IEA INTERNATIONAL ENERGY AGENCY

PHOTOVOLTAIC POWER SYSTEMS PROGRAMME

PVPS annual report 2003

IMPLEMENTING AGREEMENT
ON PHOTOVOLTAIC POWER SYSTEMS

PHOTOVOLTAIC POWER SYSTEMS PROGRAMME

ANNUAL REPORT 2003

PREFACE

The year 2003 has been an important landmark for the Photovoltaic Power Systems Programme IEA PVPS: It was the occasion to celebrate the 10th anniversary of this international co-operation programme. To mark this anniversary, an international conference was successfully held under the auspices of the IEA in May 2003, in Osaka, Japan. Together with other events – namely the 3rd World Conference on Photovoltaic Energy Conversion – held during the same period in Osaka, this formed the World PV Epoch, the largest series of public events ever held on the subject of photovoltaics. In spite of the difficult international situation in 2003, the IEA PVPS International Conference was attended by some 300 delegates from all over the world.

The conference concentrated on the needs for further and sustainable implementation of photovoltaics in different application areas, focusing on the visions and goals for photovoltaics, some of the strategies followed to achieve those, the institutional and policy framework in which this occurs and – most relevant for the PVPS Programme – the experience with and analysis of different approaches. By performing high level R&D co-operation activities, by aiming for efficient and objective analysis and information, and by providing recommended practice in various technical and non-technical areas, PVPS can play the important and independent role of a catalyst for future developments.

The conference allowed many of the key – mostly non-technical – issues for the deployment of photovoltaics to be addressed. Discussing the general framework in which the development of photovoltaics occurs allowed emphasising the challenges which this technology faces in the near future to strengthen its position in the future energy mix and supply. The PVPS programme will capitalise on its experience and credibility in order to play a leading role in this important area.

I would like to thank all those involved in the preparation, organisation and execution of this important conference, namely our distinguished speakers, chairs and rapporteurs. Most of all, my thanks go to our hosts in Japan, both the Japanese Ministry of Economy, Trade and Industry (METI) and the Japanese New Energy Development Organisation (NEDO) which have provided an excellent framework and an enormous effort to make this conference a success.

As the second important result of the PVPS programme for 2003, I would like to mention the birth of the new Task 10 on urban scale photovoltaic applications. Following the detailed preparatory work to which many countries contributed, the Executive Committee could establish this new project at its 22nd meeting in Berlin, Germany. I am grateful to the United States of America which have accepted to lead this new PVPS activity.

Based on the input received from the international conference in Japan, discussions with numerous experts and stakeholders, the Executive Committee has adapted its strategy for the third 5-year term of co-operation within PVPS. The most important elements of this new strategy can be found in this annual report.

With many new results from the various ongoing projects, 2003 was a very 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 (www.iea-pvps.org). 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.

Finally, I take this opportunity to thank all Executive Committee members, Operating Agents and Task Experts who by their dedicated efforts 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 2003, nine Tasks were established within the PVPS programme, of which one was completed in 1997 (Task 6), two were completed in 2001 (Task 5 and Task 7) and one is not operational (Task 4). A new task has begun in 2003 (Task 10), which will be a follow-up to Task 7.
The twenty-one PVPS members are: Australia, Austria, Canada, Denmark, European Union, Finland, France, Germany, Israel, Italy, Japan, Korea, Mexico, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom and the United States. Turkey has shown an interest to revive its membership.

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 and EU RDD programmes manufacturing 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 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.

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, Berlin, Germany, October 2003.

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. Operational performance, maintenance and sizing of PV power systems and subsystems;
- Task 3. Use of PV power systems in stand-alone and island applications;
- Task 4. Modelling of distributed PV power generation for grid support (not operational);
- Task 5. Grid interconnection of building integrated and other dispersed PV systems (concluded in 2001);
- Task 6. Design and operation of modular PV plants for large scale power generation (concluded in 1997);
- Task 7. PV power systems in the built environment (concluded in 2001);
- Task 8. Very large scale PV power generation systems;
- Task 9. Deployment of PV technologies: co-operation with developing countries;
- Task 10. Urban Scale PV Applications. Begun in 2003. Follow-up of Task 7.

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

TASK STATUS REPORTS

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

IEA PVPS Website, Homepage.

OVERALL OBJECTIVE

The objective of Task 1 is to promote and facilitate the exchange and dissemination of information on the technical, economic, environmental and social aspects of PV power systems. Task 1 activities support the broader PVPS objectives that relate to contributing to cost reduction of PV power applications, increasing awareness of the potential and value of PV power systems, fostering the removal of both technical and non-technical barriers and enhancing technology co-operation. All countries participating in the PVPS Programme are members of Task 1. To meet the Task 1 objective and deliver the expected outcomes, Task 1 participants focus on understanding the needs of their 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 **International Survey Report** *(Trends in Photovoltaic Applications)* is compiled from **the National Survey Reports** produced annually by all countries participating in the IEA-PVPS Programme. The national reports can now be found on the public website. The International Survey Report presents the current status and interprets trends relating to systems and components being used in the various PV power systems markets, as well as changing applications within those markets. This is reported in the context of the business environment, policies and relevant non-technical factors in the participating countries.

International Survey Reports were initially produced every two years, but a shorter report is now produced annually to provide more timely information. The first issue was printed in March 1995 and a further seven issues had been published by the end of 2003.

SUBTASK 1.2: Newsletter

A printed, colour newsletter, PVPower, is prepared and distributed to stakeholders by post 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.

Nineteen issues of the newsletter had been published by the end of 2003.

SUBTASK 1.3: Special Information Activities

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

SUMMARY OF TASK 1 ACCOMPLISHMENTS FOR 2003

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. During 2003 the PVPS Programme produced fourteen major publications, and about 70 items were added to the website. The public PVPS website enables PVPS information to be provided quickly and at a reasonable cost. The ongoing development of the website during 2003 remained a priority activity for Task 1, and was 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 8th issue of the International Survey Report was published in August 2003 and analyzed data collected between 1992 and the end of 2002. In 2003 the report was prepared by a small Task 1 group on the basis of the National Survey Reports (NSRs) prepared by all Task 1 participants. Nineteen out of twenty countries produced the required NSR (or at least provided information). Fifteen of these countries provided material close to the agreed date.
These 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.

Trends in photovoltaic applications.
Survey report of selected IEA countries between 1992 and 2002.

Newsletter PV Power issues 18 and 19.

The International Survey Report is a 24 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 must be tangible to be included.

Issue 18 of the newsletter was published as a special issue for the IEA-PVPS 10th anniversary conference in Osaka, Japan in May 2003. Issue 19 was published in December 2003. Current and back issues of PVPower are available on the public website.

SUBTASK 1.3: Special Information Activities

During 2003 work continued at a low level on activities (ongoing and new) that fall under the umbrella of special information activities. The significant issue affecting the ability to progress these activities is that they are mostly without a 'lead country' providing the required resources. Task 1 interests that will benefit from a close working relationship with the new Task 10 include market transformation, and the added values of PV. Other 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. The agreed position is that, without the resources required to carry out the detailed analyses that some of these topics require, Task 1 will build on existing activities by collecting and disseminating related information to stakeholders and target audiences.

An exception to the above is the PV Utility Forum which is being progressed by Denmark. The vision is to establish an international forum for electric utilities, network operators and regulators for exchange and dissemination of information and experiences on grid-connected PV (this may then evolve into a broader distributed generation activity that may be of interest to the IEA generally). The objectives are to openly share both positive and negative experiences, perceptions and ideas.

