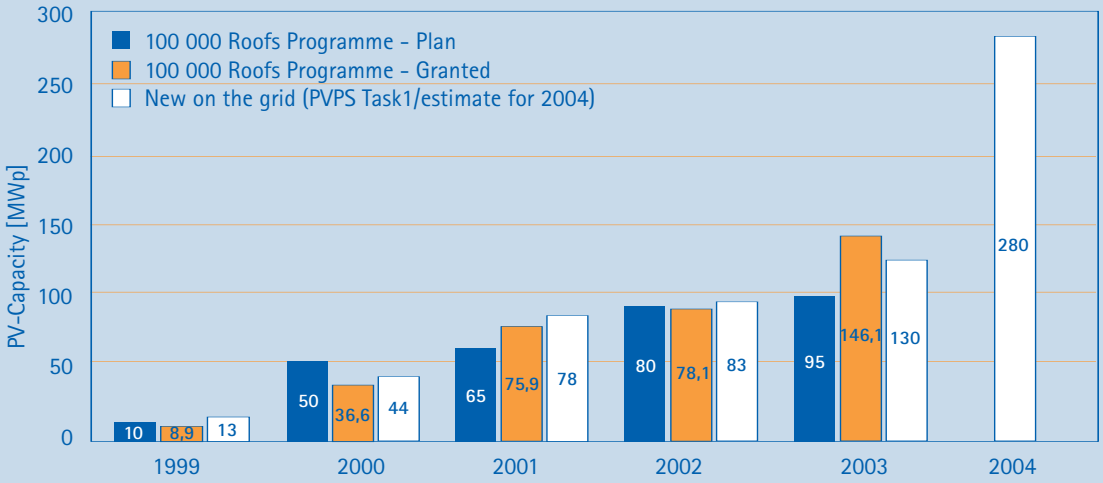

Fig. 3 – Development of the market for grid connected PV sytems, since 1999.

agree to solve this problem together with research groups and share the results among each other. The transformation of the scientific results into products will take place in individual processes of the companies after the Cluster Project is terminated.

In 2004, federal support for R&D projects on PV amounted to about 24,4 MEUR shared by 121 projects in total. The distribution of the budget shows that on the one hand funding still supports wafer based silicon technologies with 41% of the resources. Meanwhile, 49 % of the budget is spent for innovative concepts like thin film technology (Fig. 2).

Research and Development

In 2004 22 new projects could be started. The grants for these project amount to 29,5 MEUR in total. Typically they run over a period of 3 years and are mostly co-operative R&D projects where industry and research institutes collaborate. The following describe selected topics of important R&D-activities which were started in 2004.

PV System Technology: In October 2004 the PVPS Task 2 "Performance, Reliability and Analysis of PV Systems" entered its third phase. Germany again took over the lead of this group. Dealing with technical questions of the integration of decentralised small power systems into the grid the co-operate research project DINAR (Decentral renewable energy systems: Technical and economical integration into the operation of grids and adjustments of relevant frameworks) was launched (www.projektdinar.de).

While thin film technologies have the potential for a cost-effective large area production, their market share is still low. Supporting projects which address critical process steps could help to overcome technical bottlenecks. Important projects set out in 2004, deal with the deposition of microcrystalline Silicon layers for different kinds of silicon based solar cells. Concerning the CIS technology, ways for a homogeneous deposition on large areas will be examined as well as the cost reduction by the utilisation of cheaper precursor materials.

Crystalline silicon is still the most important material for manufacturing solar cells. While projects on efficient manufacturing techniques continued in 2004, two Cluster Projects were initiated to address the reliability and long term stability of silicon PV modules. Together with major German module manufacturers, it is planned to describe and predict the ageing of PV modules.

Demonstration

Today, the EEG is a powerful driving force for the development of the German PV market. Consequently, in 2004, demonstration projects were not granted within the current R&D-programme.

IMPLEMENTATION

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

- The "Electricity Feed Law" introduced in 1991 was replaced by the **"Renewable Energy Sources Act (EEG)"** in April 2000. The EEG rules the input and favourable payment of electricity from renewable energies by the utilities. In 2004, the feed law was amended and the feed in tariffs were adjusted mainly according to changes in supporting market introduction programmes. This results in a tariff increase for PV. After a feed in tariff of 0,46 EUR per kWh fed into the grid for systems built in 2003, a tariff of at least 0,54 EUR per kWh for systems on rooftops was guaranteed in 2004.
- From January 1999 until the end of 2003 the **"100 000 Rooftops Solar Electricity Programme"** was executed. With a total granted capacity of 345,5 MW and 65 700 systems built, this soft loan programme is a real success story.
  After the termination of this programme the support of PV systems by soft loans is maintained by other programmes of the KfW Promotional Bank, from 2005 on by the new programme "Solar Power Production."

- Moreover, together with other renewable energies like solar-thermal, heat pumps, hydropower, geothermal energy and biomass the PV initiative, **"Sun at School,"** is part of a federally marked introduction programme. Using a simple application process, schools get a fixed grant of 3 000 EUR for each single PV system.
- Some of the **Federal States** (Länder) have defined their own programmes, mainly to support the application of renewable energy and energy conservation.
- The **Federal German Environmental Foundation (DBU)** supports development and demonstration in the fields 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 many cases financial support for the rational use of energy and for renewable energies is provided.

INDUSTRY STATUS

Based on the EEG, the German PV-Industry and the German market experienced a period of strong growth over the last 4 years. A market size of roughly 280 MW is expected in 2004. For the first time, the German market arrived at the same level as the Japanese market, which was number one during the last years.

The range of companies dealing with PV is expanding along the whole value chain. During the last years, equipment and production companies became the most experienced ones worldwide and are heading for new markets e.g. in Taiwan, China and Korea. Thus, the EEG strongly influenced and gave new impact to suppliers of silicon feedstock, silicon wafers, solar cell- and module producers as well as manufacturers of production equipment and other PV components or systems.

The crystalline silicon technology still dominates the market and there are good reasons for a continuation over the next couple of years. Thin film technologies such as Copper-Indium-Diselenide (CIS), Cadmium Telluride and amorphous silicon currently fill niches disposing less than 5% market share.

The key figures and players in the field of crystalline PV business in Germany are:

Feedstock Silicon: Wacker the second largest supplier of silicon in the world for the semiconductor and PV industry. In 2004 Wacker proved its commitment to the solar industry, not only by keeping up the solar supply in a very short silicon market. By adding 800 t/a capacity, Wacker was the first company worldwide to expand explicitly for the solar market. And this expansion will maintain. A supply of additional 1 500 t annually is planned over the next two years. Moreover, the successful start of the pilot production of granular polysilicon in October 2004 was a big leap forward towards a large scale production of solar silicon in the future. In total, the silicon sold to the PV market has grown to 2 800 t.

Apart from Wacker, there is a joint-venture between Degussa and SolarWorld which is looking for better technology for silane decomposition, to reduce the cost of solar grade feedstock and increase capacities. In 2004, the joint-venture designed and ordered a pilot scale reactor for the decomposition of silane that will be installed during 2005, in Rheinfelden, a Degussa site.

Wafer Production: In 2004 the wafer production capacities were increased to 260 MW (end of the year). With a production of 187 MW mono- and multicrystalline wafers and 15 MW of EFG-Si-ribbon produced by RWE Schott Solar, Germany's wafer production amounts to 202 MW. This is more than 20 % of the worldwide market.

The largest stake in the worldwide production is held by Deutsche Solar AG in Freiberg (Saxony). The company itself produced and sold 120 MW on mono- and multicrystalline wafers to customers around the world and still is the largest company with a global market share of about 15 %. In 2005, Deutsche Solar AG plans an extension to 150 MW.

Besides Deutsche Solar there are two further wafer manufacturers: PV Silicon at Erfurt and ASI at Arnstadt. As PV Silicon does not disclose any figures about their production, a slicing capacity of 75 MW is estimated - see also Photon magazine, January 2005. ASI, a newcomer in this field, is producing monocrystalline material (12 MW in 2004, capacity of 18 MW for 2005).

Solar cell production: The cell production in Germany shows a steady growth rate. Rising from 58 MW in 2002 to 100 MW in 2003, the production almost doubled again reaching 190 MW in 2004. The production is dominated by seven companies. For 2005, they announced an increase in their activities to 390 MW i.e. another doubling of their production. If they succeed the global market share of German cell producing companies will grow from 16,5 % in 2003 to 22,4 % in 2004 and more than 35 % in the year 2005 bringing Germany next to Japan, in the leading position. These seven companies are:

- **Deutsche Cell:** Founded in 2001 the production started in 2002 in Freiberg (Saxony). In the year 2004, the production reached 28 MW and the sales were at more than 35 MW, resulting in a turnover of more than 60 MEUR. The number of employees is around 60. From early 2005 on the capacity of the Deutsche Cell Ltd. will be doubled to 60 MW.
- **ErSol Solar Energy:** In 2004 ErSol produced 16 MW and doubled its cell production capacity to 25 MW annually. A further increase is prepared for 2005 as an important step towards 100 MW production capacity. The company employs 130 people.
- **Q-Cells** is one of the companies with the largest growth rate. The production reached 75 MW in 2004. Announced strong expansion plans for the years 2005 and 2006 seem to be ambitious. The number of employees exceeds 350.

- **RWE Schott Solar:** The facility at Alzenau (Bavaria) was expanded in 2004 and produced 50 MW solar cells. With additional investments RWE Schott Solar is prepared to follow the growth of the German market towards a production capacity of 100 MW. For 2005 a cell production of 79 MW is planned as well as an increase of the module production, which was supplemented by a new facility in the Czech Republic.
- **Shell Solar:** The production of solar cells in Gelsenkirchen (North Rhine Westfalia) reached 10 MW in 2004.
- **Sunways** produced 11 MW in 2004. Following the recent ground laying ceremony at Arnstadt for a new cell plant with a capacity of 30 MW the planned production for 2005 will nearly double to 20 MW.
- **Solland Solar Energy** is a newcomer, who will start production at the end of 2005. The production facility is located at the border between Germany and the Netherlands. For 2005, the production of 2,5 MW is planned.

Solar Module Production: Because of the strong demand for modules and systems, the production grew much faster than expected by more than 150 % compared to 2003. After a production of 40 MW in 2002 and 80 MW in 2003 the output of modules from 25 companies in 2004 reached 205 MW which exceeds the cell production in Germany by nearly 10 %. It is not only the number of engaged companies that increased. There is also a strong expansion of capacities pushing the production to new records. Leading companies like RWE Schott Solar, S.M.D., Solar Fabrik, Solar Factory, Solarwatt Solar Systems and Solon increased their production by more than 70 %. Together, some of the other companies share 30 % of the market, are looking for niches and special products, e.g. for the automotive industry or architecture. The future looks bright for module producers because they are aiming for another production extension towards 350 MW in 2005.

In addition to these crystalline activities, thin-film technologies from Antec (CdTe) RWE Schott Solar (amorphous silicon) and Würth Solar (CIS) reached a total volume of 11 MW. These activities were on the same level as in 2003. And there is progress in technology development.

In 2004, Würth arrived at its maximum production capacity of 1,2 MW proving high productivity and quality. The numbers of employees increased to 60. According to Würth Solar, a scale up of the production capacity by an order of magnitude is highly probable for the near future.

In conclusion, the German industry is taking on the challenge to develop technologies along the whole value chain. More and more companies are entering into the business, strengthening the competition. Meanwhile, the market arrived at an annual turnover of 1,5 BEUR. The future growth will be carried out by a couple of companies, which makes it easier to afford the amount of money that is necessary for continuous rapid growth.

MARKET DEVELOPMENT INCENTIVES

The programmes described above have accelerated the installation of PV-systems in Germany significantly. At the end of 2003, roughly 410 MW have been installed. The German Solar Industry estimates a capacity of roughly 280 MW being installed during 2004, resulting in a total grid connected capacity of approximately 700 MW at the end of 2004 (Fig. 3). In addition to the market of grid connected systems, there is a stable request for stand alone systems. As in previous years, another 3 MW were demanded for this kind of application in 2004.

FUTURE OUTLOOK

For 2005 the course is set for an even stronger cooperation between research and industry. At the Fraunhofer Institut für Solare Energiesysteme, Freiburg, the realisation of a PV Technology Evaluation Centre (PV-TEC) is planned. PV-TEC will deal with the development of new silicon solar cell concepts and is designed to facilitate the transition between laboratory and production. While the BMU intends to support the initial set up of PV-TEC with roughly 11 MEUR, the operation of the centre will be financed by cooperative R&D projects of industry and research groups.

Ongoing high-level R&D together with the EEG and supporting soft loan mechanisms feed the conviction that the sustainable growth of the German PV market will continue.

FURTHER READING ABOUT GERMANY

- Federal Ministry of Environment, see www.bmu.de
- BSi - German Solar Industry Association, see www.bsi-solar.de

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ISRAEL

PV TECHNOLOGY STATUS AND PROSPECTS: AN UPDATE
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GENERAL

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

533 kWp have been installed so far; 30 kWp were installed in 2003. Nearly all the applications are off-grid remote electrification systems. Most installations were made on an economic basis, the PV system being the most economically viable alternative (because of its distance from the electric grid).

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

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

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

INDUSTRY INVOLVEMENT

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

Presently, there is no local production of either PV cells or 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

A relatively large number of research teams is 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).

Fig. 1 - The MCPV demonstration unit (photo Tel Aviv University).

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

- A novel thin-film solar cell from carbon, in its new form of buckminsterfullerene(C_{60}), is being investigated at the National Solar Energy Center in Sde Boker.
- DiSP Ltd. is developing a Miniature Concentrating PV (MCPV) system for distributed power applications, in cooperation with Tel Aviv University. The system is designed to provide both electricity and high-grade heat, making it a true Combined Heat and Power (CHP) system. It includes a small (about 1 m diameter) concentrating dish and a high-efficiency CPV module. Preliminary calculations indicate that the power generated by the MCPV may be less expensive than grid power. The heat can be provided at temperatures suitable for steam generation, cooling, space and water heating, and process heat. A demonstration unit is currently under construction.
- R&D activity at the Solar Energy Laboratory of the Jerusalem College of Technology is directed toward increasing the efficiency of silicon solar cells and photovoltaic modules without significant additional fabrication expenses. It consists of:

1. Improvement of solar cell fabrication technologies, including the development of industrial technology for the production of high efficiency single-crystal solar cells (in cooperation with Italy and Russia) and multi-crystalline wafers (in the framework of the multinational EU project INDHI - INDustrially scalable HIgh efficiency silicon solar cell);
2. Development of a cheap glass antireflective coating to increase the PV module efficiency by about 3,5 % (or more than 0,5 % absolute) - also in the framework of INDHI.

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

DEMONSTRATION AND APPLICATION

A number of projects have been completed or are underway. The following are particularly worth mentioning:

- A 1 kWp grid-connected system was installed on the roof of the science school in the Druze village of Yirka, in Galilee. Its purpose is to expose the pupils to this technology, as a part of their environmental education.
- Another 1 kWp grid-connected system was installed in a regional school in the Arava valley. Performance data are reported on-line on the school website.
- A novel aircraft-warning system was installed on 18 high-voltage pilons; it includes a 50 kWp PV panel and LED lighting.
- Interactive tourist information systems powered by PV panels were installed in a number of sites, distant from the grid.
- Applications of Light Emitting Diodes (LEDs) for urban uses such as solar traffic signs and street names are being developed.
- The Israel Electric Corporation (IEC) is investing 1 MUSD in a 29-home grid-connected demonstration project in the Negev. Each home will have a 3 kWp PV array, and the system will include inverters, meters and data-collection units. This project, known as "Solar Village," will enable the IEC to investigate the operating regime, the impact on the local grid, the types of interconnections, the selection of suitable meters, etc.

Fig. 2 - Grid-connected system in Yirka (photo Interdan).

Fig. 3 - 1 kWp grid-connected system in the Arava (photo SolarPower).

Fig. 4 - Novel aircraft-warning system (photo SolarPower).

Fig. 5 - Tourist information system on the Dead Sea (photo SolarPower).
Fig. 6 - Solar lighting near a mosque in East Jerusalem (photo Millennium Electric).

Fig. 7 - Solar street names (photo Millennium Electric).

EDUCATIONAL ACTIVITIES

In the Nitzana village in the Negev desert, an educational project is underway, called "Science Following the Sun." The project brings the message of solar energy, including photovoltaics, to hundreds of school children.

GOVERNMENT ACTIONS

As mentioned above, it is expected that the recent Government resolution establishing a minimum quota for electricity from renewables will favorably influence the PV market. In addition, a number of actions are being taken to encourage 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 160 000 USD in 2004; however, additional funding is available in this area from other research foundations.
- Supporting innovative demonstration projects by up to 30 % of investment.

ITALY

PV TECHNOLOGY STATUS AND PERSPECTIVES

S. CASTELLO, ENEA
S. GUASTELLA, CESI

Fig. 1 - Regional roof-top Programme: 4 kW on a residential house.

GENERAL FRAMEWORK

In Italy, the year 2004 has been characterized, on one hand, by broad budget availability for dissemination Programmes implementation as well as very high public demand and, on the other hand, by rather slow market growth; essentially due to bureaucratic issues related to the incentive mechanism.

In this framework, during 2004 the cumulative installed PV power increased similarly to the previously year reaching a total of about 31 MW. Most of this capacity has been due to the expansion of the grid-connected market, in response to the incentives committed by the Ministry of Environment and Land Protection (MATT) and the Italian Regions. Small grid connected systems, now amounting to 12 MW, account for 40 % of PV installed in Italy, with respect to 30 % at the end of 2003.

Owing to this stagnating situation, by the end of 2004, the production of photovoltaic modules, applying both single and multi-crystalline technologies, amounted only to 4 MW, in comparison with the 4,3 MW in 2003. Reasons for the low growth rate were uncertainties concerning the future support of PV and the weak situation of the Italian PV firms with respect to the foreign ones.

From the market point of view, the average module prices have slightly decreased in 2004, reaching the lowest values of 3 EUR/W, for reasonable volume orders, while prices reach typical values of about 3,8 EUR/W for small orders. A similar trend has been recorded for system prices.

During the last year, the total budget for photovoltaics has remained at approximately 25 MEUR. From this amount, expenditure on PV research and demonstration activities has been about 5 MEUR and has been mainly supported by ENEA and CESI, remaining essentially at the same level, with respect to the previous years. The other 20 MEUR have been provided by both the MATT and the Italian Regions in the framework of the Regional Roof-top Programmes.

IMPLEMENTATION OF SYSTEMS

The cumulative installed power in Italy is at present about 31 MWp, 5 MWp being installed during the last year. This capacity begins to be dominated by on-grid distributed PV systems that amounting to over 12 MW, accounting for 40 % of PV installed power. The other primary applications for photovoltaic power systems regard:

- off-grid domestic systems (5,3 MW), mainly promoted in the 1980s;
- off-grid economic industrial applications amounting to 6,7 MW;
- on-grid centralized systems (6,7 MW), sharply increasing at the beginning of 1990s.

DISSEMINATION PROGRAMMES

Over the last years, dissemination initiatives have included several, still ongoing Local Programmes.

These Programmes are completely managed by all the 19 Italian Regions and the 2 Autonomous Provinces. A contribution percentage ranging from 50 % to 70 % has been requested by the applicant and constitutes the main parameter for financing grants.

With reference to public funds allocation, local Programmes have been divided in two phases.

During the first phase, 70 % of the total incentives was provided by the MATT (i.e. 20,7 MEUR), while the remaining 30 % (9,3 MEUR in total) was provided by the Regions and Autonomous Provinces. Because of a great amount of applications submitted, well beyond the objective of the Programmes, a second phase was approved based on an additional commitment of about 55 MEUR by the MATT in accordance with Local Authorities. In this context, priority has been given to fully integrated roof-top applications while a decrease in the economic incentive and in the maximum cost allowed, has been recorded.

On the whole, MATT and Local Authorities incentives are activating an investment amount of about 135 MEUR to install a total capacity around 17,5 MW. Nevertheless, it is worth mentioning that despite very high public demand, the Local Programmes are experiencing rather slow growth; principally due to bureaucratic delays in the application and permit procedures. As a consequence, at the end of the year 2004, only about 8 MW out of the anticipated 17,5 MW have so far been installed.

Fig. 2 - Regional roof-top Programme: 20 kW on an industrial building.

RESEARCH, DEVELOPMENT AND DEMONSTRATION

In Italy, RD&D activities on photovoltaics are conducted by ENEA (the Italian Agency for New Technology, Energy and the Environment) and CESI (the Institute for Research and Certification of electric components and systems), with the support, in some cases, of Universities, Industries and some Institutes of CNR (the National Council for Scientific Research).

As far as ENEA activities, the most significant ones concern the optimisation of innovative solar cell fabrication: laser assisted processes, buried contact, selective emitter and advanced screenprinting technologies are mainly developed in the Casaccia Centre. In the field of thin films, a-Si based multi-junction devices are still a main line of the Portici Centre's activity, with the aim of improving the stabilized efficiency of integrated large area modules. Moreover, a new cluster tool was recently installed in this Centre, to begin a new investigation on poly-Si devices. ENEA is also involved in the a-SiNET and the European PV-EC-NET. Moreover, in the field of a-Si/c-Si heterojunction, cooperation between some European operators is currently carried out in the framework of the "MOPHET" Programme promoted by the European Community. Activities on poly-Si thin film cells on foreign substrates are also carried out, in the framework of the V FP "Subaro" while development on high efficiency crystalline silicon cells are studied in the framework of the "INDI" project. Lastly, a programme based on concentration, the PhoCUS (Photovoltaic Concentrators to Utility Scale) Project, is carried out in order to investigate this technology and to assess its technical and economical feasibility. 5 standard units (5kW each) are under installation at ENEA test facilities.

In the field of photovoltaics CESI is carrying out activities in the development and industrial manufacturing of high efficiency solar cells for space and terrestrial applications, based on GaAs compounds and in the analysis and testing of PV modules based on advanced solar cells and innovative components. The R&D activities of CESI in the field of space solar cells have been funded both by the Italian Space Agency (ASI) and the European Space Agency (ESA). In addition, triple junction solar cells (InGaP/GaAs/Ge) are under development and qualification and will be commercially available from next year. GaAs single junction and multi-junction concentrator solar cells are also manufactured for terrestrial application. This development activity is aimed to investigate the expected costs using advanced high efficiency solar cells derived from the space technology and suitable to convert the sunlight with an efficiency close to 30 % at concentrator values above 300 suns. CESI is also developing GaAs solar cells on silicon substrates for concentrator systems with the aim to evaluate the feasibility of further cost reductions of the PV energy. Moreover, in the field of PV systems, CESI is involved on research and demonstration activities for electrification of remote communities, funded by the Ministry for Productive Activities, MAP (see the 54 kW hybrid plant for Valcodera in a mountain area of northern Italy and the 80 kW PV plant connected to local Diesel generators at Vulcano Island). On the whole, the R&D expenditure in Italy has been about 5 MEUR, remaining essentially the same, with respect to the previous years.

INDUSTRY STATUS

In Italy two types of major PV module manufacturers can be identified; some small assembling companies and several operators in the systems field. A major PV module manufacturer is Enitecnologie, formerly Eurosolare. Its manufacturing facilities have a production capacity of about 3 MWp/year per shift. Both single-crystal and multi-crystalline silicon cells are currently produced from wafers bought on the international market. In fact, Enitecnologie has transferred the technology for multicrystalline wafers production to a Chinese-Italian joint venture based in China. As a consequence during 2004, feedstocks and wafers have not been produced in Italy.
Another important Italian module manufacturer is Helios Technology. Its manufacturing facilities have a production capability of 4.5 MWp/year. Helios Technology module manufacturing process includes the fabrication of cells and modules from mono-crystalline silicon wafers.

Additional small companies assembling and encapsulating tailor-made and especially designed modules, such as windows integrated cells or using colored cells, can be found in Italy.
Finally, it is estimated that the number of companies installing PV systems in Italy has reached 100 units. These are specialist PV companies offering consultancy, installation services and component delivery and include ENEL (the biggest Italian Electricity Utility) Group, CESI and some electric municipalities. The most important operators in this field are associated in the Italian PV firms Group (GIFI).