SUMMARY OF TASK 1 ACTIVITIES PLANNED FOR 2004

Task 1 activities will reflect the broader strategy for the PVPS Programme that is currently being developed for the next five years. 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 ninth issue of the International Survey Report is August 2004, with the electronic version to be made available in July 2004. It is planned to broaden the report to include information from non-PVPS countries, and to further highlight industry development matters. National Survey Reports will be completed by the end of May 2004, based on the revised guidelines and data collection pro forma, so that the information can be incorporated in and analyzed for the International Survey Report.

SUBTASK 1.2: Newsletter

Task 1 participants will continue to review and update the target audiences within their countries, and to seek feedback regarding preferred format (e.g. electronic or printed) and content from these audiences. The newsletter will increasingly be provided to countries and institutions outside the PVPS membership.

PVPower Nos. 20 & 21 will be published in April 2004 and October 2004 respectively, maintaining current editorial policy.

SUBTASK 1.3: Special Information Activities

The matters of interest to Task 1 participants will increasingly be incorporated into existing activities – such as the newsletter, the survey reports, the website – and as input to other tasks except where a dedicated activity, for example the PV Utility Forum, can be supported.

Denmark proposes to hold the first two-day workshop of the PV Utility Forum in Denmark, in the second half of 2004, with about 50 invited international participants. It is envisaged that the general framework of the workshop would be key presentations outlining experiences, engagement of attendees for ongoing participation in the forum, definition of a work plan and associated responsibilities, and consideration of future activities.

LIST OF PARTICIPATING COUNTRIES, KEY TASK 1 PARTICIPANTS IN 2003 AND THEIR ORGANIZATIONS

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

COUNTRY	NAME	ORGANISATION
Australia	Greg Watt	Australian PVPS Consortium
Austria	Roland Bruendlinger	Arsenal Research
Canada	Gordon Howell	Howell-Mayhew Engineering Inc.
Denmark	Peter Ahm	PA Energy A/S
European Union	Rolf Öström	DG Research
Finland	Leena Grandell	MOTIVA
France	André Claverie	ADEME
Germany	Frank Stubenrauch	Forschungszentrum Jülich
Israel	Yona Siderer	The Ben-Gurion National Solar Energy Centre
Italy	Salvatore Guastella	CESI - ENEL
Japan	Osamu Ikki	Resources Total System Co. Ltd.
Korea	Kyung-Hoon Yoon	KIER
Mexico	Jaime Agredano Diaz	IIE
Netherlands	Job Swens	NOVEM
Norway	Fritjof Salvesen	KanEnergi AS
Portugal	Luis Silva	ADENE
Spain	no participation	
Sweden	Lars Stolt	Uppsala University
Switzerland	Pius Hüsser	Nova Energie GmbH
United Kingdom	Rebecca Gunning	IT Power
USA	Glenn Hamer	SEIA

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

INDUSTRY INVOLVEMENT

Task 1 activities continue to rely on close co-operation with government agencies, PV industries, electricity utilities and other parties, both for collection and analysis of quality information and for dissemination of PVPS information to 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 be promoted.
PVPS / industry workshops are seen as important activities, and more timely production of key information could be helpful to industry.

KEY DELIVERABLES (2003 AND PLANNED)

The following were published and also made available on the public website during 2003:

Trends in photovoltaic applications in selected IEA countries between 1992 and 2002 Report IEA-PVPS T1-12: 2003;
Newsletter – PVPower issues 18 and 19.

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 2004 it is planned to produce the ninth issue of the International Survey Report, PVPower issues 20 and 21, a broad range of country information, case studies and key topics on the website, to hold a PV Utility Forum workshop, and to organize a PVPS / industry workshop in conjunction with the European PV conference in Paris in June 2004.

MEETING SCHEDULE (2003 AND PLANNED 2004)

The 22nd Task 1 Participants' meeting was held in Basingstoke, UK, 5-7 March 2003.
The 23rd Task 1 Participants' meeting was held in Uppsala, Sweden, 10-12 September 2003.
The 24th Task 1 Participants' meeting will be held in Daejeon City, Korea, 3-5 March 2004.
The 25th Task 1 Participants' meeting will be held in Australia, 8-10 September 2004.

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

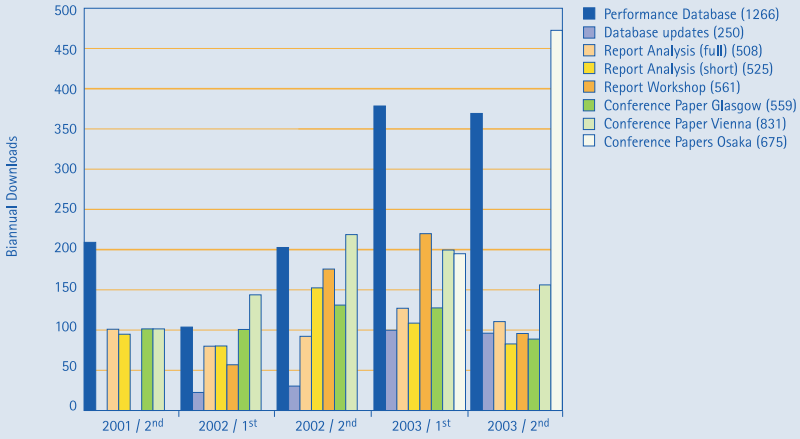

Fig. 1 - Statistics on information retrieval of different Task 2 products (database, reports, conference proceedings) from public website "http://www.task2.org".

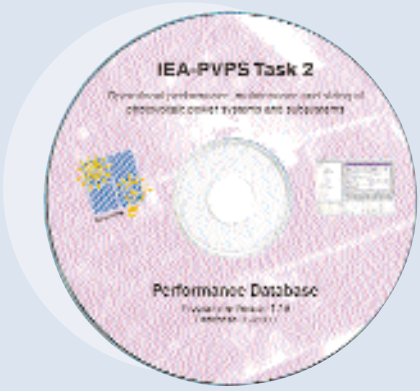

Fig. 2 - IEA-PVPS Task 2 Performance Database programme: The third update available on CD-ROM and for Internet download was released in May 2003.

OVERALL OBJECTIVE

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

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

SUBTASK 1: International Database

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

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

SUBTASK 2: Analysis of Photovoltaic Systems

Participants analyse performance and maintenance data for photovoltaic power systems and components in their respective countries, both in order to ensure the quality and comparability of data entered in the database and to develop analytical reports on key issues such as operational performance, reliability, expected output and sizing of PV systems. Activities to date include 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 are developing recommendations on sizing of PV power systems and suggest improvements for better PV system performance. Participants identify tools to process and analyse data for

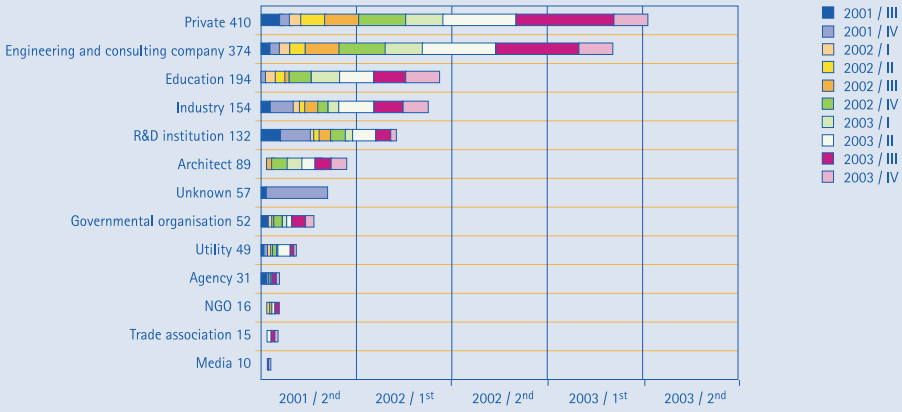

Fig. 3 – IEA-PVPS Task 2 Performance Database registrations for downloads from the Task website between July 2001 and December 2003 by different users in quarterly periods.

performance prediction and sizing purposes. Applied energy management schemes are analysed from the energy and operating cost points of view. Participants take into account the work performed in other Subtasks and in collaboration with Task 3 and Task 7.

SUMMARY OF TASK 2 ACCOMPLISHMENTS FOR 2003

During 2003, Task 2 focused on the dissemination of the updated Performance Database and other Task 2 products. The public Task website enables downloads and technical information to be provided quickly and cost-effectively to the users. The volume of visitors to the Task website, their countries and sectors as well as the number of PVPS Task 2 products retrieved are being tracked to measure the extent to which the website is visited and the products are used (see Figures 1 & 3).

SUBTASK 1: International Database

The **PV Performance Database** was updated and the programme was released in May 2003 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 372 PV systems of different system technologies, located in 15 countries. The update of May 2003 provides 13 200 monthly datasets from grid-connected and stand-alone PV systems of a total power of 11,8 MWp.
The Performance Database programme (47 MB) is available on CD-ROM (see Figure 2) and can be downloaded from the Task website http://www.task2.org. An instruction manual & installation guide in English and Japanese language, a database flyer in English and Italian language as well as electronic user support are additionally provided to the database users (see Figure 3).

Task 2 focuses on the dissemination and promotion of the Task 2 database making announcements on public PVPS and Task websites, placing articles in national and international PV magazines and newsletters as well as presenting the database programme at PV conferences, seminars and in PV training courses. As a result, 1 850 database users from 62 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 2003, the highest demand for the Performance Database came from the private sector and the engineering sector, followed by the education and industry sector (see Figure 3).

SUBTASK 2: Analysis of Photovoltaic Systems

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

- **Availability of Irradiation Data (France):** A final draft report was produced that provides information on irradiation data to be used to assess the performance of PV systems.
- **Tools for Checking the Performance of PV systems (France):** The results obtained in 2002 on some stand-alone systems have been extended to most of the SAS existing in the Database. This represents a good step forward for the recognition of these parameters in the evaluation of SAS PV systems performance. Results were published in a conference paper.
- **Shadings Effects on PV System Performance (Japan)**
- **Temperature Effects on PV System Performance (Switzerland):** Based on collected hourly data, temperature gains and losses were calculated for selected examples. First results were published in a conference paper.
- **Long-term Performance and Reliability Analysis of PV Systems (Germany):** Case studies on long-term performance trends, on reduced yield analysis and on components failures were elaborated. A final draft report was prepared.
- **Country Report on PV System Performance (Switzerland):** A draft report was prepared.

SUBTASK 4: Improving PV System Performance

Different documents on simulation tools have been collected and evaluated. The overview on simulation tools will be continued and improved. Regarding Energy Management Strategies (EMS), a draft version of a review on "Energy Management Strategies for Hybrid Energy Systems" was prepared in collaboration with Task 3. This document needs to be revised and updated with respect to some comments from experts and new achievements obtained so far.

SUMMARY OF TASK 2 ACTIVITIES PLANNED FOR 2004

Task 2 activities for 2004 will focus on the effective dissemination of technical PVPS information, which has been elaborated in all Subtasks. The Internet option will be the preferred way of distribution. For the national distribution of the Performance Database, Task 2 will use and activate distribution channels and contacts in its member countries. Task 2 intends to present its activities and achievements at 19th European Photovoltaic Solar Energy Conference and Exhibition in Paris, France, in June 2004. Contributions on Task 2 achievements, performance analysis and reliability of PV systems and on global aspects of PV solar electricity will be prepared and delivered in oral and visual presentations.

SUBTASK 1: International Database

The target date for publication of the fourth version of the PV Performance Database is May 2004. New monitoring data including 2003 data and new data sets of PV systems in additional countries of interest will be submitted and entered before the Task 2 March meeting. The checked and updated Performance Database will be available for Internet downloads and on CD-ROM at the 19th European Photovoltaic Solar Energy Conference and Exhibition in Paris, in June 2004. All 1 850 registered users will be informed about the release of this database update that can be incorporated into the existing programme.

SUBTASK 2: Analysis of Photovoltaic Systems

The activities of PV system performance analysis will be continued:

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

SUBTASK 4: Improving PV System Performance

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

INDUSTRY INVOLVEMENT

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

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 (2003 AND PLANNED 2004)

- Task 2 Performance Database programme update with collected data from 372 PV systems, released in May 2003.
- PVPS Task 2 brochure on Task 2 activities and results available in English, Italian and Japanese language, was published in March 2003.

The following publications have been prepared and presented at the Third World Conference on Photovoltaic Energy Conversion (WCPEC) in Osaka, Japan, in May 2003:

- Oral presentation: U. Jahn, W. Nasse "PERFORMANCE ANALYSIS AND RELIABILITY OF GRID-CONNECTED PV SYSTEMS IN IEA COUNTRIES."
- Oral presentation: D. Mayer, M. Heidenreich "PERFORMANCE ANALYSIS OF STAND ALONE PV SYSTEMS FROM A RATIONAL USE OF ENERGY POINT OF VIEW."
- Oral presentation: T. Nordmann "SUBSIDIES VERSUS RATE BASED INCENTIVES; FOR: TECHNOLOGY-; ECONOMICAL- AND MARKET DEVELOPMENT OF PV "THE EUROPEAN EXPERIENCE," which received the "Paper Award" of WCPEC session 8.
- Visual presentation: T. Nordmann, L. Clavadetscher "UNDERSTANDING TEMPERATURE EFFECTS ON PV SYSTEM PERFORMANCE."

During 2004 it is planned to produce and disseminate a fourth version of the Task 2 Performance Database to be released in May 2004, which will be available at the 19th European Photovoltaic Solar Energy Conference and Exhibition in Paris in June 2004. It is also planned to prepare and publish conference proceedings on Task 2 results, performance analysis & reliability, and on global aspects of PV electricity. The Task 2 conference contributions will be delivered in oral and visual presentations.

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.task2.org.

Fig. 4a - German Federal Council in Berlin: 21 kWp PV system as solar shading and light-directing system above the assembly hall. (photo Courtesy of Wolfgang Nasse)

Fig. 4b - German Foreign Office in Berlin: 23 kWp PV system as add-on construction. (photo Courtesy of Thomas Nordmann)

TABLE 1 - LIST OF PARTICIPATING COUNTRIES, TASK PARTICIPANTS IN 2003 AND THEIR ORGANISATIONS

COUNTRY	PARTICIPANT	ORGANISATION
Austria	Mr. Michael Heidenreich	Arsenal Research
France	Mr. Didier Mayer	Centre d' Energétique, Ecole Des Mines de Paris
Germany	Mr. Reinhard Dahl (OA)	Projekttraeger Juelich (PTJ) Forschungszentrum Juelich GmbH
	Ms. Ulrike Jahn (OA Alternate)	Institut für Solarenergieforschung GmbH Hameln / Emmerthal (ISFH)
	Mr. Wolfgang Nasse	Solar Engineering Decker & Mack GmbH
Italy	Mr. Salvatore Castello	ENEA C.R. Casaccia
Japan	Mr. Koichi Sakuta	National Institute of Advanced Industrial Science and Technology (AIST)
(until August 2003)	Mr. Kazuo Hasegawa	Japan Electrical Safety & Environment Technology Laboratories (JET)
(from September 2003)	Mr. Tetsuo Yamaguchi	Japan Electrical Safety & Environment Technology Laboratories (JET)
Switzerland	Mr. Luzi Clavadetscher	TNC Consulting AG
	Mr. Thomas Nordmann	TNC Consulting AG

MEETING SCHEDULE (2003 AND PLANNED 2004)

The 8th Task 2 Participants' Meeting was held in Sophia-Antipolis, France, 19-21 March 2003.
The 9th Task 2 Participants' Meeting was held in Berlin, Germany, 17-19 September 2003.
The 10th Task 2 Participants' Meeting will be held in Erlenbach, Switzerland, 22-24 March 2004.