FUTURE OUTLOOK

The rather slow market growth which occurred over the last years due to bureaucratic issues essentially related to the incentive mechanism seems to have been overcome. At the end of 2003, in fact, the approval of a law by decree regarding the implementation of the European Directive 2001/77/CE for the promotion of electricity produced from renewable sources has provided a strong expectation in the Italian PV market.

In particular, this decree law forecasts dedicated support measures for photovoltaics: they include fixed feed-in tariffs, decreasing over time, for different installations and a purchase obligation by utilities. In the next months, the details on tariffs and related application periods will be defined by purposely dedicated government acts.

JAPAN

PV TECHNOLOGY STATUS AND PROSPECTS
YUKAO TANAKA, NEW ENERGY AND INDUSTRIAL TECHNOLOGY DEVELOPMENT ORGANIZATION (NEDO)
OSAMU IKKI, RTS CORPORATION

Fig. 1 - PV system using transparent sc-Si cells, installed in National Institute of Advanced Industrial Science and Technology (AIST), 41 kW, Tsukuba City, Ibaraki Prefecture.

GENERAL FRAMEWORK

The promotion and deployment of photovoltaic (PV) systems have been implemented through the perspective for new energy in the "Long-Term Energy Supply and Demand Outlook," prepared by the Advisory Committee for Natural Resources and Energy under the Ministry of Economy, Trade and Industry (METI). Japan's target cumulative volume for PV system introduction by FY2010 was set at 4 820 MW. METI has been actively driving forward measures for PV deployment and programmes for research and development for PV systems to achieve the target. "The New Energy Law" established in 1997 defines the responsibility of each sector: the national and local governments, energy consumers, energy suppliers and energy system manufacturers, to introduce and expand new and renewable energy. "The Renewables Portfolio Standard (RPS) Law" newly established in 2002, which obliges energy suppliers the use of a certain percentage of renewable energy, was thoroughly enforced in 2003. In addition, the Government of Japan established "the Basic Energy Plan" in 2003, in order to materialize the basic policies based on "the Basic Law on Energy Policy" enforced in 2002.

In 2004, three visions foreseeing the year 2030 were released: "Energy Supply and Demand Outlook for 2030," "Vision for New Energy Business" and "PV Roadmap Toward 2030 (PV2030)," a roadmap for technological development of PV system. The efforts for larger scale dissemination of PV systems from a long-term view point were started.

Beside these, the "Law Concerning the Promotion of Measures to Cope with Global Warming" and the "Law on Promotion of Green Purchasing" were enacted to promote the introduction of new and renewable energy.

NATIONAL PROGRAMME

The Japanese Government has implemented research and development (R&D), demonstrative projects, dissemination measures, and introduced legislation toward the achievement of targeted introduction capacity of 4 820 MW of PV systems by FY2010 and further deployment of PV systems thereafter. In the field of R&D, technological development for cost reduction of PV systems, technological development for PV deployment and research for innovative next generation technologies have been conducted. Regarding demonstrative research, the Field Test Project on New Photovoltaic Power Generation Technology has been conducted to demonstrate the effectiveness of PV systems employing new PV modules, new components, advanced system technology and newly developed installation methods, etc. and enlarge the application area of PV systems. Demonstrative Project on Grid-Interconnection of Clustered Photovoltaic Power Generation Systems, in which, a large number of PV systems are intensively installed in a community, also has been conducted. As for dissemination measures, the Residential PV System Dissemination Programme has been continued. In addition, the Government has implemented supporting programmes for local governments and private entrepreneurs in order to introduce new energy.

The budgets for major national PV programmes implemented in FY2004 are as follows;

1. Research and development of photovoltaic power generation technologies: 6 540 MJPY
2. Residential PV System Dissemination Programme: 5 250 MJPY
3. Field Test Project on Photovoltaic Power Generation Systems for Industrial and Other Applications: 140 MJPY
4. Field Test Project on New Photovoltaic Power Generation Technology: 5 030 MJPY
5. Demonstrative Project on Grid-Interconnection of Clustered Photovoltaic Power Generation Systems: 5 940 MJPY
6. Project for Supporting New Energy Operators: 48 260 MJPY
7. Project for Promoting the Local Introduction of New Energy: 11 030 MJPY
8. Project for Establishing New Energy Visions at the Local Level: 1 180 MJPY
9. Project for Promotion of Non-profit Activities on New Energy and Energy Conservation: 1 330 MJPY
10. Project for Supporting Regional Activities for Prevention of Global Warming: 610 MJPY
11. Demonstrative Project of Regional Power Grids with Various New Energies: 6 360 MJPY

The budgets for items 6, 7, 8, 9, 10 and 11 include ones for PV and other new and renewable energies.

R&D,D

The New Sunshine Project established in FY1993, aiming at comprehensive and long-term R&D, finished in FY2000, and a new technological programme, "5-Year Plan for Photovoltaic Power Generation Technology Research and Development (FY2001 - FY2005)," which covers the following 4 research areas, has been underway by New Energy and Industrial Technology Development (NEDO) since FY2001, based on the results obtained so far.

Fig. 2 - PV system at Saishunkan Hilltop Yakusai Factory Park, 480 kW, Kami-Mashiki Gun, Kumamoto Prefecture.

Fig. 3 - PV system installed in the canopy at Suntory Kyushu Kumamoto Plant, 2,16 kW, Kami-Mashiki Gun, Kumamoto Prefecture.

1. Development of Advanced Solar Cells and Modules

Short- to medium- term goal of this programme is to establish elemental technologies that can achieve PV power generation cost on par with typical residential electricity rate and transfer developed technologies into practical applications at an earlier stage.
The programme is focusing on development of thin-film crystalline Si solar cells, thin-film CIS solar cells and super high-efficiency polycrystalline compound solar cells (InGaP/InGaAs/Ge).

2. Development of Technology to Accelerate the Dissemination of Photovoltaic Power Generation Systems

This programme aims at developing of industrial technologies in order to accelerate practical application of results of technological development thus far. Technological development has been advanced in the following area: silicon feedstock for solar cell, mc-Si sheet silicon wafers for solar cells, mass-production process of a-Si solar cell on plastic films and fabrication equipment of a-Si/thin-film mc-Si hybrid solar cell.

3. Development of PV System Technology for Mass Deployment

This programme was designed to develop common infrastructural technologies to support the environment for large-scale PV deployment from technological aspects. Development of technologies for performance evaluation of solar cells, PV modules and PV systems and recycling and reuse technologies of PV systems has been carried out under the programme.

4. Development of Photovoltaic Power Generation Technology (Investigation for Innovative Photovoltaic Power Generation Technology)

The programme has a long-term goal for exploring seeds technologies for further improvement of performance and economical efficiency of PV power generation in and beyond the year 2010. R&D has been carried out for new materials, novel concepts and structures: nano-structure silicon solar cells, dye-sensitized solar cells (DSC), carbon-based thin-film solar cells, organic thin-film solar cells, etc. In FY2004, NEDO has transferred these programmes into the preliminary R&D programme with an eye to the year 2030 and designated 5 R&D areas: 1) thin-film silicon solar cell, 2) crystalline silicon solar cell, 3) CIS solar cell, 4) dye-sensitized solar cell (DSC) and 5) PV system technology, in order to efficiently promote technological development of innovative next generation technologies for PV systems.

DEMONSTRATION

4 major demonstration programmes were implemented in FY2004: "Field Test Project on Photovoltaic Power Generation Systems for Industrial and Other Applications," "Field Test Project on New Photovoltaic Power Generation Technology," "Demonstrative Project on Grid-Interconnection of Clustered Photovoltaic Power Generation Systems" and "Demonstrative Project of Regional Power Grids with Various New Energies."

1. Field Test Project on Photovoltaic Power Generation Systems for Industrial and Other Applications

This programme started in FY1998 and installations were completed with great success in FY2002. 740 PV systems with 18 100 kW in total were installed to schools, medical facilities, welfare facilities, factories, office buildings and private-sector facilities by the end of FY2002. Data collection and analysis have been continued since FY2003.

2. Field Test Project on New Photovoltaic Power Generation Technology

This field test programme aims at leading dissemination of middle-scale PV systems by installation of PV systems employing advanced technologies on trial basis and promoting improvement of performance and cost reduction of those PV systems. This programme is regarded as a succeeding programme of Field Test Project on Photovoltaic Power Generation Systems for Industrial and Other Applications. Under the programme, the following 4 model technologies are defined:
1) the PV system with new modules, 2) the PV system with building material integrated modules, 3) the PV system with new control systems and 4) the PV system aiming at higher efficiency. Introduction of the PV systems for public facilities and industrial uses are promoted under this programme. 148 projects were selected and PV systems totaling 4 480 kW were installed in FY2003. 300 projects totaling 8 671 kW were selected in FY2004.

3. Demonstrative Project on Grid-Interconnection of Clustered Photovoltaic Power Generation Systems

This programme started in FY2002 for a 5-year scheme to install grid-connected PV systems equipped storage batteries into 600 households to conduct demonstrative research of a large-scale and intensive introduction of on-grid PV systems. The programme aims at establishing grid connection technologies for grid-connected PV systems intensively installed to one area. The specific research objectives are

Fig. 4 - Intensively installed residential PV systems under Demonstrative Project on Grid-Interconnection of Clustered Photovoltaic Power Generation Systems, Ota City, Gunma Prefecture.

1) development of technology to avoid restriction of PV system output by using storage batteries, 2) analysis and evaluation of higher harmonics, 3) analysis and evaluation of devices for mis-actuation function to prevent islanding operation, 4) development of applied simulations and 5) evaluation of characteristics of power generation and economical efficiency. Residential PV systems with storage batteries were installed about 250 residences by the end of FY2004 and the demonstrative researches have been carried out.

Demonstrative Project of Regional Power Grids with Various New Energies.

This programme was launched in FY2003 to intensively install various types of distributed power sources such as PV systems, fuel cells and wind power generators, etc. in one area, aiming at demonstrating various issues: ensuring quality of electricity, balance between supply and demand of electricity, stability, and studying economical performance of distributed power sources. In FY2003, 3 demonstrative sites were selected across the country: Aichi Prefecture (total 2 400 kW of distributed power generation systems including 3 PV systems totaling 330 kW), Aomori Prefecture (total 710 kW of distributed power generation systems including an 80-kW PV system) and Kyoto Prefecture (total 850 kW of distributed power generation systems including a 50-kW PV system). Installation of power generation systems was started in FY2004. The demonstration site of Aichi Prefecture is located on the premises of the 2005 World Exposition (EXPO 2005), Aichi, Japan, and the power generation systems will supply electricity for the Government Exhibition, etc.

IMPLEMENTATION

The Ministry of Economy, Trade and Industry (METI)

The main implementation programmes carried out in FY2004 were "Residential PV System Dissemination Programme," "Project for Promoting the Local Introduction of New Energy" and "Project for Supporting New Energy Operators."

Residential PV System Dissemination Programme

The "Residential PV System Monitor Programme" initiated in FY1994 was renamed "Residential PV System Dissemination Programme" in FY1997 to develop the initial residential PV system market. The total number of PV systems installed under these programmes expanded to the scale of 200 000.

This programme aims at reducing the cost burden of purchasers of residential PV systems and creating the initial PV market through subsidizing the installation cost for residential PV systems. The subsidy is given through three categories; i) an individual to install a PV system to one's own house, ii) a ready-built house supplier of housing development and iii) a local public organization to introduce PV systems to public housings. PV systems with 9,99 kW of the maximum output capacity, connected to low voltage grid and allowing reverse power flow are qualified for the subsidy. Although the amount of the subsidy in FY2003 was 90 000 JPY/kW, it was further reduced to 45 000 JPY/kW in FY2004.

Under this programme, Residential PV systems were installed to 115 765 houses, total 421,4 MW, from FY1994 to FY2002. In FY2003, 52 863 houses equipped PV systems totaling 201,4 MW. In FY2004, 55 842 applications for the programme were received as of January 14, 2005.

Project for Promoting the Local Introduction of New Energy

This programme aims at accelerating new energy introduction by supporting the regional projects developed by local governments for promoting the introduction of new and renewable energy. Another object is raising awareness of the local residents for new and renewable energy. Subsidy is provided for local public organizations who are going to introduce and promote power generation using new and renewable energy such as PV power generation, wind power generation, use of solar thermal energy, differential temperature energy, natural gas co-generation, fuel cells, wastes generation, use of waste thermal energy, production of wastes fuel, clean energy vehicles and energy conservation measures. PV systems with 50 kW of output capacity and over are qualified under the programme. Half of installation cost is subsidized. 184 systems in total were subsidized from FY1998 to FY2002. 78 systems out of them were PV systems. Total capacity installed was 9 994 kW. In FY2003, 101 systems in total were qualified and 70 systems out of them were PV systems. Total capacity installed was 8 311 kW. In FY2004, 71 systems in total were qualified and 45 systems out of them were PV systems. Total capacity installed was 3 433 kW. The programme allows local governments to understand the benefit of introduction of new and renewable energy and introduce PV systems intensively to school buildings and public facilities, etc. over several fiscal years.

Project for Supporting New Energy Operators

This programme aims at accelerating new energy introduction by supporting the industrial entrepreneurs who set about introducing new energy, such as PV power generation, wind power generation,

Fig. 5 - Louver integrated PV system installed in the showroom of Panasonic Center, 12,12 kW, Koto-ku, Tokyo.

solar thermal energy, differential temperature energy, natural gas co-generation, fuel cells, wastes power generation, use of waste thermal energy, production of wastes fuel, etc. The private entrepreneurs who start new energy business are eligible for guaranteed debt or subsidization. A third of installation cost is subsidized, and 90 % of the debt is guaranteed. The capacity of eligible PV system is 50 kW and over. 135 systems in total were qualified from FY1998 to FY2002, and 4 systems out of them were PV systems, 381 kW in total. In FY2003, 39 systems were qualified and 2 systems, 217 kW in total, out of them were installed. In FY2004, 37 systems were selected and 3 systems were PV systems, and the total installed capacity was 147 kW.

Besides these programmes, supports have been offered to local governments for their projects to develop their own visions for introduction of new energy and to nonprofit organizations (NPOs) for their supporting activities to introduce new energy at local level.

The Ministry of Land, Infrastructure and Transport (MLIT)

Under "Guideline for Planning Environmentally-Friendly Government Building (Green Building)," construction of green government buildings equipped PV systems has been promoted. Introduction of PV systems with 455 kW in total was completed in 13 central government office buildings as of June 2003. In addition, MLIT introduces PV systems to local facilities for the central government such as the national government buildings of local branches every fiscal year.

The Ministry of Education, Culture, Sports, Science and Technology (MEXT)

MEXT continues the "Eco-school Promotion Pilot Model Project" initiated in partnership with METI in FY1997 and has been promoting the introduction of PV systems to elementary schools, junior high schools and kindergartens. 341 schools all over Japan were designated as the pilot model schools by the end of FY2003, and 229 schools among them installed PV systems with output capacity of 10 kW and over each. In FY2004, 82 schools were newly selected as the pilot model schools and PV systems are to be installed to 49 schools among them.

The Ministry of Environment

The Ministry of Environment is promoting projects of CO_2 emission reduction by use of natural energy under the "Law Concerning the Promotion of Measures to Cope with Global Warming," enforced in FY1998. In addition, it implemented "Law on Promotion of Green Purchasing" in April 2001, and commodities procured by the national and local governments have to be replaced by environmental-friendly products. Since the PV system is specified as one of the special procurement products, introduction of PV systems to governmental facilities has been in progress. Besides this, the Ministry implemented measures for maintaining and improving the local environment such as the "development of practical application of technology to introduce renewable energy" and the "model town project for virtuous cycle of environment and economy," as measures for technological development projects to cope with global warming.

The Local Governments and Municipalities

The movement to actively work on environmental issues has been spreading among the local governments and municipalities year by year. Prefectures began to set their own target for introduction volume of new energy following the national target for PV system introduction (4 820 MW) one after another. More and more local authorities began to develop their own new energy introduction visions and plan the introduction of PV systems into public facilities and public housings. Some local governments and municipalities also additionally provide their own subsidies to the national subsidy for residential PV systems and offer preferential loans for the introduction of PV systems, and the number of such local governments has been increasing over the years. Promotional supports to PV systems are enhanced at local governments and municipalities. The number of local governments that provide additional subsidy for residential PV systems increased from 262 in FY 2003 to 282 in FY 2004.

Utilities

Electric power companies in Japan continue the introduction of PV systems to their own facilities and net billing to buy-back surplus PV electricity at the same rate as selling.
Electric power companies established the "Green Power Fund" in October 2000, aimed at introducing and promoting PV systems and wind power generators. The utilities bill an additional charge as a contribution of 500 JPY/share/month to the supporters among their customers, and contribute the same endowment as the amount of their supporters' contribution for installation of PV systems and wind power generators. From 2001 to 2003, 285 public facilities including schools across Japan were subsidized through the Fund and the total capacity installed was 5 116 kW. In FY2004, 160 sites were selected, and installation of PV systems totalling 3 254,5 kW are underway.
Electric utilities achieved to purchase required amounts of new energy designated under the Renewables Portfolio Standard (RPS) Law that was enforced from FY 2003. Usage volume of electricity generated by new energy by utilities for FY 2003 was 4 015 TWh in total, including 147 TWh from PV power generation. The accredited facilities for power generation using new energy under the RPS Law

was 141 935 systems totaling 4 099 MW as of March 2004. Among them, PV systems are 141 154, accounting for 528 MW of generation capacity.

Financing Institutes

Some banks and other financing institutes provide preferential financing at low interest rates for the introduction of residential PV systems for private use and houses equipped with PV systems.

INDUSTRY STATUS

The PV industry in Japan has been rapidly growing toward expansion of global demand for PV systems and self-sustainability of the industry. The annual production of solar cell and PV modules in Japan reached the 100 MW level in 2000, and it increased to 500 MW scale in 2004. In the domestic market, the PV industry has been working on 1) enhancement of production capacity, 2) promotion of cost reduction, 3) improvement of conversion efficiency of solar cells and PV modules, 4) development of the products considering user's viewpoint, 5) development of new solar cells for further diversification of application, and 6) new entrants starting in the PV business. In the overseas market, the PV industry also has been advancing 1) expansion of overseas manufacturing sites of PV modules, 2) enhancement of production capacity of overseas PV module plants, 3) acquisition of international certification for PV modules. Among these movements, it should be noted that new activities to correspond the growth of the residential PV systems have been continued: PV manufactures enhance production capacity and construct new manufacturing facilities, several companies started PV business, etc.

As for the activities of Japanese PV manufactures in 2004, following topics were particularly noteworthy.

Sharp raised the production capacity of solar cells from 248 MW/year to 400 MW/year. It also has a plan for further enhancement in 2005. Sharp has newly constructed a PV module manufacturing line in Wrexham, the UK, in 2004, in addition to the PV module plant constructed in 2003, in Memphis, Tennessee, the USA, and has been extending its overseas manufacturing sites.

Kyocera announced a plan to increase the manufacturing capacity of mc-Si solar cells from 150 MW/year to 240 MW/year during 2005. It also started to produce PV modules in the newly constructed plant in Tijuana, Mexico, following the PV module plant in Tianjin, China, that started operation in 2003. In addition, Kyocera will construct another overseas PV module plant in Kadan, Czech Republic in 2005, and establish the "quadripartite global production framework" for PV modules.

Sanyo Electric increased the total production capacity of a-Si/sc-Si solar cells (HIT solar cell) and a-Si solar cell from 68 MW/year to 160 MW/year. Moreover, it announced further increase of the production capacity to 250 MW/year in 2006 and 1 GW/year by 2010. It will construct a new PV module manufacturing plant in Oizumi-Cho of Gunma Prefecture. As for the overseas factory, it will newly establish a PV module manufacturing site in Dorog, Hungary, and start operation in 2005, in addition to the PV module factory in Monterrey, Mexico.

Mitsubishi Electric enhanced the production capacity of mc-Si solar cells from 50 MW/year to 90 MW/year in 2004. Further expansion plan is underway toward 135 MW/year in 2005 and 230 MW/year in 2006 and beyond.

Kaneka and Mitsubishi Heavy Industry (MHI) also increased the production volume, and plan to expand production capacity of a-Si/mc-Si solar cell.

Shell Solar Japan (SSJ), a joint venture of Showa Shell Sekiyu and Shell Solar GmbH is working on its PV business specialized in the residential PV system market.

MSK newly constructed a PV module factory with 80 MW/year of manufacturing capacity in Omuta City of Fukuoka Prefecture, in addition to Saku Factory, a 100-MW/year plant in Nagano Prefecture to expand domestic manufacturing sites.

Fuji Electric started the business of flexible a-Si PV modules using plastic film substrates with 3 MW/year of production capacity. It plans to cultivate the market by taking advantages of the PV module: lightness in weight (1 kg/m^2) and flexibility.

As for new types of solar cells, Clean Venture 21 and Kyosemi have been developing spherical micro Si solar cells. Showa Denko, Aishin Seiki, Fujikura, Hitachi Maxell and other companies have been working on commercialization of dye-sensitized solar cells (DSC). In the area of silicon materials for solar cell, JFE Steel increased the production capacity of mc-Si ingots for solar cells from 400 t/year to 800 t/year, equivalent to 90 MW/year of solar cell. M. Setec newly constructed a manufacturing plant for sc-Si for solar cells in Susaki City of Kouchi Prefecture and started its operation. It will construct another plant of sc-Si for solar cells in Souma City of Fukushima Prefecture and start production in 2005. Tokuyama decided to construct a demonstrative plant for polysilicon for solar cells based on vapor to liquid deposition (VLD) process using $SiHCl_3$ in 2005. Besides these activities, with the growth of the PV system market, manufacturers of balance of systems (BOS) and raw material providers for solar cells have been actively increasing their capacity investment.

MARKET DEVELOPMENT

New opportunities and application areas of solar cells, PV modules and PV systems have been created through Residential PV System Dissemination Programme initiated by METI, field test programmes for PV systems for public and industrial facilities and Project for Promoting the Local Introduction of New Energy. The PV market in Japan consists of the following 5 market segments: 1) residential

Fig. 6 - PV system using curved crystalline silicon modules installed in Fujipream Kohto Factory, 21,66 kW, Ibo Gun, Hyogo Prefecture.

houses, 2) industrial and business facilities, 3) public facilities, 4) electric power generation and other applications and 5) consumer use.

Among them, Residential PV systems overwhelmingly dominate the domestic PV market with about 85 % of the share. In the residential PV market, dissemination of PV systems for newly built and existing houses has been successfully ongoing, and the market size has expanded to the annual sales of over 60 000 systems. Thus, PV manufactures place great importance on development of PV modules for houses and commercialize PV modules with higher conversion efficiency, small-sized PV modules which can increase installation areas on the roof, lead-free PV modules and so on. In addition to these, PV manufacturers promote value-added products combining a residential PV system with "Eco-Cute," a highly-efficient heat pump and induction heating (IH) cooking equipment. Leading housing manufacturers are creating a new market for residential PV systems by developing all-electrified houses equipped with PV systems and zero utility charge houses by raising the power generation capacity of the PV systems to 5 to 7 kW. They also promote large-scale housing developments in which PV systems are installed in all the houses built for sale and disaster-prevention housings equipped with PV systems and storage batteries.

In the area of industrial and business facilities and in the area of public facilities, more and more large-scale PV systems have been installed and installations of middle scale PV systems with 10 to 30 kW of power generation capacity have been increasing. In order to correspond to these movements, inverter manufacturers commercialized 100-kW inverters and small-sized 10-kW inverters that occupy smaller space. Application areas are expanding year by year in these two sectors. In the industrial and commercial segments, PV systems are installed in factories, commercial buildings, research laboratories, railway stations, warehouses, convenience stores, service stations, parking spaces, etc. In the area of public facilities, PV systems are installed in the national and local government office buildings, schools, hospitals, welfare facilities, parks, water treatment facilities, etc. PV modules used for these areas become more and more diversified. As well as conventional ones, various types of PV modules are adopted: flexible modules, lightweight modules, light-transmitting modules, bifacial power generation modules, roofing material-integrated modules, wall-material integrated modules and PV modules using plastic film substrates, etc.