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

Fig. 1 - SAPV system for water treatment (Brazil).

OVERALL OBJECTIVE

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

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

SUBTASK 1: Quality Assurance: Quality assurance schemes for improved reliability and lower global life cycle costs.

SUBTASK 2: Technical Issues: Technical recommendations for the cost reduction of systems

The main targets are technical groups such as:

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

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

SUBTASK 1: Quality Assurance

Activity 11: Critical Review of Implementation of Quality Assurance Schemes

Objective

All phases in the life cycle of stand-alone PV systems must be considered as potential sources of failure to ensure the good management of the quality of installed systems. To provide both end-users and programme managers with guidance for the quality assurance of systems, projects and programmes, participants share their experience on methodological and practical aspects concerning quality assurance.

For this topic, participants aim to develop quality assurance schemes that will lead to a warranty of service for the end user at reasonable costs (that means as low as possible).

Major Activities in 2003

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

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

Objective

Implementation of Quality Assurance procedures is often difficult in the field, particularly when the procedures are too complicated or otherwise inappropriate. This is especially the case when considering the installation, operation and maintenance phases.

In addition, the performance assessment of installed stand-alone PV systems depends on both technical and non technical criteria, such as economic and social criteria.

Even when methodological and conceptual aspects of the performance assessment have been implemented, realistic methods and concrete supports must be recommended for use in the field and laboratory. Under these considerations, the objective is to provide new project managers with realistic and efficient recommendations based on Task 3 participants experience concerning the management of the quality of SAPV systems.

Major Technical Activities in 2003

The document **IEA- PVPS T3-15:2003 "Managing the Quality of Stand-Alone Photovoltaic Systems - Recommended Practices,"** has been published. The document aims to provide simple but effective guidance in order to implement quality procedures within a realistic project timeframe. Implementing these procedures will be less

Fig. 2 - SAPV system for Telecom station (Mauritania).

expensive than solving the problems that result when the quality issues are not properly addressed.

The main objective is to make potential actors aware that there is more attention to give to the management of the quality of a system than simply to manage a good design; a lot of effort must be implemented in each step of a project. Real practices are introduced in this report, as well as both success and failure stories collected through feed back from case studies.

SUBTASK 2: Technical Issues

Activity 21: Hybrid Systems

Objective

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

Major Activities in 2003

One of the activity of experts was to prepare proposals for performance indicators of SAPV systems and monitoring guidelines, setting out how to equitably monitor system performance for a range of SAPV system.

The current activity is to produce **"Guidelines for Performance Assessment of Stand-Alone Photovoltaic Systems."** The objectives of the cooperative work are:

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

Another technical report entitled **IEA PVPS T3-13:2003 "Monitoring Stand-Alone Photovoltaic Systems: Methodology and Equipment - Recommended Practices,"** has been published.
The guidelines provide a reference manual in which the information is organised so that a user is able to focus on a specific performance aspect, avoiding irrelevant data collection.
To achieve this, the performance parameters have been organised into customised data sets designed to cover the spectrum of likely monitoring needs. There is a set of general parameters that provide the site information that is universal for all case studies. Thereafter, purpose specific sets include: quality assurance parameters, commercial evaluation parameters, scientific evaluation of system performance, battery performance parameters, appliance performance parameters, user-satisfaction and adaptation to technology. A person proposing to monitor the performance of a system need only peruse the index to identify the set that best suits their purpose, then turn to the relevant section of the guidelines to view the parameters recommended for measurement.

As a third activity, the technical report **IEA-PVPS T3-14:2003 "Protection Against the Effects of Lightning on Stand-Alone Photovoltaic Systems – Common Practices,"** has been published.
This report first gathers general information about photovoltaic installations lightning protection measures and then describes lightning experts' recommendations for different specific installations. Six examples of common installations with photovoltaic systems are considered separately.

Activity 22: Storage

Objective

This subtask aims to be a technical contribution to cost reduction of the storage function in PV and PV Hybrid systems by decreasing investment costs and increasing performance (capacity, lifetime, etc.) through design, selection procedures of storage systems, and energy management recommendations.
One of the main objectives of this activity is to show that there should be a correlation between the type of batteries and the type of application and to recommend, in a situation of call for tender, how to specify the best battery for a given application.

Major Activities in 2003

A technical work programme was undertaken concerning possible alternatives to lead-acid batteries for short, middle and long term storage (main performance, field of applications, estimated costs). Opportunities of storage systems relevant for Stand-Alone Photovoltaic systems are under study. The technical report, "Alternative Technologies to Lead-Acid batteries in Stand-Alone Photovoltaic Systems," is under progress. The general objective of this document is to make the state of the art about the various possibilities of energy storage that could be used in stand-alone photovoltaic (SAPV) systems.

Fig. 3 - SAPV-Wind hybrid system (Korea).

The document describes the main features of different storage technologies and emphasizes the main advantages and drawbacks of each. The baseline of the study is the lead-acid battery, which is widely used in many applications. Other potential technologies are then studied to assess their characteristics and performances and evaluate their possible use in SAPV systems instead of classical lead-acid batteries.
This technical report is composed of three parts: the first one is a short analysis of lead-acid battery performances and limits, the second one presents the characteristics of the other technologies of energy storage and the last one deals with their specific use in SAPV systems.

As a contribution to assist people (project managers, end-users, etc.) in selecting lead-acid batteries to be used in SAPV systems (in order to decrease investment, operation, and maintenance costs), a study was launched to produce guidelines for **"Selecting Batteries to be Used in Stand-Alone Photovoltaic Systems."** In a photovoltaic system, the energy storage part has a deep impact on the whole system performance. The document is divided in three parts that correspond to three main goals:

- To recall the classifications of lead-acid batteries (according to the type and application) and stand-alone PV systems;
- To present some case studies showing situations where a bad choice of a battery type has lead to the failure of the PV system;
- To give recommendations to choose the battery according to key parameters.

As an annex some results are addressed such as an assessment of management strategies to preserve the state of the battery, a presentation of some methodologies for field testing, the description of characteristics of testing procedures that permit to evaluate battery performances and finally, a cost analysis for the whole life cycle of the battery.

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

Objective

This subtask aims to be a technical contribution to cost reduction by showing the cost efficiency of a "good" load management strategy and well adapted appliances designed for low energy power systems.

Major Activities in 2003

The activity launched in 2002 relative to the Demand Side Management (DSM), has been achieved. DSM for Renewable Energy Systems involves the change of consumers energy use habits not only by using high efficiency appliances, decreasing the peak of the load curve, but also by using energy in a way that the load is well matched with the renewable source.
The technical report **IEA-PVPS T3-16:2003 "Demand Side Management for Stand-Alone Photovoltaic Systems,"** has been published.