In the sector of electric power generation and other applications, off-grid non-domestic PV systems, which do not require governmental supports, are mainly utilized as power supply sources for telecommunications, traffic signs, monitoring devices, ventilation, lighting and charging for mobile devices. Recently, lighting fixtures combining light emitting diodes (LEDs) and solar cells, small-scale hybrid systems combining wind and PV power generation and PV system for agricultural uses have been commercialized one after another. In 2004, a luminescent PV module integrated with light emitting diodes (LEDs) was commercialized as a novel product.

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

SUB-MARKET /APPLICATION	1998 KW	1999 KW	2000 KW	2001 KW	2002 KW	2003 KW
Off-grid domestic	450	500	550	600	955	1 101
Off-grid non-domestic	52 300	56 200	63 000	66 227	71 692	77 792
On-grid distributed	77 750	149 000	263 770	383 086	561 295	777 830
On-grid centralized	2 900	2 900	2 900	2 900	2 900	2 900
Total	133 400	208 600	330 220	452 813	636 842	859 623

As for new development of the PV system market, development of power supply systems for communities utilizing distributed power generation systems was started. In the Demonstrative Project on Grid-Interconnection of Clustered Photovoltaic Power Generation Systems, grid-connected PV systems are intensively installed on houses in one area. Under the Demonstrative Project of Regional Power Grids with Various New Energies, several types of power generation systems using new energy technologies such as PV systems, wind power generators, fuel cells and biomass power generation systems for supplying electricity are installed in each community. Housing manufacturers started to offer preferential loans for newly built houses equipped with PV systems in corporation with financial institutes, and work on sales expansion.
Table 1 shows the cumulative PV power installed by the end of 2003 in 4 sub-markets.

FUTURE OUTLOOK

In 2004, The Ministry of Economy, Trade and Industry (METI) compiled the "Vision for New Energy Business" as the strategy for the new energy industry. The Energy Supply and Demand Subcommittee of Advisory Committee for Natural Resources and Energy, a consultative body of METI compiled the draft interim report of "Energy Supply and Demand Outlook for 2030," New Energy and Industrial Technology Development Organization (NEDO) disclosed a roadmap for technological development of the PV system, "PV Roadmap toward 2030 (PV2030)."

All of these are developed toward the year 2030 from a long-term perspective, and the strategies for technological development of PV power generation, the new energy industry and the energy policy were presented. As each vision presents the future potential and significance of the role of the PV system, these visions are regarded as key guiding principles of further deployment of PV systems and development of the PV industry in Japan.

PV2030 Roadmap laid out technical background to achieve 7 JPY/kWh of PV power generation cost, similar cost level as that for electricity rate for industrial use, by continuous enhancement of technological development and milestones for technical development for the target. In the Vision for New Energy Business, PV systems, wind power generation and biomass energy are emphasized. The Vision shows that the new energy industry would be self-sustainable and competitive by shifting measures on new energy from the current measures depending on subsidies to the measures for creating the market environment based on the needs from the demand side.

The Energy Supply and Demand Outlook describes energy supply and demand outlook for 2030. As the paths of energy supply toward 2030, the report set out several pictures of the future: 1) Reference case based on business as usual, 2) Energy technology advanced case (Energy conservation advanced case, New energy advanced case), 3) Nuclear power case (High case, Low case), 4) External macro factor case (High & Low economic growth cases, High & Low crude oil price cases). Among these cases, PV system delivers significant impact on the New energy advanced case of Energy technology advanced case. Under this case, supply volume of new and renewable energy in FY 2030 is estimated to be 39,46 million kilolitres, accounting for about 10 % of the total primary energy supply, and about half of the estimated volume is generated by PV power generation as shown in Table 2. The supply volume of PV power generation corresponds to about 80 GW, and the potentiality of PV systems is highly regarded.

With the Government's supports for promotion and deployment of PV systems, publicity activities, promotion measures to arrest global warning and green procurement thus far, individuals, ministries and agencies, local governments and private entrepreneurs have been promoting further introduction of PV systems. With the growth of the PV market, PV manufacturers make an effort to expand their production capacity and reduce PV system price. More and more industries such as the roofing industry, the building material industry, the housing industry, the construction industry and the power source equipment industry, which are expected to play an essential role to promote PV systems as a go-between of the PV industry and end users, have been engaged in the PV market. At the same time, the producers providing mass volume of raw materials for various types of solar cells to PV manufacturers and the manufacturers of production equipment for solar cells are being fostered.

Consequently, the PV system market is being structured on the basis of solar cells and PV modules with raw materials, components, production equipment of solar cells and application products using PV systems. Thus, the PV system market, especially led by the segments

of residential houses, public facilities, industrial and business facilities, is expected to expand and grow to be a self-sustainable market in the near future, by achieving cost reduction with the Government's support for research, development and introduction of PV systems.

TABLE 2 - SUPPLY VOLUME OF NEW ENERGY IN FY 2030 BY CATEGORY:

NEW ENERGY	SUPPLY VOLUME (crude oil equivalent)	SHARE
PV power generation	**20,24 million kl**	**51,3 %**
Wind power generation	2,69 million kl	6,8 %
Waste power generation	3,74 million kl	9,5 %
Biomass power generation	1,20 million kl	3,0 %
Solar thermal utilization	1,12 million kl	2,8 %
Unused energy (including thermal utilization of ice and snow) and waste	0,87 million kl	2,2 %
thermal energy Thermal utilization of biomass	4,23 million kl	10,7 %
Black liquor, waste materials, etc.	5,37 million kl	13,6 %
Total	39,46 million kl	100,0 %

Source: "Energy supply and demand outlook for FY 2 030" (draft interim report), The Energy Supply and Demand Subcommittee of Advisory Committee for Natural Ressources and Energy, June 2004.

KOREA

PV TECHNOLOGY STATUS AND PROSPECTS

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GENERAL FRAMEWORK

In December 2003, the Government, Korea Ministry of Commerce Industry and Energy (MOCIE), announced "The 2nd Basic Plan for New & Renewable Energy Technology Development & Dissemination". This new plan aims at developing the relevant New and Renewable Energy Technology and has a target to attain 3 % share of New and Renewable Energy by year 2006, 5 % by year 2012. In order to achieve this target, an aggressive approach must be taken to create the mark and to expand market size. With the limited amounts of funds, development of all New and Renewable Energy technologies could not be effective without selection or concentrated efforts. Hence, PV that has only been a promising technology for the future until now and which has a large potential in reducing environmental pollution has been selected as a high priority programme.

NATIONAL PROGRAMME

Korea's national PV plan was recently renewed. The goal was previously 30 000 roofs by the year 2010. Now the goal has been increased to 100 000 roofs and 70 000 buildings, for a total capacity of 1,3 GW by the year 2012. The new plan for this technological progress is divided into different steps focusing on developing the technology for mass distribution and commercialization of PV. In the short-term, the PV cell R&D is focused on crystalline silicon. The target is to increase PV module efficiency from the current 12 % to 15 %, until the year 2006, and to 18 % until the year 2010. The cost target of the module is 5,4 USD/W until the year 2004, 3,3 USD/W until the year 2006 and 1,9 USD/W until the year 2010. Finally, targeted developed technologies will be commercialized by the year 2012.

Since 1993 the MOCIE (Ministry of Commerce, Industry and Energy) has been implementing, via the KEMCO (Korea Energy Management Corporation), demonstration and field tests of various renewable energy technologies. In addition, the government has been encouraging and supporting local authorities to implement their own demonstration or field test projects under the framework of the "Local Energy Development Programme." This programme aims in part to raise public awareness on renewable energy technologies and to develop indigenous renewable energy sources for each region. In both of these projects, PV technology remains the top priority.

The Renewable Energy Demonstration Programme: Among a total of 33 projects implemented under this programme, the number of projects related to PV amounted to 21 in the year 2003. Various grid-connected PV systems with a power capacity of 5-30 kW were installed in schools and universities. In addition, fifteen other individual buildings had PV arrays on their rooftops. All the rooftop PV systems have the same 3kW capacity. A total of 1,3 billion KRW was invested on PV power systems. The beneficiary paid only 30 % of initial investment.

The Renewable Energy Field Test Programme: Several PV rooftop systems have been tested at the "Solar Energy Field Test Site" at Chosun University in Gwangju metropolitan city. System performances and reliability are tested and evaluated.

Fig. 1 - 100kWp grid-connected PV systems installed at a parking place inside Gwangju metropolitan city hall, under the Local Energy Development Programme, in 2004.

The Local Energy Development Programme: Under the local energy development project, a wide variety of PV systems including off-grid domestic, non-domestic and grid-connected systems were constructed. In 2003, the government allocated more than 25,7 billion KRW for this programme, PV accounted for more than 47 %. Local authorities, in cooperation with the MOCIE, implemented a variety of PV system installation aimed at increasing public awareness on PV and to develop PV as indigenous renewable energy sources for their region. It is worthy to note that several local authorities started the planning of "Green Village" projects. The objective of this project is to construct a small-size solar village by using photovoltaic power systems and solar thermal systems as much as possible. In 2003, two local authorities, Gwangju and Daegu metropolitan cities, were beneficiaries of "Green Village" projects. In 2004, more local authorities were designated as the target of this project.

As a collaborative project, known as DURE-Gobi Project with Mongolia, KIER has installed a PV (5kWp) - Wind (3kW) hybrid system and Solar Home Systems at an isolated village in the Gobi Desert in October 2003. With the Solar Village Project through the International Joint Project between Korea and Vietnam, KIER has installed 3kW PV system and 50W solar home systems in a remote area of Vietnam in 2003. The new international collaborative project with China has begun in 2004. The 100kWp grid-connected PV systems will be installed in Tibet and the system performances will be monitored during a 3 year period. Collaborative Project in 2003.

R&D ACTIVITIES

The PV R&D projects are mainly supported by the MOCIE, and some basic research projects are supported by the MOST(Ministry of Science and Technology). The KEMCO is a leading organization in management of R&D projects as well as in demonstration and field test projects. At the end of 2003 the KEMCO has established the 'R&D Center for Photovoltaics," in order to carry out R&D activities more efficiently and promote cooperation among the government

Fig. 2 - 3kWp PV systems (left) and 50W solar home system (right) installed in remote areas of Vietnam, through the International Collaborative Project in 2003.

organizations, research institutes, universities and industries. This center is carrying out planning on R&D, commercialization and widespread deployment scenarios of PV power systems.

The R&D projects implemented in 2003 included various categories. In the short term covering the period 2001-2004, the key project has been to develop solar cell mass production technology and BOS systems for 3-kW residential rooftop systems. In the mid- and long-term, two projects have been implemented. One was related to BIPV and the other one was aimed at developing polycrystalline thick-film silicon using solution growth.

In addition, research institutes and university laboratories have been carrying out some basic R&D projects on thin-film solar cells. The materials included CIGS, amorphous silicon (a-Si), polycrystalline silicon (p-Si), organic materials and TiO2 for dye-sensitized PV cells. The KIER is very active in R&D on CIGS chemical compound and polycrystalline silicon thin film solar cells in order to develop low-cost and high-efficiency solar cells. Recently, dye-sensitized solar cells and organic solar cells attracted much interest from university research teams.

IMPLEMENTATION

The PV market was still dominated by off-grid non-domestic sector that occupied about 71 % of the cumulative installed PV power. However, the market share of this sector has been decreasing year by year. Among the various off-grid non-domestic applications, telecommunications was still the largest sector of application, followed by marine applications such as lighthouses and street lighting. In the year 2003, marine applications were the largest sector of application, followed by highway emergency call box and street light lamps. Other important applications include PV systems for river flood warning systems, aviation warning lamps on high-voltage transmission towers, environment- monitoring equipment such as water-borne pollution, sewage, forest fire monitoring and traffic signaling. For off-grid domestic application, no system was installed in 2003. The share of this sector has decreased to about 7 % of the total cumulative installed PV power.

In 2003, several dozens of grid-connected distributed systems with a capacity in the range 3 kW to 200 kW were installed. Among them, 16 systems were for public office buildings and 5 systems were for rooftop systems on residential houses (Figure 5). The share of these grid-connected distributed systems increased to 22 % of the total cumulative installed power; compared to 14 % in the previous year. In 2003, the total installed power of this sector was 667 kW, representing 65 % of the total PV market. In 2002 a total capacity of 237 kW were installed, and the share was 36 %. This sector has been intensively promoted under the framework of the "Renewable Energy Demonstration Programme" or the "Local Energy Development Programme," and is supported by the government and local authorities.

The total cumulative installed PV power for each sub-market on the 31 December of each year, from 1992 to 2003, is shown in Figure 4. The total installed power of PV systems in Korea was 6 438 kW at the end of 2003. The total PV power installed during the year 2003 was 1 028 kW, which is about 60 percent higher than that achieved in the previous year (653 kW). For the first time the annual installation exceeded 1 MW.

INDUSTRY STATUS

The status of PV cells and module production in 2003 is summarized in Table 1. Until 1999, High Solar Company (independent from former LG Siltron Co. in May 1999) continued to manufacture PV cells, but this company stopped its operation in 2000. In 2001, there was no PV cell manufacturer in Korea. In 2002, two new companies entered into PV cell production. Neskor Solar Co. produced 0,24 MW and Photon Semiconductor & Energy Co. 0,3 MW in 2003. The latter significantly increased its production capacity from 0,5 MW to 6,0 MW in 2003. These two companies provided a part of their production to domestic module manufacturers and some to foreign companies. These two companies import wafers from foreign companies.
In 2003, five companies including one that started its operation at the end of 2002, produced about 2,29 MW of PV modules. This nearly tripled the previous year's production figure. This remarkable expansion of PV module production was due to the newly established company "ATS Solar Co." This company produced about 1,4 MW PV modules

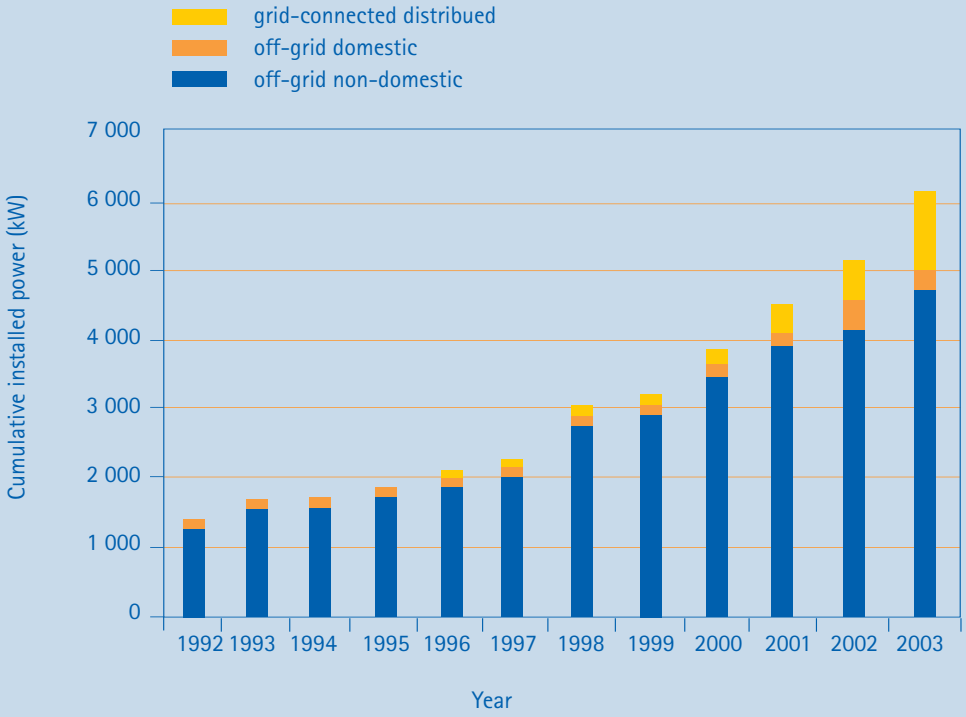

Fig. 4 – The cumulative installed PV power in 3 sub-markets from 1992 to 2003.

with a production capacity of 3,0 MW. This production line is the largest one in Korea. The total production capacity was also tripled, compared with that of the year 2002. Most of single and multi-crystalline silicon PV cells were imported from foreign countries. The average PV module prices decreased about 10 % in 2003 compared to the previous year. The prices were in the range of 5 700 to 8 000 KRW/W, depending on the manufacturing company and the order volume.

In 2003, Hex Power Systems was the only company to manufacture inverters for grid-connected systems. This company produced various products with a capacity 1 - 50 kW. The prices ranged between 2,83 MKRW/kVA for a size smaller than 1 kVA and 1,57 MKRW for larger than 100 kVA, depending on the inverter size.

Two companies were involved in producing inverters for stand-alone systems. In the case of inverters for stand-alone systems, the average price was about 2,2 MKRW/kVA for a size larger than 10 kVA. There is one PV battery manufacturer, Global High-tech Co. that produces lead-acid batteries of a tubular plate stationary type. The unit price of the battery with a capacity 2 000Ah/100hr is about 1 000 kKRW. Concerning the supporting structures, PV system installers used their own type of support structures made from anodised aluminium or galvanized steel. That is why the price of the supporting structures is so multifarious.

FUTURE OUTLOOK

Korea's national PV plan was recently renewed. The previous goal was 30 000 roofs by the year 2010. Now the goal has been increased to 100 000 roofs and 70 000 buildings for a total capacity of 1,3 GW by the year 2012. The total capacity is broken down into different sectors. Three different sizes of systems will be developed such as 3 kWp for residential homes, 10 kWp for public buildings, and 20 kWp for industrial buildings. An explosive growth of the market is expected between 2006 and 2012; once the foundation is set into place by the year 2006. The Korean government recognizes that PV industry will grow and take up to 10 % of the world market by the year 2012 with the export amounting to 3 BUSD and employing 50 000 people. The strategies for promoting the distribution of PV systems are described below. The whole programme will be managed and monitored by the experts group organized solely for the PV technology distribution.

- Establish the foundation for mass distribution through developing PV systems for distributed electricity system. During 2001-2006, focus on developing the standardized systems for residential homes and for commercial buildings that have large potential demands.
- Setup the test sites and villages for demonstration. Establish "green villages" throughout Korea starting from Daegu and Kwangju. For new buildings, encourage the installation of 10 kW PV systems and, for factory buildings, 20 kW PV systems.
- Complete the regulatory system for promoting PV.
- Maximize the subsidization programme that has a strong short-term effect. Further promotion should be pursued by "green pricing" and other tax incentives.

To fuel the plans and strategies mentioned above, Korea will spend about 2,3 BUSD during 2004-2012. The fund will be provided by the government. As the PV world market rapidly grows, investment from industry is expected to quickly increase.

Fig. 5 - 3kW grid-connected PV systems installed at private residential houses under the Program of Local Energy Development Program in 2003.

TABLE 1 - ANNUAL PRODUCTION AND PRODUCTION CAPACITY INFORMATION FOR EACH MANUFACTURER

CELL/MODULE MANUFACTURERS (MWP)	TECHNOLOGY	TOTAL PRODUCTION CAPACITY (MWP)		MAXIMUM PRODUCTION CAPACITY (MWP)	
		CELL	MODULE	CELL	MODULE
1. Neskor Solar Co.	sc-Si		0,24		0,6
2. Photon Semiconductor & Energy Co.	sc-Si		0,30		6,0
3. S-Energy Co	mc-Si			0,35	1,0
4. LG Industrial System Co.	sc-Si			0,25	0,5
5. Haesung Solar Co.	sc-Si, mc-Si		0,07		0,5
6. SolarTech Co.	sc, mc-Si			0,2	1,0
7. ATS Solar Co.	sc, mc-Si			1,42	3,0
TOTAL		**0,54**	**2,29**	**6,6**	**6,0**

MEXICO

PV TECHNOLOGY STATUS AND PROSPECTS IN MEXICO
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Fig. 1 - Quality Assurance in PV Rural Electrification Projects.
Fig. 2 - PV Street lighting in rural communities.

GENERAL FRAMEWORK

Implementation of PV systems in Mexico during 2004 maintained the same dynamics as in previous years. Rural electrification remains as the main application niche, although other applications, such as water pumping for small agricultural irrigation and livestock watering, keep growing steadily. New applications in the urban setting are emerging, such as a larger system of around 30 kWp, now under design, to be installed as part of the roof on a health food store building in Mexico City.

NATIONAL PROGRAMME

The National Energy Plan 2001 - 2006 sets a target for the electricity sector of 1 000 MW of additional installed capacity from renewables (excluding high temperature geothermal and large hydropower plants). That means a country commitment to the development and deployment of renewable energy, including photovoltaics.

The Government of Mexico is currently negotiating a GEF-WB project for the large scale deployment of renewable energy. Also under development is a project for capacity building in the area of rural electrification, including PV. Participation of national institutions and organizations, the Global Village Energy Partnership (GVEP), and the World Bank, among other international agencies, is anticipated.

RESEARCH AND DEVELOPMENT

During 2004, R&D efforts focused on the development of an inverter for grid connected applications. Other activities carried out included the continued performance monitoring of the grid connected systems installed in the Northern States of Baja California, Sonora and Nuevo Leon.

IMPLEMENTATION

The first privately owned grid-tied PV system is in the planning stage. The conceptual and basic engineering for the system has already been done. The system, around 30 kWp in capacity, will be installed on the roof of a health food store called the "Green Corner," in Mexico City. The system set-up is planned to begin during the first half of 2005.

The Shared Risk Trust Fund of the Agriculture and Livestock Secretariat, (FIRCO, its name in Spanish) continued the technical and financial support for the installation of PV powered water pumping systems, electric fences, and cold tanks for milk storage.

The projects carried out by FIRCO were partially financed with funds from the Global Environment Facility (GEF), the Mexican Federal Government and the users. Under this programme, more than 450 PV water pumping systems were installed during 2004, with an installed power capacity near 300 kWp. FIRCO also co-sponsored with the Mexican Branch of ISES, The World Congress on Renewable Energy, held in central Mexico, where the application of PV for productive uses was one of the main topics.

The construction of a large hydroelectric power Plant located in the mountains of the western state of Nayarit, required the relocation of some rural communities to higher lands. Plans for the energy supply for some of those communities include Solar Home Systems, because PV represents the best techno-economic solution for this application.

MARKET DEVELOPMENT

The Mexican PV market for 2004 was a little bit above 1 MWp. Market segmentation was as follows. rural electrification remains as the main application for PV in Mexico with an installed capacity in 2004 of 574 kW; professional applications (telecommunications, off shore oil platforms and cathodic protection) amounted to 151 kW; water pumping 300 kW; and others miscellaneous applications 16 kW. The cumulative PV capacity installed in Mexico by the end of 2004 was 18,14 MWp.

FUTURE OUTLOOK

Distributed generation is attracting the attention of the national utility as an alternative to support the electrical grid in some areas, and could become an important application in the near future.

Rural electrification is once again back at the top of the priorities of the federal government, so that a growth in capacity installed in this area is also expected for the coming years.

THE NETHERLANDS

PV TECHNOLOGY STATUS AND PROSPECTS

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GENERAL FRAMEWORK

In 2004, the investments in solar PV in the Netherlands dropped dramatically in comparison to 2003. This was caused by the simultaneous ending of both the EPR (Energy Premium Incentive) and the utility subsidies, which together had led to the excessive support during 2003. As a direct consequence of the ending of both subsidies, the size of the Dutch PV market went back to the level of the year 2000. First estimates of the amount of PV installed in 2004 point at 4 MW, 20 % of the PV power installed in 2003. Some smaller PV companies, mainly electrical contractors, stopped their PV activities or ceased to exist, others shifted a large part of their activities to foreign countries, and in particular to Germany.

For PV RTD on the other hand, new opportunities arose, as the new scheme for energy RTD activities was introduced in the second half of 2004. This new scheme is a well-balanced set of support mechanisms, reaching from new ideas to demonstration, with PV RTD as one of the priority areas.