When planning and designing stand-alone PV and PV hybrid systems, substantial effort and expense go into the design of electricity generation and storage sub-components. Very often, demand side characteristics are overlooked or considered to be of minor importance. Nevertheless, reasons for system failure can often be found on the neglected demand side.
The document aims at increasing awareness for project planners, system designers and energy service companies of the importance and efficiency of demand side management in stand-alone PV power systems.

OTHER ACTIVITIES

Other activities were dedicated to dissemination activities:

- Task 3 Workshop for Dissemination of results of the Present Programme, March 2003, Switzerland;
- Participation to the ISES Solar World Congress, June 2003, Sweden;
- Contribution to a Workshop on Hybrid Systems, September 2003, Germany;
- Dissemination of activities and results of the present programme, December 2003, Japan.

A new work programme dealing with the use of photovoltaic systems in stand-alone and island applications is under preparation.

MEETING SCHEDULE

Meetings held in 2003

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

Meetings Planned in 2004

- 24th Task 3 Experts Meeting, March 2004, Italy.

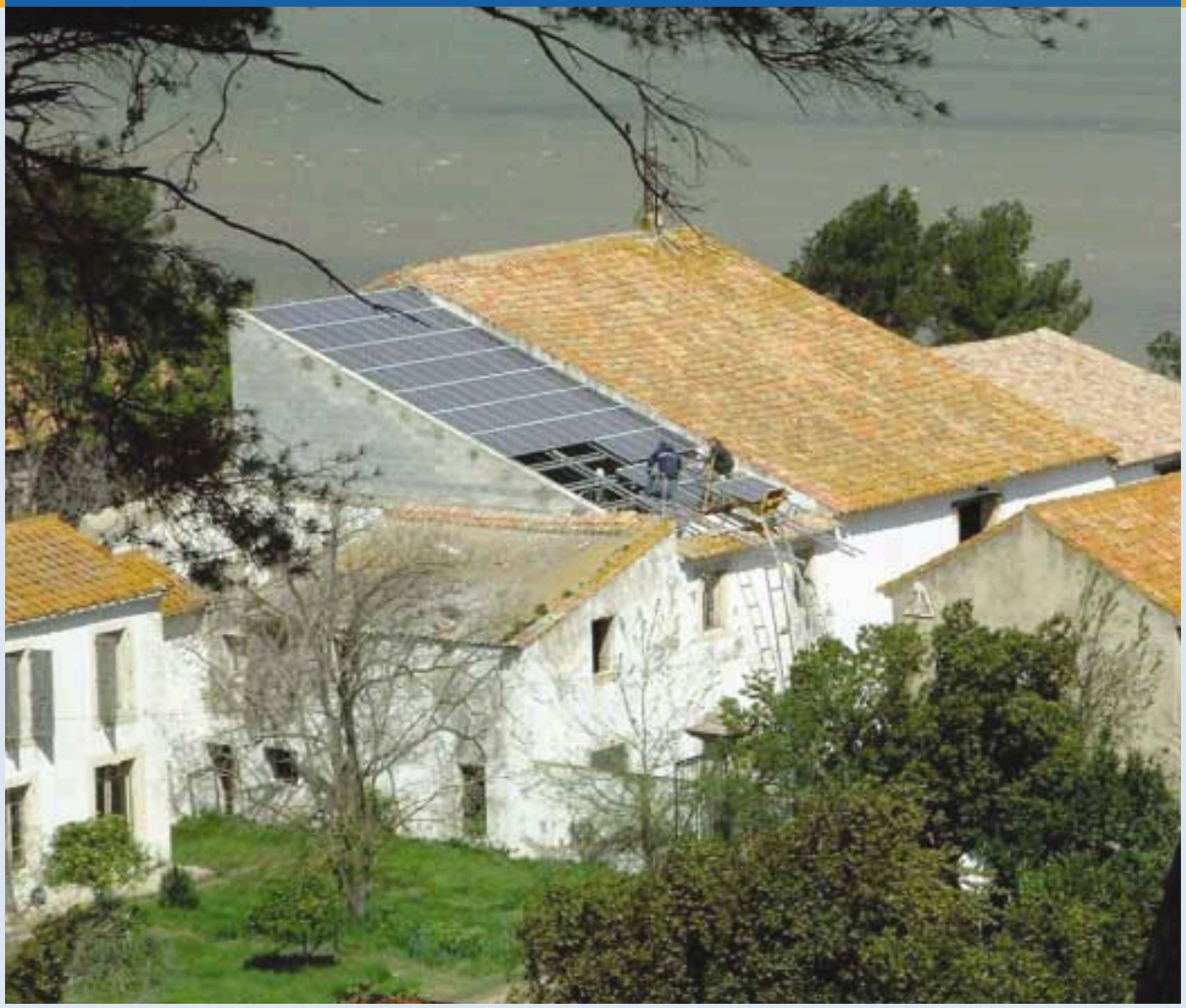

Fig. 4 - SAPV system for Household (France).

PUBLICATIONS

Reports 2003

- Report IEA PVPS T3-13: 2003: Monitoring Stand-Alone Photovoltaic Systems: Methodology and Equipment - Guidelines.
- Report IEA PVPS T3-14: 2003: Protection Against the Effects of Lightning on Stand-Alone Photovoltaic systems – Common Practices.
- Report IEA PVPS T3-15: 2003: Management of the Quality of Stand-Alone Photovoltaic Systems – Recommended Practices.
- Report IEA PVPS T3-16: 2003: Demand Side Management in Stand-Alone Photovoltaic Systems.

Reports to be published in 2004

- Report IEA PVPS T3-18: 2004: Selection of Batteries to be Used in Stand-Alone Photovoltaic Systems – Guidelines.
- Report IEA PVPS T3-19: 2004: Alternative Technologies to Lead-Acid Batteries in Stand-Alone Photovoltaic Systems.

PARTICIPATING COUNTRIES AND PARTICIPANTS

COUNTRY	NAME	ORGANISATION
Australia	Keith Presnell	Centre for Energy Research NT
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Sweden	Peter Krohn	Vattenfall Utveckling AB
Switzerland	Michel Villoz	Dynatex SA
United Kingdom	Alison Wilshaw	IT Power Ltd

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

OVERALL OBJECTIVE

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

MEANS

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

SUBTASK 10: Review of Previously Installed PV Experiences (From 1993 to 1998).

To review existing technical guidelines, local regulations and operational results of grid interconnection with building- integrated and other dispersed PV systems to aid Subtask 20 in defining existing guidelines and producing concepts for new requirements and devices.

SUBTASK 20: Definition of Guidelines to be Demonstrated (From 1993 to 1998).

Utilizing the results of Subtask 10 and a questionnaire, existing technical guidelines and requirements to be demonstrated will be defined, and concepts for new requirements and devices will be developed; with safety, reliability, and cost reduction taken into consideration.

SUBTASK 30: Demonstration Test Using Rokko Island and/or Other Test Facilities (From 1993 to 1998).

To evaluate, by demonstration tests, the performance of existing and new technical requirements and devices defined in Subtask 20.

SUBTASK 40: Summarizing Results (From 1993 to 2001).

To summarize the results of Task 5 and to produce a general report for all participating countries of Task 5, as well as for the ExCo members.

SUBTASK 50: Study on Highly Concentrated Penetration of Grid Interconnected PV Systems (From 1999 to 2001).