NATIONAL PROGRAMME

Anticipating the new energy RTD scheme) programme, the last version of the DEN subsidy included only 1 call for 2004, which closed in June. As in previous years, this programme again supported R&D-, demonstration-, feasibility- and knowledge transfer projects for all forms of renewable energy. The main evaluation criteria for proposals for this programme were innovation and overcoming thresholds, expressed in the expected contribution from spin-off projects to the Dutch energy production in 2010. Though especially the latter criterium might not look favourable for PV, nearly 30 % (2 MEUR) of the R&D budget went to PV RTD projects, mainly because of their high innovation rating.

During the first half of 2004, the Ministry of Economic Affairs and SenterNovem developed a new coherent and consistent set of Energy RTD programmes, covering the full range from new unconventional ideas to pilots and demonstration. This new set (fig. 1) consists of two already existing programmes: NEO and IS and three new programmes: EOS LT, EOS Demo and Transi-tion UKR. The different programmes are targeted as follows (in sequence from fundamental re-search to implementation):

- **NEO:** New Energy Research, focussing on new, unconventional ideas. This programme is mainly intended for inventors. The programme covers all new energy options.
- **EOS LT:** Energy Research Subsidy - Long Term, focussing on a selected range of promising energy saving- or renewable energy technologies, with expected serious impact between 2010 and 2030.
- **IS:** Innovation Subsidy Collaboration Projects, focussing on technology transfer from research to industry, in order to convert technologies into products.
- **EOS Demo:** Energy Research Subsidy - Demonstration, focussing on testing and demonstrating new energy saving- or renewable energy applications in a realistic user environment.

Fig. 1 - Successful roll-to-roll pilot line at AKZO (insert: coat mounted amorphous silicon thin film "module"), (photo AKZO Nobel Nederland).

- **Transition UKR:** Transition - Unique Opportunities Scheme, focussing on improvement of material- and energy use and on the application of renewable in general, and biomass in particular.

The priorities for this set of programmes, especially the EOS and Transition UKR programmes, had been determined in 2003 during a wide consultation amongst energy research, industry and policy professionals.

Main criteria for the selection of the preferential technology areas under this scheme are the contribution to the Dutch energy production in 2010, 2030 and 2050 and the level of expertise in the Netherlands. PV came forward as one of the priority areas, with specific strong positions for polycrystalline silicon and inorganic thin film technologies.

The actual EOS programme started with the opening of the first EOS LT call in October 2004. Due to the high priority for PV RTD within these programmes expectations are high for the (support of) PV RTD in the coming years.

RESEARCH AND DEVELOPMENT

The main focus of PV RTD activities in the Netherlands is still on cost reduction and quality im-provement of both polycrystalline- and low temperature thin film silicon solar cells. Special attention in these fields is given to improvement of the PUM cell (positive and negative back contacts), RGS processes, and roll-to-roll processes. Apart from this, serious work is done on solar grade silicon, CIS cells, dye-sensitised solar cells ("Grätzel" cell), polymer-based solar cells and new concepts for solar cells based on sensitised oxides (ETA solar cell). With a small new PV dedicated programme, the Dutch PV R&D community is trying to bring in and start co-operation with R&D centres and industries outside the traditional PV community. A good and successful example of such collaboration is the participation of the Dutch Polymer Institute in polymer-based cell research.

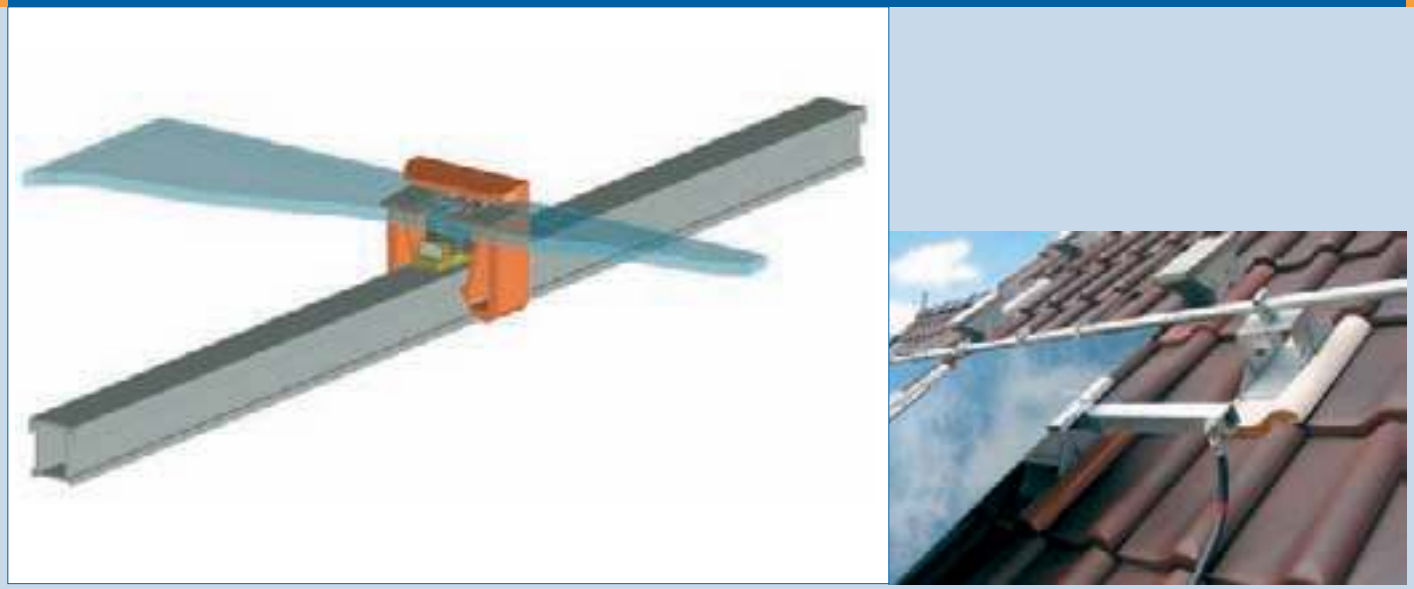

Fig. 2 - Schematic drawing and field test set-up (insert) of PV Wirefree, with wireless connection of the PV module to the conducting mounting frame (photo OKE services).

Main players in the fundamental Dutch PV RTD activities are ECN, AKZO Nobel Nederland, TNO, and the Universities of Utrecht, Eindhoven, Groningen and Delft.

The main activities in the field of BOS were the continuation of the development of the wire-free mounting system, (Fig. 2) an intelligent PV facade system and the PV watchdog, showing with two leds the actual status of a module.

At the international level, Dutch PV RTD centres and industries collaborate in several networks, amongst which the CrystalClear project, which is co-ordinated by ECN and started early in 2004. Other PV RTD or PV RTD related international projects with Dutch participation granted in 2004 are PV-ERA-NET and the PV Policy Group.

Consolidated figures showed that the budget for PV RTD in the Netherlands is decreasing slightly from 16 MEUR in 2002 to 14 MEUR in 2003 .

INDUSTRY STATUS

As mentioned earlier, the Dutch PV industry, was strongly affected by the changes in the EPR and the utility subsidies. With the ending of these PV market introduction support schemes many project developers and electricity contractors shifted their focus to foreign countries and in particular Germany.

In 2004 only two companies, DOPT and Scheuten Glas Group were responsible for the total Dutch PV module production. However, a new solar cell production company was founded to start solar cell production in September 2005, while AKZO successfully installed the roll-to-roll pilot line (Fig. 1). Scheuten Glas Group is continuing its activities in cell research.

1 These figures relate to all public RTD on universities, institutions etc. The 2004 figure is not yet available.

There was little change in the field of BOS, during 2004. Main inverter producers are still Mastervolt, Philips and Exendis.

DEMONSTRATION PROJECTS, IMPLEMENTATION AND MARKET DEVELOPMENT

Though 2004 showed a serious collapse of the PV market, still some interesting larger demonstration projects could be realised. A good example is the PV facade of a parking garage in Zwolle, consisting of 840 amorphous silicon solar panels, powering the automatic parking system of the garage (Fig. 3). Most of the activities were generated in municipalities already known to actively support PV. The City of the Sun project again made progress in its goal of installing 5 MW in the new urban area between Heerhugowaard, Alkmaar and Langedijk.

Apart from such projects, the market for PV decreased dramatically in 2004. With the phasing out of the investment subsidies, the market for small PV systems for private house owners almost disappeared. This resulted in an estimated total implementation in the Netherlands of less than 4 MW (which is around 20 % of the systems installed in 2003), of 25 % of the 4 MW was installed by private house owners.

FUTURE OUTLOOK

With the installation of the new EOS programme, and the carefully balanced set of instruments, the Dutch environment appears to become friendlier for PV RTD and demonstration activities. Furthermore, a positive aspect of these programmes is the increased international orientation, allowing more international interaction and exchange of knowledge and experience and thereby improving the effectiveness and efficiency of the Dutch programmes.

In the national renewable energy policy, no priority is given to market introduction of the more costly RE technologies, like solar PV. For PV on the other hand, the Dutch policy focuses on R&D, especially on technology development for more cost efficient PV systems in the next dec-ade. Nevertheless, existing PV installations may profit from the 10 ct/kWh feed-in tariff of the so-called MEP scheme offers. Also net metering for small domestic systems was allowed in 2004. These two schemes together allow private PV-owners a net subsidy of almost

Fig. 3 - Amorphous silicon façade on a parking garage in Zwolle (photo Oskomera).

30 ct/kWh. However, this subsidy is expected to be not enough to reach market figures like in the EPR period (2002-2003).

The final step in the liberalisation of the energy markets took place in 2004, but the effect of this on the solar interest was not significant. However, some utilities are setting aside large budgets to increase their installed renewable energy for the growing green energy market. This may be beneficial for PV in the future Furthermore, the announcement of the reduction of the EPC (Energy Performance Standard) to 0,8 (from 1,0) by 2006 for newly built houses may support the future PV market.

NORWAY

PV TECHNOLOGY STATUS AND PROSPECTS
HARALD RIKHEIM, THE RESEARCH COUNCIL OF NORWAY

Fig. 1 - New opera house in Oslo planned with 400 m² PV cells (photo Snoehetta AS).

GENERAL FRAMEWORK

Norway has no public schemes for supporting PV systems. Electricity production in Norway is almost exclusively hydro power. Growing import from other countries has increased the focus on other renewables, but this is mainly wind and small hydro. The main market for PV in Norway continues to be related to off-grid applications.

NATIONAL PROGRAMME

A new energy research programme called Renergi (clean energy) (www.renergi.com) in the Norwegian Research Council was established in 2004. In addition to industry oriented research this programme also funds basic research and socio-economic research within the energy field and among these, renewable energy sources and energy efficiency. The total funds for PV-related R&D projects were approx. 5 MNOK for 2004. Most of the R&D projects are focused on the silicon chain from feedstock to solar cells.

RESEARCH AND DEVELOPMENT

At **SINTEF Architecture and buildings**, PV research has mainly been conducted in "Smartbygg", a strategic research programme in cooperation with NTNU. The project seeks to develop energy efficient building systems of the future. One project activity is innovative use of solar cells in buildings, where the solar cells are integrated in the building structure and energy system.

SINTEF Materials and Chemistry has substantial activity related to photovoltaics and solar cell technology. The activities are centered around two aspects; - new sources and production methods for silicon to solar cell applications and - fundamental research on materials for photovoltaics.

Agder University College has an Energy Park, which includes a 20 kW photovoltaic array, consisting of 10 kW amorphous cells and 10 kW multicrystalline cells. The focus of this installation has so far been demonstration of an integrated energy system, and the power produced by the PV-system has mostly been inverted and fed to the local electricity grid.

Presently, there are plans for major upgrades of the Energy Park. Part of these plans concern the use of Hydrogen as an energy carrier. For this purpose, the Energy Park is planned as being one of the nodes in HyNor - the Norwegian hydrogen highway. Integral in these ideas is a goal to feed one of the two planned electrolysers in the park with PV-power. In fact, the power will be fed via a common DC-link, and the PV-system is intended to be one of several electricity sources for this system. Thus, at optimal insolation, the PV-system would feed all the necessary power for the smaller electrolyser.

On a smaller scale, Agder Universiy College is presently working with characterization of three different types of PV-modules: monocrystalline, multicrystalline and amorphous. An automated measurement setup has been made, and data is presently being collected, focusing on parameters such as efficiency of the various modules compared to weather data.

They are also active in making state-of-the-art analogue PV-module simulators, that mimic the behavior of such systems using light emitting diodes as light sources, but giving the output power and i-v characteristic of a real system. This is used as laboratory equipment for the development of ancillary equipment such as power electronics converters for PV-systems, and also serves as a pedagogical tool in the education of engineering students at the college.

Institute for Energy Technology (IFE) is a private research foundation with about 550 employees. IFE's activity on solar electricity is comprehensive involving 15 persons, as it stretches from basic research on feedstock of silicon, process development, process

Fig. 2 - Private house with 1,2 kWp solar cells in Bergen (photo Nakling).

optimalisation, processing and characterisation of silicon solar cells, and finally modelling and analysis of integrated PV-systems. IFE has a full inline solar cell processing line for silicon based solar cells. In addition advanced characterisation laboratories for material, electrical and optical properties are also present.

On the system level IFE continued their efforts in 2004, in the area of stand-alone power systems based on photovoltaics and hydrogen energy storage technology (HSAPS). A laboratory for testing and experimentation has been established and is continuously being upgraded. The main components of the current HSAPS-laboratory is a 2 kW PEM electrolyzer, a 14 Nm^3 (42 kWh) metal hydride storage, and a 500 W PEM fuel cell, while the PV-input is being simulated. Work on a newly acquired 1-kW water cooled PEM fuel cell that is to be thermally integrated with a custom-made metal hydride has started, and preliminary work on the integration of a 5 kW wind turbine into the HSAPS-laboratory system is also well underway. The experimental work is being complemented with modelling work. The HYDROGEMS-library (www.hydrogems.no) and simulation packages developed at IFE were used to design and evaluate the performance of renewable energy hydrogen systems, including PV-based systems, located in various parts of the world.

IMPLEMENTATION

The main market for PV in Norway continues to be related to off-grid applications. This refers to both the leisure market (cabins, leisure boats) and the professional market (primarily lighthouses/lanterns along the coast and telecommunication systems).

Exceptions are demonstration projects, for which grid-connection, in some cases was performed.

Up to 1992, the leisure market, dominated by new installations in cottages and recreational homes grew rapidly. After 1992, this market slowed down due to saturation. However, some cabins have been fitted with additional power to serve new demands like TV and refrigeration. Since the first installations are now more than 30 years old, it will probably make sense to begin replacing systems, rather than maintenance. Still however, there are not many reports about customers wanting to replace old installations with new ones. Most sales are for new installations or expansions only.

In the 1990s, PV powered coastal lighthouses emerged as a significant new market. Even north of 70°, lighthouses may be powered by PV, provided the battery bank has sufficient capacity. The programme was launched by the Norwegian Coastal Administration in 1982 and was completed in 2000-2001. Approximately 1 840 installations with a total of 3 600 modules are now supplying lighthouses and coastal lanterns along the Norwegian coast. The smallest are equipped with one single module of 60 W, the largest with arrays counting up to 88 modules. A large number of the systems are powered by 3 to 4 modules of 60 W. The average is 135 W per installation. The cumulative installed PV power capacity is 215 kW. The installations are equipped with battery banks (NiCd) with spare capacity ranging from 10 to 120 days and mean lifetime of 20 years. In the future, solar power will be combined with other renewable energy technologies in hybrid systems. The Coastal Authority is presently testing small wind turbines in combinations with PV. Solutions including fuel cells are also being considered.

Applications of stand-alone PV for telecommunication stations and hybrid utility systems (called here the professional market, as opposed to the leisure market) have also grown during the past years. Utility companies have made some selective investments for providing electricity to remote dwellings. PV in combination with other energy sources have been demonstrated for permanent dwellings, and may offer a viable solution where the distance to existing electricity grid exceeds 10 km. An earlier demonstration project, where PV was combined with a LPG fired engine generator-set, has been followed up by a few other LPG or diesel powered systems. Although these systems include battery storage, they do not appear to have included PV installations. Actual turnover and installations vary from year to year, depending largely on project allocations.

Norway does not have any incentive schemes supporting the installation of PV systems, and consequently, there are very few grid-connected systems. Some building integrated installations have, however, been built during the last few years. Among these are The Technical University in Trondheim (16kW), the BP administration building in Stavanger (approximately 16 kW), and the low-energy dwelling at Hamar (2,2 kW). All of these were installed before 2003. Two other more recent projects are worthwhile mentioning:

Vest Agder Clinic in Kristiansand: The PV system consists of a total of 48 modules arranged in two strings of 24 modules each. The module brand is GETEK PVP102012, made by GPV in Sweden. Each module has a 102 Wp capacity (12V). There are two inverters, one for each string, type SMA Sunnyboy 2100. The PV system is connected to the grid through two 16 A circuits. The system was made operational in February 2004, with an expected power production of 5000 kWh/year. The PV system at the Vest Agder Clinic is part of the PV-NORD project. PV-NORD is a combined RTD project (research, technology and development) supported by the European Commission, DG Energy & Transport under the Fifth Framework Programme. The 16 project partners share an overall budget of 2,8 MEUR. (see www.pvnord.org)

Rebuilt private home in Bergen: During extension-/rehabilitation work on a single family house in Bergen, PV cells, as well as other renewable energy technologies have been utilized. So far, a PV system with 1,2 kWp is mounted on a roof surface facing south. The PV-system consists of 4 German (RWE) manufactured modules (ASE-300-DG-FT), each with a capacity of 300 Wp. The DC-current is rectified via a Sunny Boy 2100 DC/AC rectifier before it is either consumed domestically, or fed into the local grid. The PV system was commissioned in February 2004. Most of the planning and installation work has been done by the house owner himself, Dr. Arne Nakling, who is a physician by professional.

New Opera House in Oslo: The most exciting building integrated project currently being planned is the use of transparent double glass modules on the 400 sqm southern façade of the new Opera House of Norway, to be located in the Oslo Harbour area, see picture. This is part of an EU project EcoCulture.

INDUSTRY STATUS

Elkem Solar was established in 2001 with its main objective being to develop a process for feedstock to solar cell production. With the developed metallurgical route ES has the potential to be an important player in this market. During the last year of development, feedstock from ES has been tested industrially. Silicon from ES (ES-Si) has been mixed with standard feedstock in the range 25 to 65 per cent, and the obtained solar cell efficiencies are similar to what is obtained with standard charge. Results from these tests have been published at 19th PVSEC in Paris, June 2004 and latest at the 31st IEEE PV Specialist Conference in Orlando, Florida, USA, January 3rd to 7th this year. Cell efficiencies above 16 per cent have been demonstrated. From being a research organisation, ES is now building up production capabilities. The first production plant will be a pilot scale unit planned to start operation in third quarter of 2005. The next development phase is a production unit with a minimum capacity of 2500 MT/year.

Renewable Energy Corporation (REC) is a significant player in the international solar energy industry. From the headquarters and R&D centre at Høvik outside the Norwegian capital of Oslo, subsidiaries are operated on three continents. REC is the only company in the world that covers the whole value chain of solar energy - from the manufacturing of solar grade polysilicon feedstock to the marketing of photovoltaic systems to the consumer.

The research staff in **Solar Grade Silicon** is now conducting experimental tests in a pilot 200 ton/year fluid bed reactor (FBR) built in 2004 by Solar Grade Silicon. The experiments will study reactor design, further scale-up and process parameters for production of polysilicon from silane. The goal of the research is to determine the design of a commercial reactor for large-scale production of PV feedstock. **Scan Wafer** is currently expanding its plant NR. 3 in south of Norway (Porsgrunn), started up in 2003 and is ready to invest in a twin plant in the neighbouring area. Scan Wafer's total capacity (silicon wafers), when these expansions are completed, is estimated

Fig. 3 - Vest Agder Clinic in Kristiansand, part of PV-NORD project (photo PV-NORD).

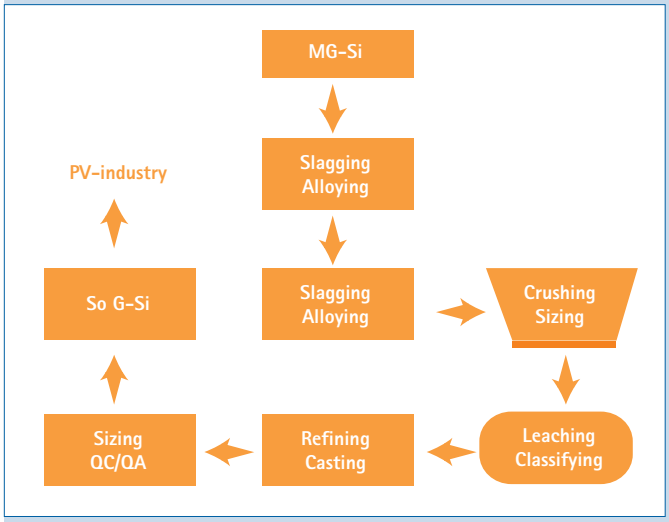

Fig. 4 – Elkem Solar metallurgical process for solar grad silicon.

at ~ 450 MW/year against a capacity of 200 MW/year at year-end 2004. Further expansions are being prepared for the West-Coast of Norway in the Aardal industrial area. **ScanCell** in Narvik and **ScanModule** in Arvika, Sweden are currently producing about 24 and 12 MW respectively of cells and modules. Major expansions are being planned and/or implemented in both companies.

The company **Solar Grade Silicon AS** was established in 2003, based on a process (pat.pend.) developed by professor Per K. Egeberg, Faculty of Mathematics and Sciences at Agder University College. The process is designed to utilize Trichlorosilane ($HSiCl_3$) as raw material in the production of solar grade silicon. Hydrogen chloride (HCl) from the reactor will be reused in the production of silane. The reactor principles have been verified in laboratory scale, and an upscale version is now being designed to facilitate industrialisation. In a feasibility study carried out by SINTEF Materials and Chemistry, the production cost is calculated to approx. 10 USD/kg SoGSi.

PORTUGAL

PV TECHNOLOGY STATUS AND PROSPECTS

PEDRO SASSETTI PAES, LABELEC - EDP GROUP

Fig. 1 - Renewable Energy Demonstration Platform at LABELEC (EDP).

GENERAL FRAMEWORK

In 2004, there have been no major changes at the energy policy level. The framework is based on the government Cabinet Resolution No. 63/2003, which defines three main strategic axes:

- To assure the security of the energy supply (reducing the dependence on primary energy sources, diversifying external sources, assuring mandatory fuel reserves and guarantying adequate power generation);
- To promote the sustainable development (supporting the development of endogenous energy sources - renewables - and improving energy efficiency, in order to comply with the Kyoto Protocol commitment and the EU renewable electricity Directive 2001/77/CE).
- To promote the national competitiveness (implementing the Iberian energy market, promoting gas and electricity market competition, extending regulation to the gas market and liberalising fuel prices).

NATIONAL PROGRAMME

The Portuguese strategy for the promotion and market development of renewables is based on a favourable legal framework and incentive schemes, introduced in 2001 (E4 Programme) and further reinforced in 2003 (Cabinet Resolution 63/2003). The government established ambitious targets for 2010, for each renewable technology, according to which wind power will form the bulk of the new installed capacity (3 750 MW by 2010), while PV's contribution is set to increase from the current level of about 2,5 MW to 150 MW. The overall RES contributions will allow Portugal to be able to meet the targets agreed to under the 2001/77/CE Directive - 39 % of the gross electricity consumption from renewables in 2010.

The main legal and incentive framework related to PV is:

- Decree-Law defining the conditions regulating the awarding and management of grid interconnection points for Independent Power Producers (IPP).
- Decree-Law establishing a range of favourable feed-in tariffs for RES electricity.
- Decree-Law regulating the delivery of electrical energy into the low-voltage grid (micro-generators, including PV).
- PRIME (Incentive Programme for the Modernisation of the Economy), which provides financial incentives, namely for energy efficiency and endogenous energies projects.

RESEARCH, DEVELOPMENT AND DEMONSTRATION

Fundamental research activities are focused on amorphous and nano-crystalline thin film silicon technologies and involve mainly public bodies (Universities):

- CENIMAT: Department of Materials Science, Faculty of Sciences and Technology (New University of Lisbon).
- LAFS: Laboratory of Photovoltaic Applications and Semiconductors (University of Lisbon).
- Department of Ceramics and Glass Engineering/UIMC (University of Aveiro).

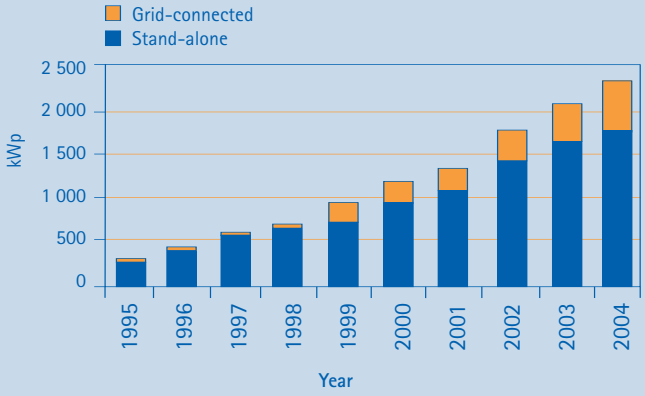

Fig. 2 – Cumulative Installed PV Power (Portugal).

Other institutions, such as Public Research Laboratories (INETI - National Institute for Engineering, Industry and Innovation), Energy Agencies (ADENE and regional agencies), utilities (EDP) and private research institutions (INESC Porto - Institute for Systems and Computers Engineering), are performing applied research and implementing PV demonstration projects. Besides these institutions, associations such as SPES (National Solar Energy Society) and APISOLAR (manufacturer and installer association) are also involved in dissemination activities.

IMPLEMENTATION

There has been no significant new government initiative in 2004 as far as PV is concerned. The legislation promoting renewable electricity (IPP law) is already quite favourable for grid-connection PV applications, with buy-back rates of about 0,32 EUR/kWh (installed power above 5 kWp) and ~0,54 EUR/kWp (installed power up to 5 kWp), guaranteed for the lifetime of the plant, with automatic adjustments based on the inflation rate. IPP must deliver all the generated power to the grid and the utility is obliged to buy the whole power.

Financial incentives are available under the PRIME programme (2003-2006) - III EC Framework Programme. Grants are provided on the basis of energy and environmental value of the projects, up to 40 % of the total eligible cost, with a maximum grant of 150 kEUR per application.

Indirect market development incentives for renewables are also available and include: reduction of VAT rate from 19 % to 12 % on renewable equipment, custom duties exemption and income tax reductions (up to 700 EUR for solar equipment).

In spite of this particularly favourable framework, only a few grid-connected installations have been realised in 2004:

- A Renewable Energy Demonstration Platform, installed at Labelec premises (campus of Sacavém, near Lisbon). Labelec is a laboratory and R&D service provider company within the EDP Group, the largest Portuguese electricity utility. The Platform includes a 1,4 kWp 2-axis tracking system, a 1,4 kWp fixed system and a hybrid PV (0,5 kWp)-wind (0,9 kW) system. All systems are grid-connected and aim at demonstration purposes and grid interconnection impact assessment.
- A "Solar Energy in Schools" project in the municipality of Moura (Alentejo, south of Portugal), which started with the implementation of grid-connected PV systems in three schools, with installed power of 15, 25 and 35 kWp respectively.

The first Portuguese building integrated project, at the Renewable Energy Department of INETI, was slightly delayed and is expected to be concluded early 2005. The 12 kWp grid-connected system, to be installed on the south vertical façade of the building, is part of a broader project - Solar Building XXI - which also includes the use of passive and active solar thermal and daylighting. The project is partly supported by the PRIME programme.

Another initiative from the utility side should also be stressed: Enernova, a renewable energy company within the EDP Group, is planning to implement its first medium size power plant (300 kWp) in Sines (Alentejo). The preliminary technical and economical studies were carried out in 2004, together with the site selection. The system will likely be installed and operational in 2005.

There has been no significant development concerning the announced world largest centralised PV power plant (64 MWp), to be built at the municipality of Moura (Alentejo). The complex negotiation process among the major stakeholders is still underway. This involves the promoter (Amper Central Solar, S.A.), the Moura municipality, BP Solar (which will do the turkey installation and will build a module assembly factory near Moura), the financial institutions (which will provide the investment on a project finance basis) and the government's Directorate General for Energy (feed-in tariff discussion).

Besides these initiatives, there is a clear sign of growing interest in PV from IPP promoters, considering the huge amount of requests for grid interconnection points (the first stage of the licensing process in order to get the installation permits) received by the Directorate General for Energy, the government agency which is managing this process. The overall power requested in 2004 totalled 5,28 MWp, for a total number of 471 PV systems, with the following distribution:

NO. OF SYSTEMS	REQUESTED POWER (KWP)
1	3
453	5
9	5 < P < 100
25	100
1	107

If all these systems were realised in 2005/2006, they would more than double the total current installed capacity in Portugal and lead to a considerable change in the share of on-grid applications when compared to off-grid applications, which still dominate the PV market.

INDUSTRY STATUS

Lobo Solar, located in Evora, is currently the sole Shell Solar module assembly plant in Europe, with a total capacity of 17 MWp per annum. The factory, which employs about 90 people, manufactures both mono and multi-crystalline modules.

Besides PV modules, there are two solar type and stationary battery manufacturers (Tudor and Autosil).

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

MARKET DEVELOPMENT

The total installed PV capacity by the end of 2004 was about 2,3 MWp, of which 79 % are stand-alone applications and 21 % are grid-connected applications. The market continued to grow in 2004, although at a lower rate, and mainly based on off-grid applications.

FUTURE OUTLOOK

The PV market in Portugal is expected to grow significantly in the next few years, based mainly on grid-connected application, either small scale systems up to 5 kWp, which are particularly cost-effective due to the high tariff rate (~0,54 EUR/kWh), or medium to large scale systems, including multi-megawatt power plants.

The major barriers to the widespread of PV, namely in the built environment, have been identified and the following measures still need to be adopted:

- simplify the licensing procedures as well as the grid-connection regulations, especially in the case of small systems connected to the low voltage grid;
- development of building codes for PV building integration;
- implement a national certification scheme for equipment and installers, aiming at better quality assurance.

Fig. 2 - Solar Energy in Schools Project - Moura High School.

TABLE 1- PORTUGAL'S TOTAL INSTALLED PV CAPACITY END 2004

YEAR	STAND-ALONE (KWP)	GRID-CONNECTED (KWP)	TOTAL ANNUAL POWER (KWP)	CUMULATIVE POWER (KWP)
Up to 1995	324	12	336	336
1996	88	0	88	424
1997	98	5	103	527
1998	100	21	121	648
1999	50	146	196	844
2000	216	84	300	1 144
2001	115	51	166	1 310
2002	285	73	358	1 668
2003	396	5	401	2 069
2004	128	78	206	2275
Total by end 2004	1 800	475	2 275	

SPAIN

PV TECHNOLOGY STATUS AND PROSPECTS

MANUEL BLASCO, CENTRO NACIONAL DE ENERGIAS RENOVABLES, CENER

Fig. 1 - External exposure test for PV modules at CENER (Centro Nacional de Energias Renovables).

GENERAL FRAMEWORK AND NATIONAL PROGRAMME

The most relevant characteristic of the year 2004 in Spain has been the introduction of a new legal support system for renewable energy sources. The new Royal Decree 426/2004, which came into force in March, represents a remarkable attempt to encourage the penetration of renewable energy sources in the Spanish energy sector. This new piece of legislation replaces the Royal Decree 2818/1998.

From the viewpoint of PVPS, the differences between the two support mechanisms can be summarized as follows:

- The new RD defines two different feed-in tariffs for plants smaller and larger than 100 kWp. In the first case, the tariff reaches 575 % of the average electricity tariff (TMR, defined by the energy authorities) for the first 25 years after commissioning, and 460 % afterwards.

For the year 2005, the value of TMR has been fixed in 73,304 EUR/MWH x 10-2/kWh, and consequently the tariffs are 0,421498 EUR/kWh and 0,337198 EUR/kWh respectively.

- In the second case, if the owner decides to sell his electricity in the market, he obtains the market price, plus a premium (250 % of the TMR for the first 25 years, and 200 % afterwards), plus an incentive (10 % of TMR), plus a fee for power guaranteed (depending on availability), and another fee for reactive power compensation, if any.

The incentive is intended to put economic pressure on PV generators to sell their electricity in the market, like any other kind of generators. Alternatively, the owner can decide not to go to the market, and in this case he obtains a tariff of 300 % of TMR for the first 25 years and 240 % afterwards, as well as a fee for compensation of reactive power.

The owner can switch from one possibility to the other, but with an interval of at least one year.

The entire support scheme will be applied until the total PV installed-capacity reaches 150 MW.

- The previous RD 2818 established a differentiation between plants smaller and larger than 5kWp. Remuneration through market price did not exist, and no guarantee of power was paid.

It is worth noting that the objective of the Plan de Fomento de las Energias Renovables (PFER), approved in December 1999 was to have 135 MW installed between the years 2000 and 2010. The general aim of the new scheme is to give the same treatment to all kinds of electricity generation technologies, taking into consideration the special characteristics of renewable energy sources and their favourable environmental impact.

Moreover, direct support for investments in PVPS is also provided, both through IDAE (the Spanish institute for diversification and

energy savings) and through some regional authorities. Since the IDAE scheme (20 % of the investment) was designed for the old support system, some distortions were arisen when the RD 486 came into force, since the number of applications for installations of 5 kWp or less diminished and were replaced by applications for much larger 100kWp units. It was necessary to devote more funds for PVPS support.

However, the present tendency seems to be to eliminate direct support for investments, and to encourage PV plants only through feed-in tariffs. Experience has shown that subventions to investments create much bureaucracy and are quite complicated and time-consuming. According to recent studies, a feed-in tariff system should be sufficient to give the necessary support to grid-connected PVPS. Of course this is not the case for isolated systems, for which direct support for investments is necessary.

It is still too early to perform an evaluation of the new mechanism, but it seems to be working quite well. As of 30 November 2004, the installed PV capacity (grid-connected) was estimated to reach 15 MWp, and the generation was slightly over 15 GWh. This implies an average of approximately 1 000 hours, and since, given the normal weather conditions in Spain, at least 1 200 - 1 300 hours are to be expected, it can be concluded that many plants have been commissioned during the last months of the year, after the RD 486 came into force.

The public perception of PV in Spain has been very positive in the past, due to their environmental advantages, but many people found it too expensive and too complicated to install; since the legal procedures are complex and time-consuming. The new approach seems to be a step in the right direction.

Nevertheless, there are still some problems to be solved. One of them is the lack in some cases of legal definition of the technical requirements for connection to the grid of PV systems. In such cases no mention is made of PVPS, and since these systems have special characteristics, the present pieces of regulation should be amended to take them into consideration.

R&D, D

R&D activities in Spain are carried out by both the PV industry and the research centres and universities. The main lines of activity can be summarized as follows:

- New semi-conductive substrates production technologies to manufacture solar cells. Practically all the Spanish PV scientific and relevant bodies are involved in this line.
- Production technologies, including industrial automation, more thin cells and improvements in efficiency.
- Concentration technologies.
- New materials (AsGa, silicon of "solar type," etc.)

There are some other programmes not exclusively devoted to PV as well, but clearly interrelated: electronics, integration with other power sources, etc.

Other activities are related to satisfy the necessities of the Spanish PV industry related to certification of new products and components, creation of new standards and methodologies for validation and analysis of new PV systems, and improvement of services related to the entire PV chain.

MARKET DEVELOPMENT AND FUTURE OUTLOOK

As indicated above, the installed PV grid-connected capacity in Spain has reached 15 MW in November 2004. This represent a considerable increase, since the installed capacity in December 2003 was 9,18 MW. In fact, the PV grid-connected installed capacity during the years 2003 and 2004 has been much higher than before.

The Spanish PV industry has made a considerable effort in investments during the past few years. From January 1999 to October 2004 the cumulative investments of the PV sector (including both manufacturers and installers) have reached 220 MEUR.

The total workforce reached 3 700 direct employments in October 2004, of which 1 485 correspond to manufacturers of cells and modules, and approximately 1 000 to installers. The corresponding total figure by the end of 2003 was 2 680, and the difference seems to reflect the strong impulse that the PV Spanish industry is experiencing as a result of the new support scheme (see above).

Furthermore, there are another 1 840 indirect employments. Therefore, the total workforce related to the Spanish PV industry can be estimated to have reached a total of 5 540.

The perspectives for the immediate future are optimistic. The public perception of PV is more and more favourable, and the support mechanisms seem to be working adequately. In the past, and due to the limitation of size to 5 kW, many "solar farms" were created (installations of, say, 100 kW with several owners, none of them owning more than 5 kW, and promoted by a unique body, in charge of connection and maintenance services). The number of these farms will probably increase, since the limitation to 5kW no longer exists, and there is a growing public consciousness of the economic profitability of PV power plants. What remains to be seen, nevertheless, is the development of larger PV plants of more than 100 kW, since, as indicated above, these plants can sell their production directly in the electricity market. However, there is still no experience on this (large plants commissioned before March 2004 can either remain under the treatment defined by RD 2818/98 until 2007, or switch to RD 486/2004).

SWEDEN

PV TECHNOLOGY STATUS AND PROSPECTS
MARIA HALL, SWEDISH ENERGY AGENCY
MONIKA ADSTEN, ELFORSK AB

Fig. 1 - The majority of the Swedish PV installations are small domestic off-grid systems such as this module on a summer cottage in the Stockholm archipelago (photo Energibanken AB).

GENERAL FRAMEWORK

The Swedish electricity supply system is largely based on nuclear power (about 50 % of the electricity supply) and hydropower (40 %). Although growing rapidly, mainly due to the introduction of a national renewable electricity certificate system in 2003 (see below), wind power and biomass-fuelled CHP still provides a minor contribution to the national electricity supply. Less than 0,1 % of the electricity supply comes from PV and the market growth for PV continues to be fairly slow (6-7 % per year). Although the number of grid-connected PV systems has increased during the last few years, the bulk of the Swedish PV plants are small domestic off-grid systems.

Until now, there have been no general subsidies aimed directly at promoting PV in Sweden. Beginning in 2005, there will, however, be a subsidy for PV on public buildings (see the section about Implementation and Market Development below).

The Swedish policies, which could indirectly promote the use of PV power systems, are taxes and fees related to conventional electricity production and a market based renewable energy certificate scheme, which was launched in May 2003.

The certificate scheme promotes electricity generated from renewable energy sources like biomass, small-scale hydro, wind and PV without any distinction between technologies. For every MWh of renewable electricity that an electricity company produces it receives one certificate. The electricity consumers are then required to buy certificates in proportion to the amount of electricity they consume. In 2004, the consumers were required to buy certificates corresponding to 8,1 % of their consumption, which resulted in a market price of about 25 EUR per MWh.

The current level of energy taxes and the value of the renewable energy certificates are too low to have any impact on the PV market in Sweden at today's PV system prices. Furthermore, Sweden's strong industrial demand for low energy prices in combination with the lack of subsidies for PV projects leads to little interest in PV among private investors and thus presents high barriers for market expansion and consequent cost reduction.

However, since PV is recognised as a sustainable energy technology, the attitude among the public is positive and has been expressed in form of increased consumer demand for renewable electricity and PV power. The strong international progress in the field, not least in terms of rapidly growing industries and employment opportunities, is slowly becoming more recognised in Sweden.

The Swedish Energy Agency (www.stem.se) is the national authority responsible for issues regarding the supply and use of energy. Its main task is to implement the Swedish energy policy programme, which is decided by the Swedish Parliament. The aim of the programme is to establish an ecologically and economically sustainable energy system and to secure the energy supply. The main emphasis is on the promotion of the use of renewable energy such as biomass, hydropower, wind power and PV.

The Swedish Energy Agency provides funding for PV research, cost-shared technological development and, in some cases, demonstration projects. A new but important task for the agency is to facilitate the commercialisation of the results of government funded energy-related R&D.

NATIONAL PROGRAMME

In Sweden, there is no formalised policy or R&D programme for PV alone. Instead, PV is a part of the national long-term energy research programme. The previous long-term programme (1998-2004) ended in December 2004 and a new seven year programme started in January 2005. Some of the major projects which were carried out during the last programme period are described in the next section.

Sweden is participating in the EU network of national programme managers, PV-ERA-NET, which is a four-year project that started in October 2004. The project aims at increased collaboration and coherence between the national PV R&D programmes in the European Research Area.

RESEARCH, DEVELOPMENT AND DEMONSTRATION

In 1996, the Swedish Energy Agency and the Swedish Foundation for Strategic Environmental Research decided to start a joint programme for PV R&D, the Ångström Solar Center (www.asc.angstrom.uu.se). Today, the centre is considered to be the flagship of solar energy research in Sweden.

Fig. 2 - One of the most recent PV installations in Sweden. The 22 kW project Lysande in Hammarby sjöstad in Stockholm was connected to the grid during spring 2004 (photo Carl Michael Johannesson)

The research at Ångström Solar Center has dual goals: to contribute to a sustainable energy system in the future and to increase the economic competitiveness of Sweden in the field of energy technology. The approach is to depart from leading scientific platforms and evolve progressively, via scale-up and prototype manufacturing, towards commercialisation in three project areas: CIGS cells, Grätzel cells and electrochromic windows.

The thin film CIGS solar cell technology is the project area which is closest to industrial realisation and a spin-off company, Solibro AB, has been started (see Industry Status below). The focus has been on CIGS film fabrication by co-evaporation. The aim is to achieve high performance and cost reduction at the same time as processes and materials that minimize the impact on the environment are utilised. Among the results, a world record in efficiency for a thin film solar cell module of 16,6 % can be noted. For the development of the next generation CIGS technology, elimination of cadmium in the buffer layer and minimization of the indium content of the cells are main objectives.

The research on Grätzel cells aims at developing nanostructured dye-sensitized electrochemical cells which can be manufactured at very low cost using a continuous process. Efficiencies are still low compared with cells of conventional crystalline silicon or CIGS and the competitiveness for this technology is currently in the area of niche products. Basic research is aimed at finding new combinations of dyes and electrolytes which can increase the cell efficiency.

The joint programme at Ångström Solar Center, which has received a total funding of about 16 MEUR, ends in March 2005. However, the research on CIGS and Grätzel cells will receive continued funding from the Swedish Energy Agency throughout 2005.

The SolEl programme is a national R&D programme with focus on PV systems and their applications. The programme is financed by the Swedish Energy Agency, Swedish utility companies, manufacturing companies (PV and other), construction companies and property managers. The present programme period runs throughout 2005.

The main objectives of the SolEl programme are to perform technological development, information dissemination and objective analysis (both technical and non-technical) of applications and costs of PV systems. The programme closely follows the rapid international development for PV in general and grid-connected BIPV in particular. It also provides a basis for international exchange, such as Sweden's participation in IEA PVPS.

In addition, the programme performs studies of the feasibility, procurement, installation and operation of Swedish PV installations and it has implemented a web based monitoring system for grid-connected PV installations in Sweden (www.elforsk.se/solenergi). Development of concentrating PV systems and PV-thermal concepts are also included the programme.

The interest from the Swedish construction industry in the SolEl-programme has increased due to the strong international development in the field of BIPV. The involvement of the building industry and property managers in the programme during the last few years has shifted the focus of the programme somewhat, from stand-alone systems towards PV in buildings. Recent programme activities include the development of a tool (www.solcell.nu) for carrying out PV projects in the built environment in the form of a web based information platform for architects, constructors and other actors which serves as a guide through the process.

The SolEl programme is managed by Elforsk AB, which is the Swedish electricity utilities' R&D company (www.elforsk.se). The overall objective of Elforsk is the rationalisation of joint industry R&D of importance to the generation, transmission, distribution and utilization of electricity.

In connection to the SolEl programme, a programme for BIPV research has been funded by the Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (Formas). The programme budget has been about 110 000 Euro per year. In addition, research and development in the area of PV systems in the built
environment has been funded by approximately 110 KEUR per year through Formas' annual open call, "Energy in the Built Environment."

Hammarby Sjöstad in Stockholm is a new residential area with a strong environmental profile and in which several construction companies have chosen to demonstrate PV as a means to fulfil ambitious goals for reduced environmental impact. The PV installations in Hammarby Sjöstad are among the first true BIPV projects in Sweden and PV modules have been used as integrated parts of buildings through integration in windows, façades and balconies.

Most of the BIPV projects in Hammarby Sjöstad have reached their completion. The two 5,7 kW BIPV projects realised by the company JM have been in operation since 2002. The 17,6 kW installation on the Holmen building was commissioned in September 2003 and the 22 kW project Lysande was connected to the grid during spring 2004.

Four Swedish actors (a real-estate owner, a real-estate management company, a centre of excellence in building related research and an architects company) have participated in the EU project PV-NORD (www.pvnord.org), which ended in the end of 2004. The project has demonstrated northern BIPV through eight highly visible and prestigious construction projects in Sweden, Finland, Denmark, Norway and the Netherlands.

IMPLEMENTATION AND MARKET DEVELOPMENT

The market for PV in Sweden is dominated by domestic stand-alone PV systems. The majority of these systems are small and predominantly used to supply electricity to recreational homes where there is no grid available. Apart from the off-grid domestic market, there are some off-grid non-domestic systems, supplying electricity for telecommunication systems, lighthouses, etc., and a few grid-connected systems. The grid-connected systems are mostly demonstration projects intended to demonstrate the PV technology in general or to conduct research. Some installations have also been made in public buildings, with the objective to increase the awareness of renewable energy solutions.

The lack of general incentives or subsidies for PV has resulted in a comparatively slow development of the PV market in Sweden. The total cumulative PV power installed in Sweden by the end of 2003 was 3,6 MW. The market size has been rather constant over the last ten years with a slight upturn (about 6 % per year) in the last three years. The power installed during 2003 was 284 kW, which corresponds to a market growth of about 7 % compared to 2002.

In June 2004, the Swedish Energy Agency reported an investigation to the Ministry of Industry, Employment and Communication on the status of PV applications, the industrial activities in Sweden and possible promotion schemes for PV. The report has formed a basis for a parliament decision on an incentive for energy efficiency refurbishing of public buildings. The incentive gives a 30 % investment subsidy for investments in energy-efficiency and installation of renewable energy technologies in public buildings. However, for solar cells, the subsidy will be 70 %. The scheme will be executed as soon as it has been approved by the European Commission and will run until 31 December 2007. There is an upper limit to the subsidies of 11 MEUR, which corresponds to 2-3 MW of new capacity. This is almost as much as the installed capacity (about 3,6 MW) in Sweden today.

INDUSTRY STATUS

The PV industry in Sweden has grown significantly in the last couple of years. Today, there are four companies in Sweden that produce PV modules. All of them buy cells from abroad and assemble modules, which are to a large extent exported. The oldest and largest module manufacture company in Sweden is Gällivare PhotoVoltaic AB (GPV) in Gällivare in the north of Sweden. Today, GPV is a fully owned subsidiary of the German company SolarWorld AG. In 2004 GPV shipped about 13 MW worth of modules.

The module manufacturer ArcticSolar AB is also situated in Gällivare. The company was started in 2001 and has increased its production volume steadily since the start to approximately 5 MW during 2004. The production plan for 2005 is 8 MW. The company is partly owned by the manager of the company (10 %), German Alfasolar Vertreibsgesellschaft mbH (45 %) and Finnish Naps Systems Oy (45 %). The modules produced at ArcticSolar are sold in Germany under the Alfasolar label.

ScanModule AB in Arvika, which is a subsidiary of the Norwegian company Renewable Energy Corporation, commenced its module production in 2003 and has 15 employees. The production in 2004 was a couple of MW and is expected to increase during 2005.

The fourth PV module manufacture company is PV Enterprise Sweden AB in Vilshult, which was started in 2003 by the former head of GPV. During 2004, the production amounted to 4 MW of modules. The company is planning to triple the production during 2005.

The amount of installed PV capacity per annum in Sweden is considerably lower than the amount of produced modules. Hence, a large part of the modules are exported. The part of the production that is exported varies from manufacturer to manufacturer, but is generally more than 95 %.