To assess the net impact of highly concentrated PV systems on electricity distribution systems and to establish recommendations for both distribution and PV inverter systems in order to enable widespread deployment of solar energy.

OVERVIEW OF PAST ACTIVITIES

SUBTASK 10

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

SUBTASK 20

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

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

SUBTASK 30

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

SUBTASK 40

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

SUBTASK 50

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

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

Important factors to decide on the limit of PV system penetration in distribution networks were listed and analysis based on distribution

line voltage limit was conducted. Measures to stretch the limit of PV penetration and some financial aspects of PV penetration were also discussed. The power value and capacity value of PV system penetration were evaluated using different customer load profiles.

SUMMARY OF TASK 5 - SUBTASK 50 CONCLUSIONS

Task 5 was officially concluded in 2003.
The main outcomes of Subtask 50 activities are described below:

Activity 51

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

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

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

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

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

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

Activity 52

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

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

2. Risks Associated with Islanding

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

3. Islanding Detection Methods

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

Activity 53, 54

1. Maximum Penetration Capacity of PV Systems in Distribution Networks

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

2. The Value of PV Systems

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

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

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

INDUSTRY INVOLVEMENT

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

REPORTS PRODUCED IN 2003

The following report was published in 2003.
This report can be downloaded from the PVPS website http://www.iea-pvps.org:

Report IEA PVPS T5-05: 2002 ; "Grid Connected Photovoltaic Power Systems: Survey of Inverter and Related Protection Equipments."

CD-ROM including all the reports was published for the distribution.

CONTACT INFORMATION

For information, contact the former Task 5 Chairman or visit the PVPS website:

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CRIEPI
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JPN - 2018511, Tokyo
Email: ishikawa@criepi.denken.or.jp

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

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

1. OVERALL OBJECTIVES

The objective of Task 7 was to enhance the architectural quality, the technical quality and the economic viability of PV systems in the built environment. The objective 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 2004.

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

1.1 Objective

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

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

1.2 Activities

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

1.3 Conclusive results

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

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

2.1 Objectives

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

2.2 Activities

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

2.3 Conclusive Results

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

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

3.1 Objectives

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

3.2 Activities

3.1 Barrier assessment
3.2 Potential
3.3 Economics
3.4 Strategies

3.3 Conclusive Results

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

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

4.1 Objectives

The results of the other Subtasks were brought to the market by dissemination of collected information and the demonstration of new concepts. Demonstration of mounting and system concepts takes place through the EPFL Demosite. Results are disseminated by the use of different media (ranging from papers, books, and brochures to new media such as a CD-ROM or a WWW-site).

Dissemination will also occur through the second and third International Solar Electric Buildings Conferences and national workshops in conjunction with the semi-annual meetings of the Task. Furthermore, the possibility of a training and education program was assessed and resulted in a CD-ROM.

4.2 Activities

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

4.3 Conclusive Results

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

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
Mulgrave, Victoria 3170, Australia

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.

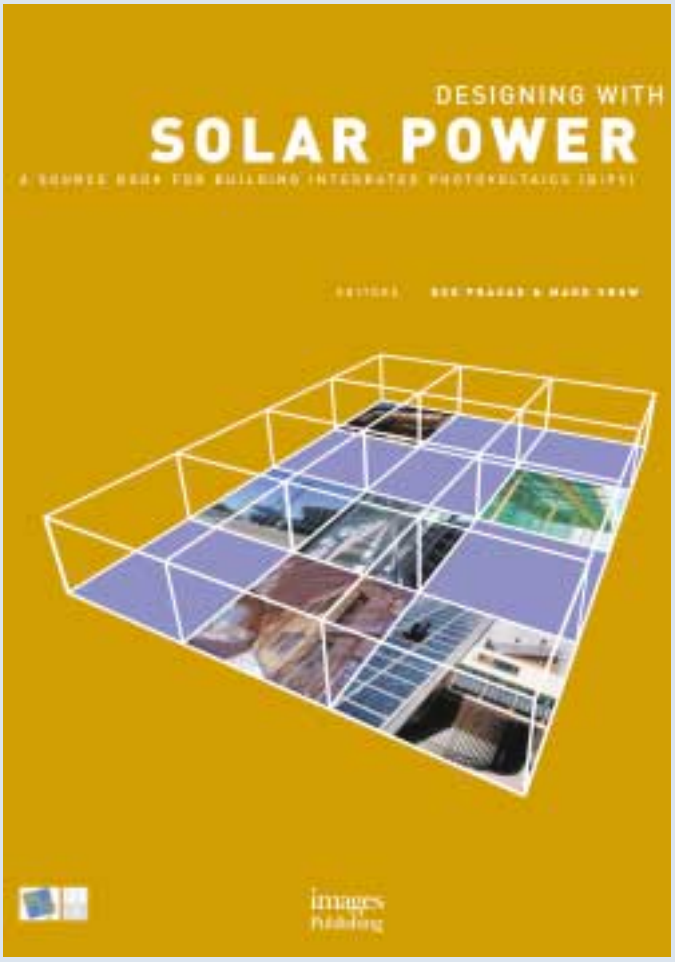

Fig. 1 – Cover of the book, "Designing With Solar Power." This book can be ordered at Images Publishing, as noted in the "DELIVERABLES" section of this report, below.

Fig. 2 – Order Form for "Designing With Solar Power." To order the book, visit the website: www.imagespublishinggroup.com

CONTACT INFORMATION

For information contact the former Task 7 OA or visit the websites:

Former Task 7 Operating Agent:
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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

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

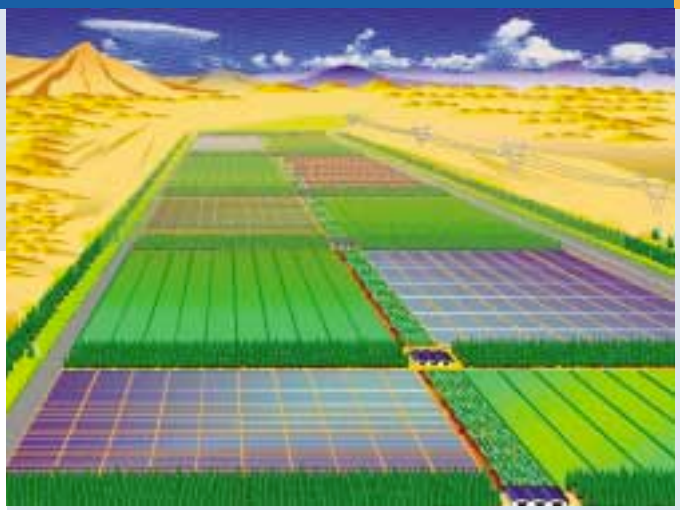

Fig. 1 - Image of a VLS-PV System in a Desert Area.

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), the key factors that enable VLS-PV system feasibility are identified and the benefits of this system's application for neighboring regions are clarified as well as the potential contribution of system application to global environment protection and renewable energy utilization in the long term is clarified. Mid- and long-term scenario options for making VLS-PV systems feasible in some given areas will be 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 system 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.

SUCCESSFUL COMPLETION OF TASK 8'S PHASE I (1999-2002)

The first phase of Task 8, which was launched in 1999, successfully completed its mission and published the report, "ENERGY FROM THE DESERT," which is a commercially available book (see Fig. 2). This approximately 200-page book covers not only remarkable results of our studies but also a wide range of photovoltaic technologie from solar cells from system application. It consists of three parts (Part I – III).