An additional industrial initiative in Sweden is the company Solibro AB in Uppsala. The company, which is a spin-off from the Ångström Solar Center, is currently up-scaling the processes for making thin film CIGS. When scale-up of the CIGS fabrication process has been successfully demonstrated, a complete line for fabrication of modules will be installed. The aim is to have modules on the market in 2008. Solibro AB is financed by three large corporations and two investment funds. The Swedish Energy Agency co-finances the technology development in the company.

There are also a small but increasing number of SMEs which designs, markets and sells PV products and systems.

There are currently no feed-stock or cell manufacturers in Sweden or any manufacturers that produce PV specific balance of systems components, such as inverters, storage batteries, supporting structures or DC switch-gear.

FUTURE OUTLOOK

The research at Ångström Solar Center (ÅSC) has been highly relevant for the Swedish Energy Agency and the Swedish energy programme and the Swedish society as a whole since it has been focussed on technologies which can contribute to a more sustainable energy system as well as be commercial ventures. The Swedish Energy Agency's funding for ÅSC ends in March 2005 and there will be no continuation of ÅSC as a joint effort. However, both the CIGS and the Grätzel cell research will receive continued funding from the Swedish Energy Agency, at least throughout 2005.

Another government funded project which will start during 2005 is the demonstration of building-integration and grid-connection of 6 kW rooftop PV systems in about ten new single-family houses in the Mälardalen region in Sweden. One of the goals of this project is to show that PV can supply a major part of the household electricity on an annual basis.

During 2005, the Swedish Energy Agency will assess the current status of Swedish and international PV R&D in order to layout a roadmap for future Swedish research activities in the field. This, together with experiences from the new investment subsidy for PV on public buildings, will form the basis for future PV initiatives in Sweden.

Further reading about PV in Sweden

- *Sweden - Country information*
- *www.stem.se*
- *www.elforsk.se*
- *www.solcell.nu*
- *www.pvnord.org*

SWITZERLAND

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

Fig. 1 - Solar Impulse, flying around the world in a solar powered airplane (photo Oxyde.ch - Saprisiti / ©EPFL Solar Impulse).

GENERAL FRAMEWORK

Following the political debate regarding the future of the *SwissEnergy* Programme (www.swiss-energy.ch) during 2003, the consequences of the budget reductions for this programme became reality in the course of 2004. In particular, the federal government support for pilot and demonstration systems had to be strongly reduced for all energy technologies, leaving only marginal means for new projects in this area. This represents a severe cut along the chain from technology towards the market and thus affects rapid transfer of results from R&D into industrial solutions and products. Discussions are ongoing with different parties on how to continue this important activity.

Further matters related to energy policy are presently on the political agenda. On the one hand, this concerns the introduction of a CO_2 tax on fossil fuels. The legal basis for the introduction of such a tax is defined by the CO_2 law which has been in force for a number of years. Different variants of this tax are presently in discussion with an alternative proposal for the introduction of a climate-cent on the use of fossil fuels. In particular, the proposed variants represent differences whether their impact will mainly concern CO_2 emission reductions realised on a national or on an international level through the use of the Kyoto instruments and emissions trading. The second issue on the policy level is a new proposal for a liberalisation of the electricity market. After the rejection by public referendum of the first attempt on this subject in 2002, a new law has been proposed. Within this proposal, a goal of additional 5 400 GWh from renewable energies by 2030 is formulated. Here, the political debate concerns the instruments to be used to achieve this goal, namely a bidding model or feed-in tariffs. The Swiss Parliament will deal with this subject in the course of 2005.

Finally, the framework for the energy research remains otherwise unchanged: The energy research strategy is defined by a 4 year energy RTD master plan for the period 2004 - 2007. The master plan developed by the Federal Commission for Energy Research (CORE), in cooperation with the Swiss Federal Office of Energy (SFOE), is based on strategic policy goals (energy & environment, science & education, industry & society).

NATIONAL PROGRAMME

Switzerland has a dedicated national photovoltaic RTD programme which involves a broad range of stakeholders in a strongly coordinated approach (www.photovoltaic.ch). This national photovoltaic programme focuses on R&D,D in a system and market oriented approach, from basic research, over applied research, product development, pilot and demonstration projects all the way to market stimu-lation. As indicated above, activities in pilot and demonstration projects had to be reduced in 2004. On the technical level, thin film solar cells and building integration are the foremost topics of priority. The programme is organised along the entire value chain and addresses the critical gaps from technology to the market place.

Fig. 2 - 15,4 kWp flat roof PV system using the Sarnasol product (photo Sarnafil).

Accompanying measures to raise the quality and reliability of photovoltaic power systems include thorough component analysis, work on standards and design tools. On the market side, deployment is promoted by a customer-oriented approach in the campaign "solar electricity from the utility." Finally, the programme puts emphasis on information and communication in order to raise the awareness for opportunities involving photovoltaics. Direct promotion of the market through incen-tive schemes is within the responsibility of the cantons on a voluntary basis. This has led to regional differences whereby the governments of the cantons define their priorities between promotion of en-ergy efficiency and/or renewable energies. Support for photovoltaics through direct subsidy schemes is limited to a few cantons presently.

Through the bias of Task 9 of the IEA PVPS Programme, the subject of technology co-operation with developing countries continues to be expanded. During 2004, a new interdepartmental platform for the promotion of renewable energy in international co-operation - REPIC - was launched and became operational (www.repic.ch) with first projects supported.

RESEARCH, DEVELOPMENT AND DEMONSTRATION

The Swiss Photovoltaic RTD Programme is based on a 4 year RTD master plan, presently covering the period 2004 - 2007. Overall, 75 projects, supported by various national and regional government agencies, the research community and the private sector are conducted in the different areas of the photovoltaic energy system. Market orientation, cost reduction, industrial viability and transfer as well as increased efficiency and reliability are the main objectives of the technical R&D.

For solar cells, the main focus remains on thin film solar cells with projects in a wide variety of materials (amorphous and microcrystalline silicon, compound semiconductors, dye-sensitised cells). During 2004, emphasis on flexible solar cells has increased. For flexible CIGS solar cells, a new world record efficiency of 14,1% was achieved during 2004 at the Swiss Federal Institute of Technology in Zurich. Transfer to industry of these RTD activities has continuously increased over the past years. The spin-off company VHF-Technologies has increased the annual capacity of their pilot manufacturing plant of amorphous silicon solar cells on plastic substrates to 40 kWp. Another technology transfer is occurring with the equipment manufacturer Unaxis. Building on the strong synergies with this company's exper-tise for production equipment of flat panel displays, Unaxis is setting up a new business unit, Unaxis solar. This new venture of Unaxis with the Institute of Microtechnology at the University of Neuchâtel intends to develop a leading position in the industrial production equipment of thin film "micromorphous" silicon solar cells.

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

With the ongoing market development, quality assurance of products and systems, as well as stan-dardisation, continue to be of high

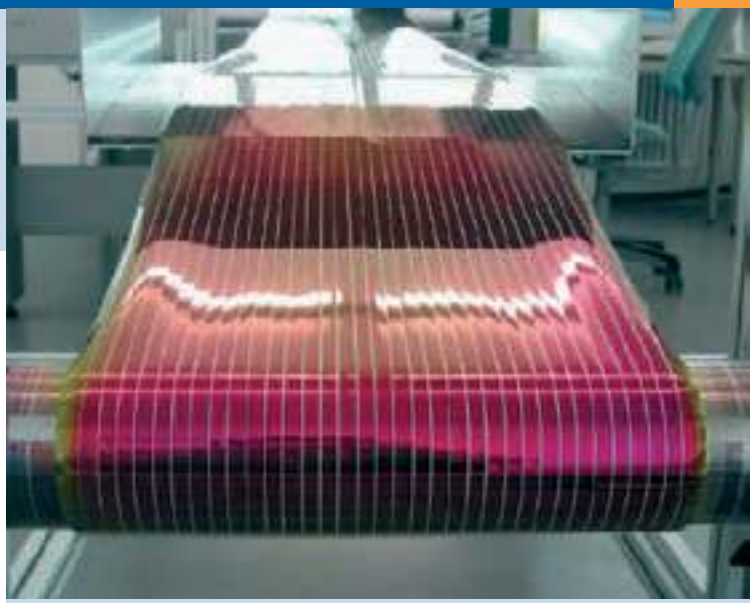

Fig. 3 - Roll-to-roll manufacturing of flexible amorphous silicon solar cells (photo VHF Technologies).

priority. Three centres of competence have been established which evaluate products such as PV modules, inverters and components for building integration. Long term experience with the operation of photovoltaic power systems is carefully tracked for a number of grid-connected systems, ranging between 10 and more than 20 years of operation. Continuous development of system solutions has resulted in a number of industrial products which are increasingly being exported.

An exceptional and visionary project has been initiated by Bertrand Piccard, the first man together with Brian Jones, to circle the earth non-stop in a balloon in 1999. This new project with the name Solar Impulse (www.solar-impulse.com) has the goal of a non-stop flight around the world in a solar powered airplane (Fig. 1). Exceptional efforts in photovoltaic cell and system technology, energy management and design will be required to achieve this ambitious goal. The project has the scientific support of the Swiss Federal Institute of Technology in Lausanne, the University of Neuchâtel and other organisations in Switzerland and abroad.

International co-operation continues to form a strong pillar of the R&D activities with about 20 projects running in the 5th and 6th framework RTD programmes of the European Union during 2004. International projects are also carried out as part of programmes such as the European Space Agency. The co-operation within the IEA PVPS programme has remained a further strategic activity for which target-group specific dissemination is crucial.

IMPLEMENTATION

Market implementation of PV systems continues to be driven by the campaign for "solar electricity from the utility" and similar approaches related to green power marketing. Since the introduction of the *naturemade*® labels for renewable electricity, utilities have started introducing different product brands, some with a mix of different renewable energy sources and others with technology specific products, e.g. the product *"Premium Solar"* by the utiltiy of the city of Zurich. Increasingly, solar electricity is thus part of mixed green power products, according to naturemade star® labelled brands. Typically, around 5 % of the customers are willing to pay the comparatively high prices for solar electricity, in the best cases. Thus, it requires a strong and consistent marketing approach. However, with mixed products, more customers can be attracted. Market implementation is further supported by regional initiatives, for example in the cantons of Basel and Geneva.

INDUSTRY STATUS

Some years ago, Swiss industrial PV products covered mainly system components such as inverters, both for grid-connected and stand-alone applications, components for electrical connection, mounting systems for building integration and custom designed PV modules. Over the past years, industrial activities in the area of solar cells, solar modules and manufacturing equipment for both of these areas have considerably increased.

In the inverter area, some products have achieved a high export rate. The Sputnik company produces grid-connected inverters at a capacity of 90 MW/year and presently ranges as number 3 in the European market. The Studer company produces stand-alone inverters and is also very successful in exporting. On the PV industry supply side, different products count among the world leaders, e.g. for wire-sawing machines from HCT as well as from Meyer & Burger; and measuring equipment for PV module manufacturers from Belval. In addition to the solar plugging systems made by Multicontact, another company, Huber & Suhner, has entered into this market. The SOLRIF® mounting system for building integrated photovoltaics made by Schweizer Metallbau and Enecolo continues to be successful on the market. A new entrant is the Sarnafil company, which has developed a flexible, watertight flat roof PV system based on thin film silicon solar cells (Fig. 2).

More recently, industrial activities have started in the field of process equipment (Unaxis solar) and small scale products based on thin-film technology (Flexcell from VHF-Technologies, Fig. 3). Further-more, Swiss Sustainable Systems (3S) is building some of the world's largest PV module laminators.

Based on the long term experience and the large number of installed systems, considerable know-how is available amongst engineering companies for the design, construction and operation of a large variety of different applications, ranging from small scale, stand alone systems for non-domestic, professional applications and remote locations, over small domestic grid-connected systems to medium and large size grid-connected systems in various types of advanced building integration. The export volume of Swiss photovoltaic products has surpassed 50 MCHF in 2004 and thus represents about twice the size of the national market.

Besides an increased interest from the manufacturing industry, the finance sector continues to pro-mote financial services directed towards renewable energy. Increased investments have occurred in the renewable energy sector, including photovoltaics, and dedicated

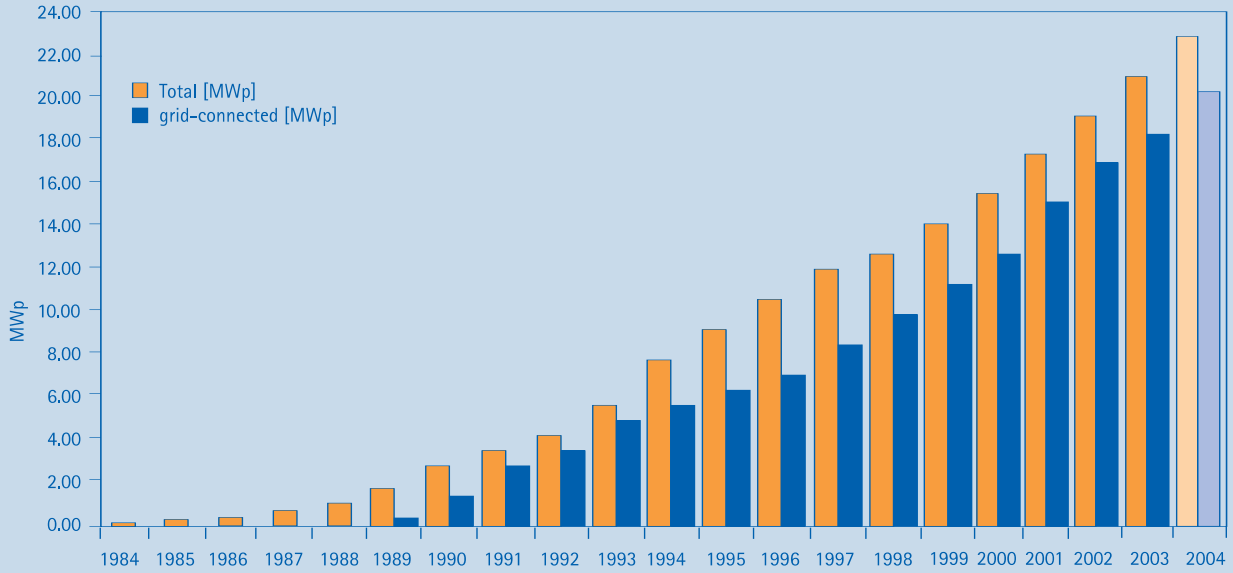

Fig. 4 - Evolution of the installed photovoltaic capacity in Switzerland between 1984 and 2004 (total and grid-connected, estimated values for 2004).

funds are operated by important finance organisations. This trend is manifested by the regular investment analysis reports published by the Bank Sarasin.

MARKET DEVELOPMENT

The market development has been mainly driven by the federal campaign "solar electricity from the utility" or similar schemes, supported by promotional programmes and actions in some cantons. The annual market volume for grid-connected systems is estimated to about 2,0 MWp, similar to previous years. The total installed capacity has thus risen to about 23 MWp (Figure 4), corresponding to about 3,3 Wp/capita. The PV energy statistics have been established by tracking the energy produced by grid-connected PV systems and their statistical distribution since 1992 (Table 1). The record summer of 2003 resulted in an increased energy production of about 10 % with a specific energy production reaching 875 kWh/kWp and a total energy production of 15 GWh.

FUTURE OUTLOOK

Regarding photovoltaic technology in Switzerland, the broad support of the national PV programme can be expected to continue with an ever-increased focus on industrial developments, new products for niche markets and ongoing international involvement. For solar cells and modules, the effort to bring Swiss technology to the market place will continue. Efforts in the technology development will concentrate on market oriented approaches and continuous quality assurance. The strategy to promote international co-operation on all levels will continue, related to activities in the 6th framework programme of the European Union, the IEA PVPS programme and increasingly in technology co-operation projects. Increased co-operation with other European PV RTD Programmes will be established in the framework of the PV-ERA-NET project. The initiative of the European Photovoltaic technology Platform will be closely followed.

In the near term, PV market implementation will continue to depend on the initiatives of regional authorities and even more on those from the private sector, namely the utilities. A market volume of about 2,0 MWp/year can be expected under these circumstances. For the mid-term, market imple-mentation will further strongly depend on the outcomes of the political debate concerning the new electricity law during 2005.

TABLE 1: SWISS PHOTOVOLTAIC ENERGY STATISTICS FROM 1989 - 2003 (GRID-CONNECTED SYSTEMS)

Year	Number of New Systems	Total Number of Systems	Installed Capacity [MWp DC]	Energy Production [MWh]	Specific Energy-Production [kWh / kWp]
1989	60	60	0,3		
1990	110	170	0,8	400	
1991	210	380	1,8	1 100	
1992	110	490	3,1	1 800	800
1993	110	600	4,0	3 000	810
1994	80	680	4,8	3 500	800
1995	60	740	5,4	4 000	815
1996	80	820	6,2	4 700	825
1997	130	950	7,4	6 000	880
1998	150	1 100	9,2	7 100	860
1999	125	1 225	11,0	7 700	770
2000	100	1 325	13,0	10 000	810
2001	125	1 450	15,0	11 000	800
2002	75	1 525	17,0	12 000	810
2003	75	1 600	17,9	15 100	875

(grid-connected systems)

TURKEY

PV TEHCNOLOGY STATUS AND PROSPECTS
SIDDIK ICLI, DIRECTOR OF SOLAR ENERGY INSTITUTE
METE CUBUKCU, ELECTRIC-ELECTRONIC ENGINEER,
RESEARCH ASSISTANT

GENERAL FRAMEWORK

Turkey, with a population of about 67 803 927 in 2000, lies in a sunny belt between 35°502 and 420°62 north latitudes and is geographically well situated with respect to solar energy potential. According to official reports of EIE (The General Directorate of Electrical Power Resources Survey and Development Administration), annual sunshine duration of Turkey is 2640 hours and annual horizontal solar irradiation is 1 311 kWh/m^2.

In Turkey, electricity is mainly produced by thermal power plants, by consuming coal, lignite, natural gas, fuel-oil and geothermal energy, wind energy (recently) and hydropower plants (TEIAS web page, 2004). Distribution of Turkey's gross electricity generation in 2003 is showed in Figure 1.

The electricity requirement, which is called gross demand, was reported as 141 150,9 GWh in 2003 by TEIAS (Turkish Electricity Transmission Co.). According to the report, the gross generation is 140 580,5 GWh, the import electricity is 1 158 GWh and the export electricity is 587,6 GWh in Turkey (TEIAS web page, 2004).

Compared to other energy sources, PV systems don't have sufficient contributions to gross electricity demand. There are no sufficient governmental driving forces to support PV systems in Turkey yet.
PV power system applications just began in Turkey in the 1980s. Early studies have started in the Turkish University Research Laboratories in the mid-1980s and some small scale pilot applications were realized in those years to gain further experience in PV. Residential and industrial consumption of solar energy in Turkey startet in 1986 and 1988, respectively. (Hepbasli, A., et.al., 2004).

NATIONAL PROGRAMME

The Solar Energy Division of EIE has been carrying out research, development, information dissemination and demonstration activities since 1982. The objective of EIE solar energy studies is centralized on encouraging the widespread adoption of the technologies in Turkey, bearing in mind the contribution of solar energy potential to a secure and diversified energy supply, as well as to environmental protection. The activities comprise technology assessment, resource evaluation and implementation of research, development and demonstration projects. Photovoltaic power applications in Turkey are solely limited with some state organizations which use PV for meeting remote electricity demands. Main application areas include the telecom stations, fire observation stations, lighthouses and highway emergency systems. (EIE web page, 2004)

RESEARCH AND DEVELOPMENT

The photovoltaic sector in Turkey is still fairly small, providing work for only a small number of employees. The main actors consist of several companies and a number of research institutes.
PV researches have been realized in the Turkish University Research Laboratories to gain further experience in PV.

Fig. 1 - 11 kWp Grid-Connected Photovoltaic systems of Solar Energy Institute in Izmir.

Fig. 2 - Photovoltaic Lighting Units of Solar Energy Institute in Izmir.

Fig. 3 - Photovoltaic Lighting Units of EIE.

Gross Generation (GWh):	*140 580.5*
Coal Total:	*32 252,9*
Liquid Total:	*9 196,2*
Natural Gas:	*63 536,0*
Hydro Total:	*35 329,5*
Geothermal:	*88,6*
Wind:	*61,4*
The Others (Renewables and wastes):	*115,9*

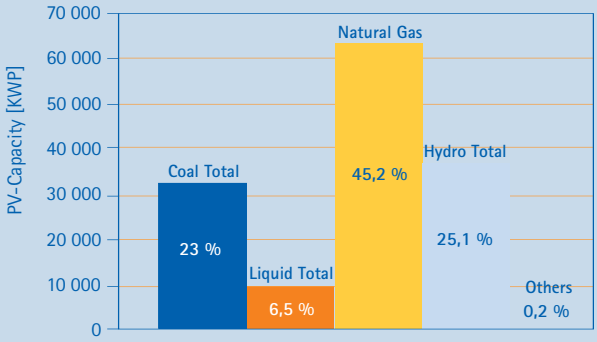

Fig. 4 - Distribution of Turkey's Gross Electricity Generation (2003).

The Solar Energy Institute, situated on the campus of Ege University in Izmir, was founded in 1978 for graduate education and research on Solar Energy and its applications. The following PV technology research subjects about are continued at the Solar Energy Institute. (Solar Energy Institute web page, 2004).

- Production of Organic Dye Sensitized Solar Cells.
- Photovoltaic (PV) Systems and Applications.
- Thin Film Technology to Produce Organic Solar Cells.
- The Correlation of Solar Cell Parameters and Operating Conditions, etc.

IMPLEMENTATION

Since 1984 various research projects on the utilization of solar cells in small scale power systems are worked out and completed at the Solar Energy Institute of Ege University. Some of those investigations are mentioned in the following. Sizing, installation and monitoring of an autonomous PVPS for residential purposes in the rural areas of Turkey was achieved in 1988 (Colak, M., 1989), (Colak, M., Erdis, F., 1991). This system was consisting of a solar generator of 756 Wp and an acid-lead battery of 1000Ah 24V with the necessary control electronics (Erdis, F., Colak, M., 1989). A research project on PV powered irrigation was also made for the performance analyze of an agricultural PV pumping system (371 Wp, 3-phase AC submersible motor, control equipment), 1989 (Arsel, I., 1989). A further investigation dealed with the design and analyze of a PV powered Peltier cooling box for medical purposes (Boztepe, M., Colak, M., 1998). Sizing, installation and monitoring of a grid connected PV-Wind system was another investigation for the design and analyze of a hybrid power system (Engin, M., Colak, M., 2001). Several research activities were also made on the simulation of components, e.g. (Colak, M., Basaran, O., 1995) and (Karatepe, E., Boztepe, M., Colak, M., 2003) and the theoretical sizing procedures of autonomous PVPS's, e.g. (Ergonul, H.A., Colak, M., Kahraman, G., 2003).

PV Lighting Units: Five lighting units have been installed within the scope of photovoltaic lighting project. Currently 5 units are installed, 2 in Ankara, 2 in Didim Research and Training Center of EIE and a 1 in the EIE building in Ankara (see Figure 3).

PV Water Pumping Systems: A photovoltaic pumping system was installed in 1988 in order to investigate the applications in small-scale agricultural irrigation. The system is installed at Didim Training Center at present. Another 756 Wp PV pumping system has been operating at Renewable Energy Park in EIE (see Figure 4).

Grid-Connected Photovoltaic systems: In 1998, a 4,8 kWp grid connected PV system was installed in Didim Solar and Wind Energy Training Center of EIE as the first grid connected PV system in Turkey. The system produces an average of 20 kWh/day. Another 1,2 kWp grid connected system was installed in Ankara for demonstration and research purposes (see Figure 5).

Other Stand-Alone Systems: A 570 Wp mobile photovoltaic system and a PV traffic warning system were designed and installed. In another research project, the production difference between the tracking and permanent PV systems was investigated (EIE web page, 2004) (see Figure 6).