Part I, entitled, "Background and Concept of VLS-PV," describes world energy issues and global environmental issues surrounding renewable energy technologies, an overview of photovoltaic technology and a VLS-PV system concept is introduced. Part II, "VLS-PV Case Studies," gives several case studies for specific deserts in the world conducted during Phase I of Task 8. Fig. 3 shows the result of the preliminary cost analysis of VLS-PV systems. This figure suggests that VLS-PV in desert areas will be economical feasible in near future according to cost reduction in PV module. Part III, "Scenario Studies and Recommendations," represents the conclusion of the entire report. In this part, there is a scenario concept for sustainable growth of VLS-PV systems; financial and organizational sustainability are discussed and recommendations are presented to a variety of stakeholders.

To celebrate the book's publication, a fruitful international symposium was held on May 18, 2003 in Osaka, Japan, in conjunction with the Third World Conference on Photovoltaic Energy Conversion (WCPEC-3). About 250 participants from all over the world joined this symposium and exchanged their views on the future of VLS-PV systems (see Fig. 4).

LAUNCH OF TASK 8'S SECOND PHASE (2003-2005)

In succession of the promising results of its first phase activity, Task 8 has started the second phase of its activity for the period from 2003 to 2005.

MEANS

In Task 8's second phase, Subtask 2 continues and two new subtasks (Subtask 4 and 5) have been initiated:

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

Objective

Employing the concepts of VLS-PV, 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.

Activity Plan

The capacity of VLS-PV system and configuration of each component will be assessed, considering future phase-in of modular subunits. The assessment will take into account the site condition, regional electricity demand, system performance, transmission technology or other alternative options and concurrent use with other energy resources. The possibility of multipurpose use of electricity generated by the VLS-PV systems to improve the nature and socio-economic environment in the region may be investigated. Furthermore, the socio-economic and environmental impacts of the installation of VLS-PV systems will be evaluated from a life-cycle point of view.

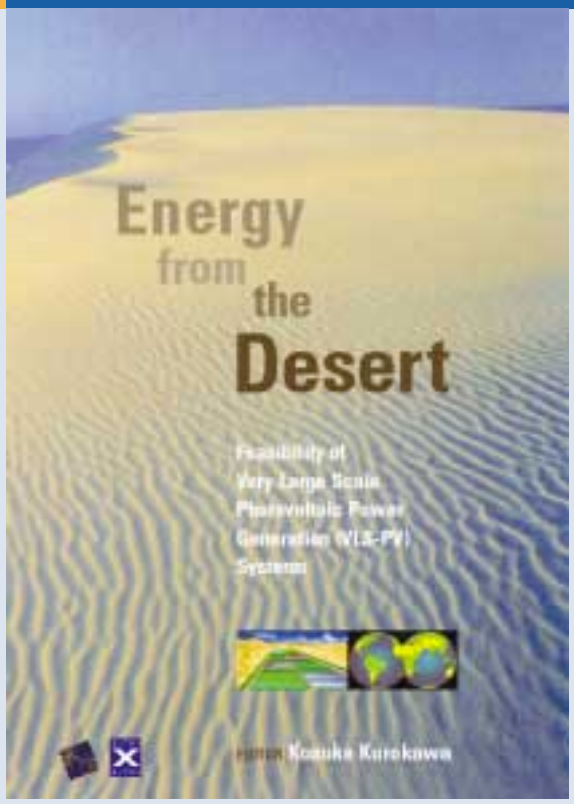

Fig. 2 - "ENERGY FROM THE DESERT": Cover Page.

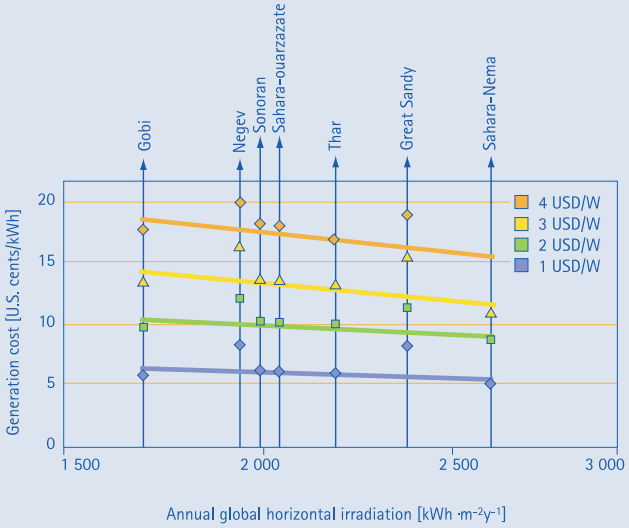

Fig. 3 – Best Estimates of Generation Cost of VLS-PV Systems for Six Major Deserts in the World.

SUBTASK 4: PRACTICAL PROJECT PROPOSALS FOR THE INITIAL STAGE OF VLS-PV SYSTEMS FOR SOME DESERT

Objectives

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

Activity Plan

Taking into account the mid- and long-term scenario studies proposed in the first phase and the guidelines of Subtask 5 described below, practical project proposals for the initial stage of VLS-PV systems, which will enable sustainable growth of VLS-PV systems in the future, will be developed for some desert areas. The project proposals may include system configuration, standardization, data monitoring, budget making, training of engineers, and possible financial scenarios for sustainable growth of VLS-PV systems. Furthermore, local, regional and global environmental and socio-economic effects given by the proposed project will be also examined.

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

Objectives

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

Activity Plan

Considering practical experiences and governmental, financial and economic requirements for large energy and development projects, guidelines for the development of practical project proposals will be developed for use in Subtask 4. By extracting essential knowledge from Subtask 4, these guidelines will be modified into detailed practical instructions and a training kit for the development of other practical project proposals, to enable others to sustainable implementation of VLS-PV systems in the future. These instructions will comprise non-technical issues such as long-term financing as well as technical issues.

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

PARTICIPANTS

As shown on the Table, currently there are eight countries participating in Task 8, with representatives from research institutes, universities, utilities, PV consultancies and industries.

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)

Meetings Planned

11th June, 2004, Paris (France)

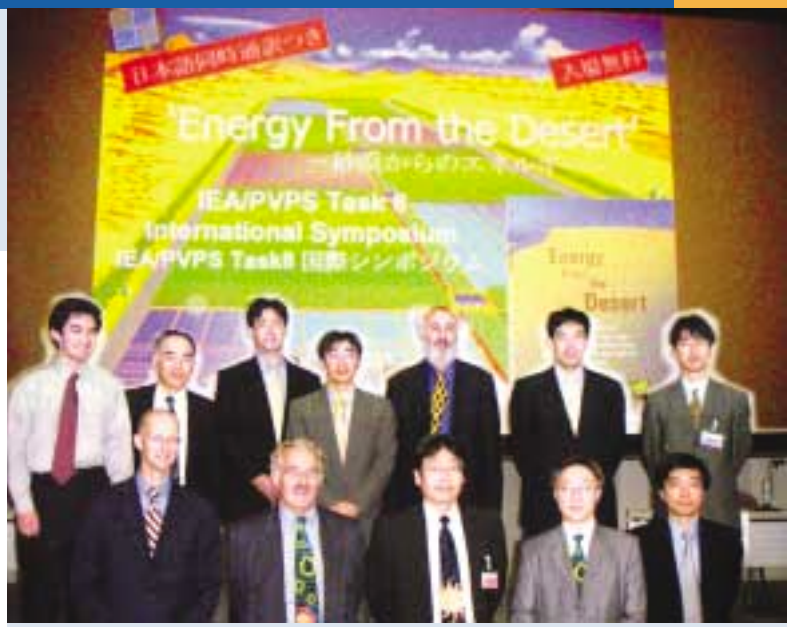

Fig. 4 - Task 8 International Symposium held at Osaka in May 2003 in conjunction with WCPEC-3.