The number of PV applications has increased in the late 1990s and four PV power plants with an approximately total power of 50 kWp were installed for telecommunications in Afyonkarahisar, Gocek, Usak and Kahramanmaras (Hepbasli, A., et.al., 2004). PV applications exist well over a total capacity of 100 kWp in this area. A 14 kWp PV power plant was installed for starting up energy of some units in Berke Dam in 2001 (Hepbasli, A., et.al., 2004). The largest grid connected rooftop PV power plant with a capacity of 54 kWp in Turkey was installed in Mugla University.

Some other applications such as irrigation pumping, telecommunication systems, remote monitoring, control systems (scientific research, seismic recording, climate recording, traffic data collection, cathodic protection) are situated all around Turkey (Celik, A.N., 2004). Including the various examples explained above, Turkey's total installed

Fig. 4 - PV Water Pumping Systems of EIE.

Fig. 5 - 4,8 and 1,2 kWp Grid-Connected Photovoltaic systems of EIE.

PV capacity is strongly growing without an organized PV programme and is estimated to have reached about 800 kWp today (Hepbasli, A., et.al., 2004).

MARKET DEVELOPMENT

The potential of Turkey as a photovoltaic market is very large, since the country abounds in solar radiation and large areas of available land for solar farms. There are more than 30 000 small residential areas where solar powered electricity would likely be more economical than grid supply as well as the holiday villages situated on the long coastal areas (Celik, A.N., 2004).

INDUSTRY STATUS

The most important companies dealing with Photovoltaics in Turkey are:

Orjin Solar Limited, is working with an American PV company "Uni-solar", and American charge controller company "ASC," and it supplies inverters from the Twain company called "PowerMaster." Orjin Solar Limited distributed PV products all around Turkey. The company produces end-user products, with those main components, such as Trackers, system boxes, street lights, mobile PV caravans etc. Orjin Solar Limited has been working to produce PV panels in Turkey since 2003. (Orjin Solar Limited web page, 2005).

Alternative Energy Systems Ltd. (Alternatif Enerji Sistemleri San. ve Tic. Ltd. _ti.) implements some of the known applications of photovoltaics in Turkey such as telecommunication systems, lighting units, farm houses. (Elternative Energy Systems Ltd. web page, 2005).

AY-SOLAR Ltd. (AY-SOLAR Enerji ve Malzemeleri Sanayi ve Ticaret A._.) has been working on PV applications since 1997. The company has installed new PV applications by collaborating with the Turkish Universities. In the beginning of 2004, AY-SOLAR Ltd. and Solar Energy Institute of Ege University has installed a 11 kWp grid connected PV system in the building of Solar Energy Institute. (AY-SOLAR Ltd. web page, 2005).

SUN POWER Ltd. was established in 1995, in order to work in the sector which electricity generation systems that work with the sun power and the wind power. In 1996, it began to make "Fitting and Installing of Lantern and Sea Lanterns" Lanterns and sea lanterns belonging to many companies in Turkey, are made by SUN POWER Ltd. In 1999, they began work in the GSM sector. The Hybrid energy systems in the base stations, which are owned by TURKCELL A.S., the leader in their sector, have been installed by SUN POWER Ltd. In this field, SUN POWER Ltd. is the solution provider for TURKCELL A.S. In 2002, in the "NATO Project" the biggest solar island system was installed by the company. In 2003, in Mugla University within the "Research Project" the biggest solar energy station in Turkey was installed by the company. (SUN POWER Ltd. web page, 2005).

FUTURE OUTLOOK

The current installed photovoltaic energy in Turkey is insignificant when compared to the economically utilizable solar energy potential. Turkey's total PV installed capacity is expected to be 3 MWp in 2010 (Hepbasli, A., et.al., 2004).

Urban population as a percentage of the total population has sharply increased from 34 % in 1965 to 65,03 % in 1997; representing an average urbanization growth of about 2 % annually. Although net electricity generation in Turkey has more than doubled over the past decade, it is not sufficient to keep up with expected demand. (Hepbasli, 2004).

Turkish energy consumption has risen dramatically over the past 20 years due to the combined demands of industrialization and urbanization. In order to limit imported energy, the contribution of renewable energy resources in the total electric generating capacity has to be increased (Hepbasli, 2004).

Turkey needs adaptations in the energy field in order to meet European standards, as Turkey is seeking full membership in the European Union. The alternative and renewable energy systems have been neglected so far in Turkey, but must be included in the new energy programmes. The alternative and renewable energy systems in general, and photovoltaics in particular, should be included in the new energy programmes in Turkey (Celik, A.N., 2004).

Fig. 6 - Photovoltaic Traffic Warning System of EIE.

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UNITED KINGDOM

PV TEHCNOLOGY STATUS AND PROSPECTS

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GENERAL FRAMEWORK

The Department of Trade & Industry is the lead Department on matters of UK energy policy. To ensure that energy policy is coordinated with other Departmental interests such as climate change, transport and planning, the implementation of UK energy policy is delivered by a Sustainable Energy Policy Network which includes representatives from the Department of Trade and Industry (DTI), Department of the Environment, Food and Rural Affairs, the Office of the Deputy Prime Minister and the Department of Transport.

The Government published an Energy White Paper in February 2003 "Our energy future - creating a low carbon economy." The White Paper sets out the long term strategy for the UK's energy policy based on the four pillars of the environment, energy reliability, and affordable energy for the poorest and competitive markets for businesses.

The Renewables Obligation (RO) forms the main element of the Government's strategy for renewables deployment. It was designed to enable the UK to make progress towards its target of generating 10 % of its electricity from renewable energy sources covered by the Obligation by 2010. The Government also has an aspiration to reach 20 % of electricity from renewables in the UK by 2020. The RO began in 2002 and sets out targets for electricity suppliers to source an increasing amount of their electricity from renewable resources. Renewables Obligation Certificates, or ROCs, are awarded to suppliers using renewable sources. ROCs can be traded between suppliers to make up any shortfall.

A review of the Renewables Obligation will take place in 2005, with the aim of strengthening the development of electricity generation capacity using renewable energy sources. Consultation prior to this review took place in 2004 and measures to be introduced by the review were published in November 2004. The main measures outlined are to:

- Extend the level of the Renewables Obligation beyond 2010/11 to 2015/16;
- Allow tradeability between Northern Ireland Renewables Obligation Certificates (NIROCs) and Great Britain ROCs;
- Introduce measures that will further secure the buy-out fund in the event of a shortfall occurring;
- Introduce more flexibility for small generators.

Other initiatives which supplement the RO are described below. The Renewables Innovation Review was published in February 2004 and identified:

- the key renewable technologies for the delivery of the UK targets and aspirations for renewables.
- the barriers to the development and deployment of the key renewable technologies;
- the most cost effective Government measures to facilitate delivery of the UK targets.

Fig. 1 - 51 KW installation at Cotswold Water Park (photo BP Solar).

The Review can be found at: http://www.dti.gov.uk/energy/renewables/policy/renewables_innovation_review.shtml

The International Energy Strategy was launched in October 2004, and states that the UK Government will tackle climate change and curb carbon emissions and diversify the energy mix to lessen our dependence on fossil fuels.

NATIONAL PROGRAMME

The UK's National Programme for photovoltaics consists of the following elements:

- Research and development, under the DTI's Technology Programme and various programmes of the Engineering and Physical Sciences Research Council (EPSRC)
- Field trials and demonstrations, under DTI programmes
- Participation in international programmes (EC and IEA)

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

The renewables innovation review, described in the section above concluded that with current technology, solar PV installation is expensive under UK conditions. It recommended that research should focus on 3rd generation PV, and collaborative efforts with nations with complementary capabilities. Future grant funding for PV should come through a technology blind programme to support building integrated renewables and energy efficiency technologies.

Fig. 2 - Two 5 kW installations at St Mary's Island Community Centre and Doctors Surgery (photo SEI).

Fig. 3 - PV installer training as part of the nationally recognised course (photo IT Power).

RESEARCH, DEVELOPMENT AND DEMONSTRATION

Research funded by the EPSRC may be dedicated specifically to photovoltaic research, or may support more general research which may result in advances in photovoltaics as well as in other adjacent areas. The area of research is changing. Research effort is moving slowly away from traditional silicon based materials toward new organic polymer based systems and micro/nano structured devices, as well as exotic new materials such as semiconductor quantum dots and copper indium diselenide. EPSRC supports a major strategic initiative in photovoltaics, namely Supergen - PV Materials for the 21st Century, and another consortium on next generation cell technologies.

The PV elements of the DTI R&D programme concentrate mainly on cost reduction. The main emphasis is on new, leading edge cell technology and manufacturing, and also on improving the cost-effectiveness of balance of systems components. The DTI is working with a number of industrial partners to pursue these objectives. This includes basic research into low cost dye-sensitised solid state plastic encapsulated solar cells, and a project working to produce low cost thin film polysilicon solar cells.

Since 2000 there have been three PV field trial and demonstration programmes in the UK:

- The Domestic Field Trial (DFT) which ran in two phases between 2000 and 2003. The DFT aimed to use the design, construction and monitoring of the installations as a learning opportunity for utilities, building developers and other key players. A total of 660 kW was installed by the end of 2003, the majority of which is on social or mixed housing. Monitoring of the systems is being carried out to assess performance over the two years following commissioning.
- Large Scale Building Integrated PV Trial (LSBIPV): Since 2001 4,2 MGBP funding has been made available for 18 projects totalling almost 1,15 MW on public buildings across the UK. The objectives of the programme include raising awareness of the technology and of creating confidence in the application of PV as well as increasing UK capabilities in the application of PV. All the designs are for true building integrated systems. 8 of the 18 projects were completed by the end of 2003.
- The PV Major Demonstration Programme (MDP): In 2002 20 MGBP was made available for the three-year programme. A further 11 MGBP additional funding was announced during 2004 to enable the scheme to run until 2006.

The scheme, administered on DTI's behalf by the Energy Savings Trust, comprises two application streams:

- Stream One - individual or small-scale applications (systems from 500 W to 5 kW) are dealt with on a rolling basis.
- Stream Two - medium or large-scale company or group applications of between 5 kW and 100 kW are dealt with quarterly by a competitive call process.

Grants are available for both on and off-grid applications (since June 2003) and are eligible for modules, inverters and installation but not batteries or complex charge controllers. Subsidy levels are on average 50 % and for small scale applications are subject to a maximum amount per kW. All grant applications require the use of approved products and accredited installers and designers.

IMPLEMENTATION

The three UK funding programmes described above accounted for approximately 66 % of the total installations (in kW) during 2003. The majority of this came under the MDP which during 2003 funded 172 small scale (<5kW) projects totalling 337 kW and 16 large scale projects (>5 kW) totalling 503 kW. The total figures for 2004 are expected to be much higher following the approval of 261 small scale and 67 large scale applications during 2003.

The MDP has put in place an installer accreditation scheme to ensure the quality of installations which are receiving grant funding. The first nationally recognised course to train practising electricians to install PV has now been successfully piloted in four colleges across the UK. Course 2372 'Certificate in Installation and Testing of Domestic Photovoltaic Systems', developed by IT Power, in association with CREST (University of Loughborough), TNEI and ISPQ Europe, gained City & Guilds accreditation in February 2004. The course is recognised by the Solar PV Grants Scheme and is part of a new route to becoming an accredited installer under the grants Scheme.

The process for obtaining network connection for small PV systems has been simplified and improved. Network connection guidelines (G83/1) have been put in place following consultation involving the PV industry and utilities, and DNOs do not now require prior inspection of network connections for systems less than 3,7 kW.
Planning Policy Statement 22 replaced Planning Policy Guidance note (PPG)22 in 2004 and sets out the Government's planning policies for renewable energy in England , which planning authorities should have

Fig. 4 - 85 kW CIS 'solar wall' in Denbighshire, North Wales -the world's largest single CIS PV installation (photo EETS).

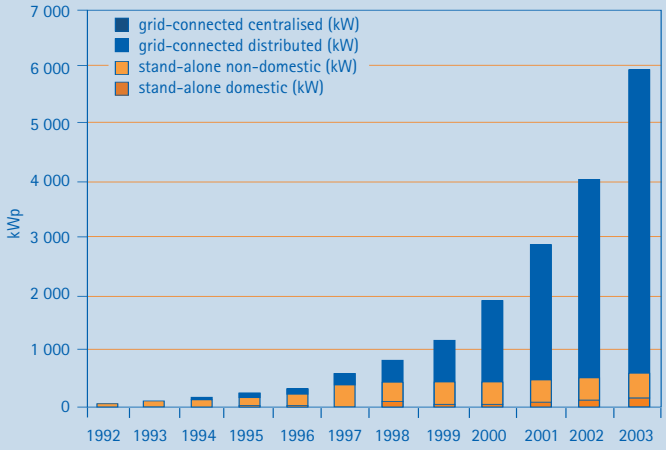

Fig. 5 - Cumulative Installed PV Power in the United Kingdom (1992-2003).

regard to when preparing local development documents and when taking planning decisions. A companion guide, which is still to be published, will include technical guidance on PV.

INDUSTRY STATUS

ICP Solar Technologies UK Ltd (ICP UK), which manufactures thin-film amorphous silicon cells and modules at its factory in South Wales, increased its annual production capacity from 3,0 MW in 2002 to 3,5 MW in 2003. Currently 95 % of the company's production is exported, 65 % of which to North America, 25 % to Europe and 10 % to Africa. The UK's largest employer in the PV sector is Crystallox which produces multi-crystalline silicon ingots saw continued growth in its total annual production capacity.
July 2004 saw the opening of Sharp's new 20 MW capacity PV module manufacturing facility in Wrexham (which already has plans to expand to 40MW) and Romag, a specialist glass manufacturer started production at its new 6 MW lamination facility in Consett, County Durham. It facility uses BP Solar PV cells in the manufacture of semi transparent crystalline PV laminates.

MARKET DEVELOPMENT

The cumulative installed PV generation capacity increased by 43 % during 2003 to reach 5,9 MW. Much of this increase is due to the rapid expansion of the grid-connected market, accounting for 92 % of the 2003 installations.

FUTURE OUTLOOK

Further installations under the Major Demonstration Programme will facilitate a continued healthy rate of grid-connected PV installation until 2007. The proposed technology-blind building integrated renewables capital grants scheme will continue to provide opportunities for support for the PV sector. In particular, it may continue to stimulate Building Integrated PV, which seems to offer somewhat better prospects than bolt-on solar PV technology for long-term UK benefit.

The future development of the sector is also dependent upon the performance of existing manufacturers, installers and suppliers. Current programmes are addressing the need for well-qualified technicians and the participation of players from the building and planning sectors so it is important that the UK PV industry delivers quality products and services when required.

THE UNITED STATES OF AMERICA

PV TECHNOLOGY STATUS AND PROSPECTS IN THE U.S.A.
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GENERAL FRAMEWORK

The U.S. Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy directed the U.S. PV Program through its Office of Solar Energy Technologies in the U.S. and was part of an overall Solar Energy Technology Program. The "Office of Solar Energy Technologies" refocused all of its renewable energy work into a systems-driven approach strategy whereby the market needs now have greater influence in determining priorities for future research and development (R&D). The U.S. DOE was the primary funding source for PV research and development in 2004, and it directed the resources of its national laboratories to assist in the PV industry's applied research and development activities. The Office of Energy Efficiency and Renewable Energy led the national laboratories to develop a comprehensive operating plan based on a strategic, multiyear technical plan that responds to the broad policies for energy R&D determined by the executive and legislative branches of the federal government. The National Center for Photovoltaics (NCPV) continued working with the PV industry through various cost-shared programs to develop and improve component designs, device manufacturability and systems components and systems. Education, technical transfer, technical assistance and competitive contracts were used extensively to accomplish the work in 2004. Photovoltaic-related activities were allocated to PV cell and module development, manufacturing processes, balance-of-system and system technology categories. The U.S. Department of Energy web site http://www.eere.energy.gov/solar provides up-to-date information on and links many of the PV activities in the United States.

The "U.S. Photovoltaics Industry Roadmap," was updated in September 2004, and continues to unify the vision, long-term strategies and goals for the PV industry through 2030. The vision goals are geared toward the electrical/energy consumer, competitive and environmentally friendly energy products, and services from a thriving U.S.-based solar electric power industry. The "DOE Solar Energy Technology Program - Multi-Year Technical Plan 2003-2007 and Beyond" (MYTP) remained in concert with the "Industry Roadmap" to help guide the National PV Program activities to reflect a systems-driven approach (SDA) to R&D.

The NCPV, an alliance of technical organizations, continued to serve as the focal point for the nation's capabilities in PV. The R&D goals and strategies were formulated in concert with the "Industry Roadmap" and through the NCPV "Annual Operating Plan." The "Annual Operating Plan" was coordinated with the MYTP and focused on the Systems-Driven Approach. It is also used to coordinate work for PV and "Solar Thermal" technologies.

NATIONAL PROGRAM

The National PV Program research is focused on increasing domestic capacity by lowering the cost of delivered electricity from PV and improving the efficiency of PV modules and systems. Laboratory and university researchers worked with industry on high-volume, low-cost manufacturing, such as increasing deposition rates to grow thin-film layers, improving materials utilization, reducing cost, improving reliability and using in-line monitoring to increase yield and performance. Specific goals were not changed in 2004 and were to:

- Reduce the direct manufacturing cost of PV modules by 30 percent to USD 1,75/W;
- Identify and develop leap-frog technologies with the potential for cost reduction;
- Establish greater than 20-year lifetimes for PV systems by improving the reliability of balance-of-system components and reducing recurring costs by 40 percent;
- Work with the PV industry to facilitate achievement of its roadmap goals of 1 GW cumulative U.S. sales (export and domestic) by 2006.

These National PV Program R&D activities were directed through the U.S. Department of Energy with headquarters in Washington, DC, and by research centers at the National Renewable Energy Laboratory (NREL) and Sandia National Laboratories (Sandia). Overreaching goals of the U.S. PV activities were the "acceleration of the development of PV as a national and global energy option," "assurance of the technology" and "global market leadership for the nation." The dissemination of information pertaining to PV technologies is handled through printed reports, web sites, conferences and workshops. Two such SDA direction-related workshops for inverters and energy storage were held in 2004. The National Solar Program shared the costs in areas of fundamental research, technology development and advanced materials and devices. The authorized

Fig. 1 - Shell Solar's Camarillo, California factory. Shell Solar installed a 245-kilowatt thin-film CIS PV system on its factory in Camarillo, California. The average aperture-area efficiency of the modules is between 11 % and 11,5 % (photo courtesy of Shell Solar).

"Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000."

funding for PV was categorized into three major areas for FY2004. They were as shown in the following.

TABLE 1- AUTHORIZED FUNDING FOR PV - FY 2004

PV Fundamental Research	39 % of the program budget
PV Technology Development	22 % of the program budget
PV Advanced Materials and Devices	39 % of the program budget

The FY2004 federal budget for the Photovoltaic component of the National PV Subprogram totaled USD 76,5 M. Additional funding for PV-related R&D was administered through state and local governments, partnerships, and through PV industry cost sharing.

The NCPV relies on the core expertise of NREL and Sandia National Laboratories to create, develop, and deploy PV and systems-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. DOE Centers of Excellence at the Georgia Institute of Technology and the University of Delaware (Institute of Energy Conversion). In addition, more than 90 university, industry and utility research partnerships across the country are linked together. The NCPV awards most of its federal funds through competitive procurements requiring cost sharing to industry, and through contracts to universities, and other research facilities.

RESEARCH, DEVELOPMENT AND DEMONSTRATION

The U.S. National PV efforts were categorized according to fundamental research, advanced materials and devices, and technology development. Critical PV program contributions were provided through national laboratory support to the industry via basic research; device characterization; and environment, safety and health activities. A web-based virtual laboratory allowed collaborators from universities and industry to access real-time data on test results related to their projects.

Research on Thin-film Photovoltaics

Research and development of thin-film devices and materials was a major part of the PV program and was administered primarily through the "Thin-film Partnership Program." The "Thin-film Partnership" was a high priority capturing 13 % of the PV program funding. Thin-film device support ranged from amorphous-silicon (a-Si), copper-indium-diselenide (CIS), copper-indium-gallium-diselenide (CIGS), cadmium-telluride (CdTe), thin-film silicon and others.

Major advancements were achieved in first-time manufacturing of three thin films (CIS, CdTe, and a-Si), taking fiscal year US productions levels up from about 12 MW in FY2003 to about 20 MW in FY2004: (1) in CIS, Shell Solar and Global Solar produced approximately 3 MW and 1 MW CIS modules, respectively; (2) in CdTe, First Solar produced approximately 4 MW of CdTe modules; and (3) in a-Si, Uni-Solar produced approximately 12 MW of a-Si modules.

Significant progress has been made in the area of thin-film CIS and related materials. For example, for small laboratory devices, total-area conversion efficiency of 19,5 % has been achieved by NCPV scientists. Using a ZnS buffer layer, a total-area conversion efficiency of 1,4 % has also been achieved by NCPV scientists.

Research and Development of the Balance-of-System

Research within the industry and the national laboratories continued to explore improved inverter reliability and performance for PV applications. Work concentrated on higher reliability, modularity and conformance with anti-islanding and electrical code requirements.

Phase II of the DOE "High reliability Inverter Initiative" began late in 2003. Three contractors were selected to complete Phase II projects aimed at developing a prototype; finalizing development of new inverter designs; assess, test and validate new designs; and validate compliance to utility-interconnection standards. All manufacturers are working to assure UL listing, quality control programs and highly accelerated life testing.

The R&D for Phase II resulted in: (1) a 3 500-W utility-interactive, multiple input inverter which has a calculated minimum MTBF of 12 years; (2) a 5 000-W utility-interactive or stand-alone inverter with optional inputs that include a matching maximum-power-point tracker which has a calculated minimum MTBF of 10 years; and (3) a 2 500-W utility-interactive inverter with flexibility for inputs which has a calculated minimum MTBF of 12 years. Delivery of all prototypes to Sandia National Laboratories was scheduled for December 2004.

Phase III is scheduled to be conducted with at least two contractors. It will be structured to refine prototypes into commercial products. Final products will be validated through laboratory evaluations, UL listings, environmental testing, and long-term evaluation. Issues pertaining to environment, safety and health remained an essential aspect of working with the balance-of-system industry, and are included in all work sponsored by the National Solar Program.

Research on High Performance and Concentrating PV

The High-Performance Photovoltaic (HiPerf PV) initiative continued exploring the limits of the performance of existing PV technologies, with the aim to nearly double sunlight-to-electricity conversion efficiencies. There was also a goal to demonstrate a high-efficiency III-V cell in a pre-commercial concentrator module.

Fig. 2 - Photovoltaic array on the roof.
Photovoltaic system on the EPA's Research Triangle Park (RTP) facility (photo courtesy of the Environmental Protection Agency).

To accomplish HiPerf's objective, the National Center for Photovoltaics (NCPV) directed in-house and subcontracted research through the "High Performance PV-Exploring and Accelerating Ultimate Pathways" solicitation in high-performance polycrystalline thin films and multi-junction concentrators. Two specific objectives of this research included bringing efficiencies for thin-film cells toward 25 %, (for modules toward 20 %) and creating 33 %-efficient multi-junction concentrators. The objectives were met by achieving a record efficiency of 37,3 % for a 3-junction terrestrial concentrator cell, and working toward the design of a high-concentration module with efficiency greater than 33 %. It is expected that the project's three phases will steer high-efficiency technologies toward commercial, prototype products. Each phase of the project focuses on a specific approach to solving the problems associated with high efficiencies. Phase IB is a continuation of Phase I and addresses exploring and accelerating ultimate pathways to reach the project's long-term goals.

Research on Crystalline Silicon

Fabricating record high-efficiency, ribbon-silicon solar cells with screen-printed and photolithography-defined contacts was continued in 2004. Optimized rapid thermal firing (RTP) enhanced SiNx-induced hydrogenation helped to achieve record-high efficiency screen-printed edge-defined film-fed growth (EFG) (15,9 %) and a high efficiency "String Ribbon" cell (16,6 %). A two-step RTP firing process was critical in achieving high efficiency screen-printed cells. Step 1 provided SiNx-induced hydrogenation and formed an aluminum doped back surface field. Step 2 was designed for silver-grid firing and included rapid cooling to retain hydrogen introduced in Step 1. A selective-emitter solar cell design that enhances single-crystal silicon solar cell efficiency by 0,43 % absolute over conventional co-fired cells was fabricated.

Other areas of crystalline R&D included large-scale PV module manufacturing using ultra-thin polycrystalline silicon solar cells, innovative approaches to low-cost module manufacturing of string-ribbon silicon PV modules, EFG technology and diagnostics R&D for large-scale PV manufacturing, and development of an in-line minority-carrier lifetime monitoring tool for process control during fabrication for crystalline silicon solar cells.

Research on Plug-and-Play Concepts

The AC PV Building Block is a concept that could ultimately fill a major market niche for code-compliant, retrofit and building-integrated applications. New feasibility studies were initiated in 2004. These studies are structured to determine overall inverter, materials, thermal-management, mechanical and long-term reliability requirements.

Demonstration Programs

No major national demonstration programs were active during 2004. Several programs were sponsored by various sectors of state governments and utilities, most notably California. Deregulation of the electric utilities and localized energy shortages have spurred several state programs that require installation of PV energy systems along with new R&D efforts.

IMPLEMENTATION

Industry Roadmap and Technical Plans

Success of PV for the National Solar Program depends on the direction, resources, best scientific and technological approaches, use of the best technologies and continued efforts of the best and brightest among industry, federal laboratory and university partners. The NCPV worked in concert with the industry to lay the groundwork for a "Systems-Driven Approach" to guide new PV work that meets the goals of the industry roadmap and that will be funded by the U.S. DOE.

Photovoltaic Manufacturing

To improve technology leadership and market share, improvements in PV products must move from laboratories to the world marketplace. Against this backdrop of a growing market, the PV Manufacturing R&D Project continued its support through improving PV manufacturing processes and products for terrestrial applications, accelerating PV manufacturing cost reductions, increasing product performance and reliability, laying the foundation for significantly increased production capacity, and achieving these goals in an environmentally safe manner.

In an effort to accomplish the objectives, renewal for active "In-Line Diagnostics and Intelligent Processing" contracts was completed. Also completed were the "Letters-of-interest" review, source selection, and initiated awards under the "Large-Scale Module and Component Yield, Durability and Reliability" solicitation.

Energy Photovoltaics (EPV) completed evaluation of single-junction and tandem a-Si modules to determine the best option, as a function of application, based on EPV's proprietary batch deposition process. EPV also reduced the a-Si deposition cycle time for tandem devices by 20 %, increased the throughput of the deposition system by 20 %, and reduced per-watt module cost from the EPV production line by 25 %.

BP Solar International, LLC demonstrated good yields and cell efficiencies using a mix of 25 % solar grade silicon with 75 % intrinsic silicon feedstock. BP Solar also demonstrated 2,5-3 % increase in module output power using anti-reflection (AR) coated glass and qualified glass through environmental testing.

Fig. 3 - SUNSLATE solar electric roof system.
Solar Works, Inc., installed a SUNSLATE solar electric roof system form Atlantis Energy on a home in Bolton, Massachusetts. A total of 480 solar electric roofing tiles comprise the 5.8-kW, gird-tied solar electric system, which provides about 65 % of the home's average annual power needs. The SUNSLATES function as conventional, weatherproof roofing tiles and look like a conventional slate roof, while producing electric power. This building-integrated approach allows the PV modules to be part of the roof so that they are barely noticeable (photo courtesy of Solar Works).

PowerLight Corporation exceeded company goals by improving the manufacturing yield to 99,7 %, reducing lead-time, required labor, floor space, and inventory levels. PowerLight also improved design-for-manufacturability reducing per-watt cost by 18 %.

AstroPower, Inc. developed and implemented a continuous back-metallization, screen-printing, and laser scribing system; as well as addressed feedstock supply by developing continuous unidirectional solidification process to upgrade metallurgical-grade silicon to silicon-film purity requirements. AstroPower also demonstrated an overall increase of 5 % in relative power and nearly 15 % in mechanical and visual yield.

Xantrex Technology, Inc. developed three advanced, high-impact PV inverter products for grid-tied applications, and significantly reduced the weight, size, cost and conversion loses of new inverters when compared to current products. Xantrex also developed DSP-based control boards for each of the three PV inverter topologies that were designed for universal application at virtually any power rating for any inverter with similar electrical topology.

Systems Development and Evaluations

Sandia National Laboratories led the "Systems Engineering" program that included a balance-of-system program. Its goals were to accelerate evolutionary changes to power processing hardware that would result in improved reliability and performance. The initiative continues working with industry to improve "Total Quality Management" programs in the manufacturing and assembly areas. Sandia also urged industry to participate in "Highly Accelerated Life Tests (HALT™)" and "Highly Accelerated Stress Screens (HASS™)" to improve quality and reliability of hardware. The test facilities at Sandia and NREL continued to contribute significantly to all of the reliability-improving programs.

Sandia and NREL conducted PV module performance and durability studies for manufacturers. For new PV modules, or for those that have operated in the field for years, researchers collect data on electrical performance, physical properties, integrity of solder joints, and properties of encapsulants. Evaluations included outdoor electrical performance, dark current/voltage (I-V), infrared (IR) imaging, ultraviolet (UV) inspection, solder-joint metallurgy, and ultrasonic characterization, as well as destructive testing for specific failure modes.

The inverter test facility at Sandia continued to provide critical characterization, benchmarking, surge testing and accelerated life testing. The 30-kW hybrid test bed for inverters, designed for grid-connected or stand-alone PV systems was in operation as the Distributed Energy Test Laboratory (DETL). It included a complete mini-grid control unit and a 75-kVA micro turbine; a 90-kVA diesel; and load banks that are resistive, inductive, and capacitive in nature. The DETL was used to verify tests and procedures called out in standards, and to aid a certification test protocol for inverters.

Sandia National Laboratories' Distributed Energy Technologies Laboratory (DETL) performed numerous evaluations and performance studies of PV inverters ranging in size from 100Wac to 75kWac. Inverter evaluations involve two types of products (readily available and developmental prototypes). Standardized test protocols were developed at the DETL. The DETL grid-tied test protocol included tests for compliance to today's standards. Examples are IEEE Std. 519 for harmonic distortion, FCC Part 15 for radio-frequency emissions, and IEEE/ANSI 62,41 for surge voltages in low voltage ac power circuits.

NREL maintained the Outdoor Test Facility (OTF) to test performance and reliability of solar cells, modules, and small (1-5 kW) systems. The OTF also calibrated primary reference cells for use in-house, by other national laboratories, by industry, and by universities. Researchers at the OTF measured performance in actual outdoor tests and using solar simulators indoors. Indoors at the OTF, modules were tested for failure and performance in conditions of high voltage, high heat, high humidity, flexing, static loading, and simulated hail strikes. Outdoors, the test beds at the OTF measured long-term performance and stability. Two test beds performed stress tests of modules under accelerated conditions of high voltage and high sunlight concentration.

Reliability, Codes and Standards

Although manufacturers are now offering 10- to 20-year warranties on PV modules, PV systems that operate reliably for 25 years remain a major goal of the National PV Program's system activities. To reach that goal, the program is supporting research and analysis using field data and models tied to the SDA to identify areas for further technical development. Models already developed are being integrated into the "Solar Technologies (SDA) Program" models.

Sandia's "PV System Reliability Plan," drafted in consultation with industry, continues to guide hardware and system development. The plan recommends continuation of several activities such as developing a reliability database to improve understanding of the

Fig. 4 - Transparent PV on BP Gas Station Canopy in Denver, Colorado. The PowerView Semi-transparent PV modules are a novel system that serves as partial skylight and power generation. It is envisioned these panels will become a functional replacement for glass in walls, skylights, atriums in modern architecture (photo courtesy of Warren Gretz).

performance of real systems; examining PV systems and components after extended operation in the field to identify sources of performance degradation or failures that could be prevented by changes in manufacturing; modeling system performance to identify fault-tolerant designs, sensitivities to component failure, cost-effective component replacement strategies; and working with industry and users to resolve technical or institutional barriers to system reliability.

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, were continuing activities in the National Solar Program. The program supported work to provide a consensus of industry input into the National Electrical Code® (NEC®), listing and certification standards, and numerous standards activities in both the domestic and the international arenas. Sandia National Laboratories led Industry Forum work for the 2005 National Electrical Code (NEC) with proposals and balloting processes for PV system installation updates. The 2005 NEC was published in September 2004.

Sandia National Laboratories led efforts to draft a "Performance Test Protocol for Evaluating Inverters Used in Grid-Connected Photovoltaic Systems." The document, while still being refined is now being considered by several state-supported incentive programs as new trends toward performance based incentives are emerging.

The IEEE 1547 "Standard for Interconnecting Distributed Resources with Electric Power Systems" is being incorporated in utility interconnect guidelines. Four additional tasks for the standard continued to be developed. Underwriters Laboratories continued new updates for the UL1741 "Standard for Static Inverters and Charge Controllers for Use in Photovoltaic Power Systems" and expanding the standard to include inverters for all distributed generation.

The "National Voluntary Certification Program" for PV installers was developed with the support of the U.S. DOE PV Program and was launched in 2003. The North American Board of Certified Energy Practitioners (NABCEP) now certified over 200 installers. NABCEP testing is conducted twice a year.

INDUSTRY STATUS

The quantity of PV modules produced in the United States in 2004 reached 135 MW and grew at more than 30 % in 2004. Photovoltaic installations in the U.S. grew to more than 85 MW. The U.S. PV applications in 2004 involved virtually all market sectors with the exception of the central power application. The majority of the growth was in the grid-connected sector.

The U.S. now installs more than 50 MW per year of grid-connected systems. Approximately 25 MW of small, 2- to 4-kW roof-mounted systems are installed on private residences. The systems use all types of PV modules and are sometimes connected to a multiple mode inverter that permits the PV system to first serve the building's load and then to send excess power to the utility grid. When the grid power is not available, the inverter may be designed to switch to "standby" and power the local load from energy stored in a battery bank.

There are several mainstay inverter manufacturers serving the U.S. market today. Many new inverter manufacturers emerged in 2004 and those new products continue to be listed for safety and were being commercialized in 2004.

MARKET DEVELOPMENT

The National Solar Technologies Program provided technical support for state-funded PV applications using assistance through the Interstate Renewable Energy Council (IREC). Much of this work continued to provide PV applications/technology education for personnel at parks and public spaces through the "Photovoltaics for Utilities (PV4U)" program. The approach to removing barriers to PV for utilities is a network of State working groups that promote PV. Working with the states and supporting the North American Board of Certified Energy Practitioners for a "Voluntary National Certification Program for Practitioners" remained important activities for the IREC program in 2004. IREC sponsored numerous workshops and special sessions at PV conferences.

International work included continuation of 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 had been honored as one of the most successful renewable energy programs for USAID and continues to serve as a model for increasing the use of PV in other parts of the world. The 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-ranging system replication, through increased awareness of the benefits of renewable energy technologies, and improved private sector capacities to serve the market.

Fig. 5 - PowerLight's Sloped Tile.
Installed on a customer's facility in Berkley, CA, this sloped PowerGuard product generates 150Wp per tile (photo courtesy of PowerLight Corp.).

The NCPV support, such as training and technical assistance in Bolivia, Brazil, China, Ghana, Guatemala, Honduras, India, Indonesia, Kenya, Mexico, Morocco, Nigeria, Pakistan, the Philippines, Russia, South Africa, and Venezuela, has helped U.S. companies continue to make inroads into the international market.
The U.S. DOE Million Solar Roofs (MSR) Initiative promoted the use of PV and solar thermal to reduce the energy demands of buildings. It enabled businesses and communities to install solar systems on one million rooftops across the U.S. The Million Solar Roofs Initiative was designed to support states and local communities as they developed a strong commitment to the sustained deployment of solar energy technologies. Fifteen new MSR State and Local partnerships during FY2004 were added, bring the total to 89. In addition, 125 businesses, electricity providers, organizations, and agencies joined Partnerships, bringing the national total of participants to 822 MSR was awarded USD 1,6 M in State and Local Partnership grants - combined with USD 767 K in cost-share - to support localized efforts to remove barriers and develop local markets for solar energy technologies. Finally, MSR initiated/funded a telecommunications study involving Bell South, Verizon, and Emerson to explore opportunities for solar on switching stations to support their operations.

FUTURE OUTLOOK

The U.S. Department of Energy, in partnership with its national laboratories, will continue with important PV initiatives through the DOE Solar Energy Technologies Program. The "Industry Roadmap" and an updated "DOE Solar Energy Technology Program - Multi-Year Technical Plan 2003-2007 and Beyond" will guide the work using a "Systems-Driven Approach" to determine priorities based on market needs. The research and development and technical advances will include all of the components, interconnects, and materials needed for a viable PV industry. PV materials, advanced cells, improved manufacturing processes, advanced balance-of-system hardware, higher reliability, high-tech inverter/BOS/systems development, fire and personnel safety, codes, & standards, hardware certification and practitioner certification will remain vital elements in the program.

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

OVERALL OBJECTIVE

The objective of Task 5 was to develop and verify technical requirements, which served as the technical guidelines for grid interconnection with building-integrated and other dispersed PV systems. The development of these technical requirements included safety and reliable linkage to the electric grid at the lowest possible cost. The systems to be considered were those connected with a low-voltage grid, which was typically of a size between one and fifty peak kilowatts. Task 5 was officially concluded in 2003.

MEANS

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

SUBTASK 10: Review of Previously Installed PV Experiences (From 1993 to 1998)

To review existing technical guidelines, local regulations and operational results of grid interconnection with building- integrated and other dispersed PV systems to aid Subtask 20 in defining existing guidelines and producing concepts for new requirements and devices.

SUBTASK 20: Definition of Guidelines to be Demonstrated (From 1993 to 1998)

Utilizing the results of Subtask 10 and a questionnaire, existing technical guidelines and requirements to be demonstrated will be defined, and concepts for new requirements and devices will be developed; with safety, reliability, and cost reduction taken into consideration.

SUBTASK 30: Demonstration Test Using Rokko Island and/or Other Test Facilities (From 1993 to 1998)

To evaluate, by demonstration tests, the performance of existing and new technical requirements and devices defined in Subtask 20.

SUBTASK 40: Summarizing Results (From 1993 to 2001)

To summarize the results of Task 5 and to produce a general report for all participating countries of Task 5, as well as for the ExCo members.

SUBTASK 50: Study on Highly Concentrated Penetration of Grid Interconnected PV Systems (From 1999 to 2001)

To assess the net impact of highly concentrated PV systems on electricity distribution systems and to establish recommendations for both distribution and PV inverter systems in order to enable widespread deployment of solar energy.

TASK 5 REPORTS AND WORKSHOP PROCEEDINGS:

Task 5 produced the following reports and workshop proceedings:

Task 5 Reports

1. "Utility aspects of grid interconnected PV systems", IEA-PVPS T5-01: 1998, December 1998
2. "Demonstration tests of grid connected photovoltaic power systems", IEA-PVPS T5-02: 1999, March 1999
3. "Grid-connected photovoltaic power systems: Summary of Task V activities from 1993 to 1998", IEA-PVPS T5-03: 1999, March 1999
4. "PV system installation and grid-interconnection guideline in selected IEA countries", IEA-PVPS T5-04: 2001, November 2001
5. "Grid-connected photovoltaic power systems: Survey of inverter and related protection equipments", IEA-PVPS T5-05: 2002, December 2002
6. "International guideline for the certification of photovoltaic system components and grid-connected systems", IEA-PVPS T5-06: 2002, February 2002
7. "Probability of islanding in utility networks due to grid connected photovoltaic power systems", IEA-PVPS T5-07: 2002, September 2002
8. "Risk analysis of islanding of photovoltaic power systems within low voltage distribution networks", IEA-PVPS T5-08: 2002, March 2002
9. "Evaluation of islanding detection methods for photovoltaic utility-interactive power systems", IEA-PVPS T5-09: 2002, March 2002
10. "Impacts of power penetration from photovoltaic power systems in distribution networks", IEA-PVPS T5-10: 2002, February 2002
11. "Grid-connected photovoltaic power systems: Power value and capacity value of PV systems", IEA-PVPS T5-11: 2002, February 2002

Task 5 Internal Reports (Open to Public)

1. "Grid-connected photovoltaic power systems: Status of existing guidelines and regulations in selected IEA member countries (Revised Version)", IEA-PVPS V-1-03, March 1998
2. "Information on electrical distribution systems in related IEA countries (Revised Version)", IEA-PVPS V-1-04, March 1998

Proceedings of Final Task 5 Workshop

1. Introduction and table of contents
2. Flyer of the workshop
3. List of participants of the workshop
4. Final programme of the workshop
5. Key note speech
6. Islanding detection methods
7. Probability of islanding in power networks
8. Risk analysis of islanding
9. Conclusions of task V islanding studies
10. Recapitulation of first day
11. Overview of (inter)national interconnection guidelines for PV-systems
12. State of the art inverter technology and grid interconnection
13. Impacts of PV penetration in distribution networks
14. Power value and capacity of PV systems

DELIVERABLES - Where to get them?

All reports are available for download at the IEA PVPS website: http://www.iea-pvps.org
A Task 5 CD-ROM including all the reports was published for distribution. This can be ordered at the contact address below.

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COMPLETED TASKS
TASK 6 - DESIGN AND OPERATION OF MODULAR PHOTOVOLTAIC PLANTS FOR LARGE SCALE POWER GENERATION

OVERALL OBJECTIVE

Task 6 officially completed its activities in May 1998. The main objective of this Task was to further develop large-scale modular photovoltaic plants for peaking and long-term baseload power generation in connection with the medium-voltage grid.

MEANS

The Task 6 work was performed by structural engineers and PV industry experts. The work was structured into four sub-tasks, for a total of fifteen activities.

SUBTASK 10: Review of Design and Construction Experiences of Large-Scale PV Plants

To perform, on the basis of the Paestum Workshop results, an in-depth review of existing large-scale PV plants aimed both to identify the remarkable technical solutions adopted in such plants and the main common criteria applied for their design, installation, operation, monitoring, and to perform a detailed cost analysis of the plants taken into account.

SUBTASK 20: Review of Operational Experiences in Large-Scale PV Plants

To perform, also utilising the work in progress of Subtask 10 and on the basis of the Paestum Workshop results, an in-depth review of operational experiences in existing large-scale PV plants. The analysis of the acquired data was focused on the comparison between the expected and actual results, both technical and economical; the information flow was continuously updated through acquisition of data from all the plants in operation.

SUBTASK 30: Development of Improved System Design and Operational Strategies for Large-Scale PV Plants

Based on the work of Subtasks 10 and 20, the evaluation work, together with the information gathering activity, let the assessment of most appropriate, innovative technical options for modular design of large-scale PV plants. Both PV and BOS components were dealt with, taking into account: performances improvement, costs reduction, and realisation simplification.

The co-operation among utilities and industries of many countries offered the opportunity to review in detail the performance data and the technical aspects which determined the design approach of the largest PV plants in the world, and to develop improved system design, and operational strategies for such plants.

SUBTASK 40: Outlook of Perspectives of Large-Scale PV Plants

Based on the assumption that large grid connected PV power plants have proven their applicability under the technical point of view, the Subtask was aimed at identifying the path in order to let such plants become a substantial option and play an increasing role in a future oriented energy concept in OECD countries, as well as in developing countries.

TASK 6 REPORTS AND WORKSHOP PROCEEDINGS

Task 6 produced the following reports and workshop proceedings from 1993 to 1998:

1. The Proceedings of the Paestrum Workshop.
2. A PV Plant Comparison of 15 plants.
3. The State of the Art of: High Efficiency, High Voltage, Easily Installed Modules for the Japanese Market.
4. A document on "Criteria and Recommendations for Acceptance Test."
5. A paper entitled: "Methods to Reduce Mismatch Losses."
6. Report of questionnaires in the form of a small book containing organized information collected through questionnaires integrated with statistical data of the main system parameters and of the main performance indices.
7. The "Guidebook for Practical Design of Large Scale Power Generation Plant," edited by the Japanese expert.
8. The "Review of Medium to Large Scale Modular PV Plants Worldwide."
9. Proceedings of the Madrid Workshop.

DELIVERABLES – Where to get them?

All reports are available for download at the IEA PVPS website: http://www.iea-pvps.org

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COMPLETED TASKS
TASK 7 - PHOTOVOLTAIC POWER SYSTEMS IN THE BUILT ENVIRONMENT

OVERALL OBJECTIVE

The objective of Task 7 was to enhance the architectural quality, the technical quality and the economic viability of PV systems in the built environment. The objective was 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 motivated the collaboration between these groups and PV system specialists, utility specialists, PV and building industry and other professionals involved in photovoltaics.

Task 7 considered all grid connected systems other than classified as "ground based arrays". Primary focus of this Task was on the integration of PV into the architectural design of roofs and facades of residential, commercial and industrial buildings and other structures in the built environment (such as noise barriers, parking areas and railway canopies), and on other market factors, both technical and non-technical, that need to be addressed and resolved before wide spread adoption of PV in the built environment will occur. Task 7 officially started on January 1, 1997 and finished end 2001. In 2002, the last reports and deliverables were published. At the end of 2003 there remained only one outstanding issue: the publication of the book "Designing with Solar Power". This book is expected in Spring 2005.

SUBTASK 1: Architectural Design of Photovoltaic Power Systems in the Built Environment

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

SUBTASK 2: Systems Technologies for Photovoltaic Power Systems in the Built Environment

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

SUBTASK 3: Non-Technical Barriers in the Introduction of Photovoltaic Power Systems in the Built Environment

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

SUBTASK 4: Demonstration and Dissemination of Photovoltaic Power Systems in the Built Environment

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

TASK 7 REPORTS

Task 7 produced the following reports from 1999 to 2002:

1. Literature Survey and Analysis of Non-technical Problems for the Introduction of BIPV Systems, B. van Mierlo & B. Oudshoff, IVAM Environmental Research, 1999. To be ordered at IVAM Environmental Research, NL, Fax + 31 20 525 58 50
2. PV in Non Building Structures - A Design Guide, M.A. Romero, EcoCode-Miljö och Architectur, 1999. To be ordered at Energiebanken, SE, Fax: +46 652 13 427
3. Potential for Building Integrated Photovoltaics, M. Gutschner, Nowak Energy Technologies AG, 2001. To be ordered at NET, CH, Fax: +41 26 49 40 034
4. Guidelines for the Economic Evaluation of Building Integrated Photovoltaics, P. Eiffert, National Renewable Energy Laboratories, 2002. To be ordered at NREL, USA, website: www.nrel.gov/buildings/highperformance.
5. Market Deployement Strategies for Photovoltaics in the Built Environment, R. Haas, Technische Universität Wien, 2002. To be ordered at Technische Universität Wien, AT, Fax: +43 1 588 013 7397
6. Innovative electric concepts, H. Wilk, Energie AG, 2002. To be ordered at Energie AG, AT, Fax: +43732 9000 3309
7. Reliability of Photovoltaic Systems, H. Laukamp, Fraunhofer Institute für Solar Energiesysteme, 2002. To be ordered at Fraunhofer Institute für Solar Energiesysteme, GE, Fax: +49 761 4588 217
8. PV/Thermal Solar Energy Systems, Status of the Technology and Roadmap for future Development, H. Sorensen, Esbensen Consulting, 2002, To be ordered at Esbensen Consulting Engineers, DK, Fax: +45 33 26 73 01
11. Executive Summary Report - Non-technical Barriers to the commercialisation of Photovoltaic Power in the Built Environment, P. Eiffert, National Renewable Energy Laboratories, to be ordered at NREL, USA, website: www.nrel.gov/buildings/highperformance

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

Task 7, Project Results and Documents.
To be ordered at:
Novem, Publication Centre
PO Box 8242
3503 RE Utrecht
The Netherlands
Tel.: +31 30 2393493
Email: publicatiecentrum@novem.nl.

Task 7 book: Designing With Solar Power"
To be ordered at:
The Images Publishing Group Pty Ltd
6 Bastow Place
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PARTICIPANTS

In total, 14 countries participated in Task 7, with representatives from all targeted groups: architects, building and PV industry, PV and building specialists and utilities.

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

ANNEX A

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