LIST OF TASK 8 PARTICIPANTS

COUNTRY	PARTICIPANT	ORGANIZATION
Canada	Mr. John McDonald	Day4 Energy Inc.
Israel	Mr. David Faiman	The Ben-Gurion National Solar Energy Centre
Italy	Mr. Fabrizio Paletta	ENEL-SRI PAL
Japan	Mr. Kosuke Kurokawa Mr. Masakazu Ito Kazuhiko Kato (OA) Mr. Kenji Otani Mr. Keiichi Komoto Mr. Isaburo Urabe (secretary)	Tokyo University of Agriculture and Technology (TUAT) The National Institute of Advanced Industrial Science and Technology (AIST) Fuji Research Institute Corporation (FRIC) 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	Mr. David Collier	SMUD
Mongolia (observer)	Mr. Mamjil Enebish	Ministry of Infrastructure

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

Fig. 1 - Participants at the Task 9 Workshop, "The Role of Renewable Energy in the Mekong Regional Development Process," in Vietnam, November 2003.

OBJECTIVE

The conventional electricity grid will not reach the estimated 1,64 billion people in developing countries without access to electricity in the foreseeable future. Renewable energy, and in particular PV, can contribute directly to the alleviation of poverty through the provision of electricity for basic services. PV systems can provide power for a wide range of applications including: systems for use in social services, such as health clinics (refrigeration for vaccines, sterilisation and lighting), schools and community centres; domestic solar home systems that provide electricity for lighting and low power appliances such as a radio; community battery-charging systems; and systems for water-pumping for drinking, livestock and in some cases irrigation requirements. In many areas the technology is cost-competitive with traditional alternatives, such as kerosene lamps and small diesel generators.

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

APPROACH

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

SUBTASK 10: Deployment Infrastructure: contributes to overcoming the critical barriers to widespread PV deployment and implementation through the development, dissemination and application of a series of guideline documents to promote the necessary infrastructure requirements in developing countries.

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

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

The Experts appointed to the Task cover a broad range of experience, including technical PV experts, development economists and sociologists, and other renewable energy technologists. Representatives from developing countries also participate.

SUBTASK 10: DEPLOYMENT INFRASTRUCTURE

Aim

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.

Fig. 2 - Following the Task 9 meeting and workshop in Mongolia, the experts also inspected the newly installed 200 kWp system at Noyon Soum. In its planned extension Task 9 will work on village power / mini-grid systems.

Activities

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

Activity 11: Information Compilation and Analysis

Sixteen case studies were compiled and published, including an introductory summary of all 16 case studies. The case studies describe experiences in PV deployment in relation to the Task 9 guideline documents on Institutional Framework and Financial Instruments, Capacity Building Requirements, Implementation Models and Quality Assurance (see Activity 12). All the case studies also provide information relating to the Task 9 guideline document on Programme Design, Planning and Implementation (see Activity 31). The case studies cover PV project and programme experience in Argentina, Brazil, Burkina Faso, Cap Verde, Chad, Chile, China, Gambia, Guinea Bissau, India, Indonesia, Jordan, Kenya, Kiribati, Mali, Mauritania, Morocco, Mozambique, Namibia, Niger, the Philippines, Senegal, South Africa, Syria, Tunisia, Zambia and Zimbabwe.

A new draft of an overview document on issues for photovoltaics in developing countries was produced. The title of this document has now been changed to Photovoltaics for Development: The Key to Success. The document presents a short, 25 page overview of PV deployment in developing countries and states the key points and messages of Task 9. This document is expected to be published in early 2004.

Activity 12: Recommended Practice Guides

All five documents planned under this Activity have been published and the activity has been completed. The titles and publication dates of the guideline documents are summarised below.

- Financing Mechanisms for SHS in Developing Countries: The Role of Financing in the Dissemination Process
  -Published October 2002
- Summary of Models for the Implementation of Solar Home Systems in Developing Countries
  -Published March 2003
- PV for Rural Electrification in Developing Countries - A Guide to Capacity Building Requirements
  -Published March 2003
- Institutional Framework and Financial Instruments for PV Deployment in Developing Countries
  -Published September 2003
- The Role of Quality Management, Hardware Certification and Accredited Training in PV Programmes in Developing Countries
  -Published September 2003

Activity 13: Dissemination and Promotion of Recommended Practice Guides

One document from Activity 11, all five from Activity 12 and one from Activity 31 have been published on the PVPS and Task 9 websites. These documents were also distributed on CD-Rom at Task 9 workshops in Mongolia (September 2003) and Vietnam (November 2003). Further workshops are being planned in France, Germany and Sweden, where these guideline documents will be disseminated to a wide audience.

All the published documents are available to be downloaded from the internet. Internet publication should facilitate easy and regular updating of documents.

Work Planned for 2004

Publication of the overview document, "PV for Development: The Key to Success," is planned for early 2004. Further dissemination of the documents will be through the internet and activities in Subtask 20. Any feedback received will be incorporated into revisions of the guideline documents. Dissemination is to be co-ordinated with PVPS Task 1.

SUBTASK 20: SUPPORT AND CO-OPERATION

Aim

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

Activities

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

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

Two workshops have been held in 2003. The first, "PV for Development: The Role of the IEA PVPS", was held in Ulaanbaatar, Mongolia in September 2003 in conjunction with the 2nd Mongolian International PV Conference. The second, "The Role of Renewable Energy in the Mekong Regional Development Process," was held in Hanoi, Vietnam in November 2003. This workshop was attended by the World Bank, the Asian Development Bank, the Vietnamese Ministry for Industry and the Asean Region Centre for Energy (ACE).

Task 9 held discussions with the World Energy Council (WEC) and the Global Village Energy Partnership (GVEP) on possible future joint workshops and information dissemination. The work of Task 9 was also presented at several conferences in developed and developing countries including the 3rd World PV Conference in Japan (May 2003), the GVEP - Latin American Conference in Bolivia (July 2003) and the Central Asian - European Solar Energy Conference in Uzbekistan (September 2003).

Sweden has joined Task 9 and Norway, through its international development agency, NORAD, has expressed an interest in joining Task 9 in the future. Following the Task 9 meeting and workshop in Ulaanbaatar, Mongolia has also expressed an interest in joining the Task.

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

Task 9 is planning a conference in China to act as a high profile event to disseminate the work of Task 9 and to promote the guideline documents to as wide an audience as possible. A concept paper for this workshop has been prepared.

Work Planned for 2004

A further three workshops are planned for 2004. These will be organised in France with the French International Development Agency (AfD) and Ademe, in Germany with GTZ and KfW, and in Sweden with the Swedish International Development Agency (SIDA). The guideline documents will be disseminated to a wide audience at these workshops.

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

Aim

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

Activities

31 Programme Design and Implementation
32 Proposal Preparation

Activity 31: Programme Design and Implementation

Activity 31 is considering issues relating to the preparation, design and implementation of PV deployment programmes. A guideline document has been prepared and published which provides guidance for programme planners on the four phases of PV programme planning: preparation, design, implementation and monitoring / evaluation. This includes needs assessment, stakeholder consultation, social context analysis, national policy consideration, establishment of goals, technical supply options available, logistics and quality assurance. The guide, titled, "PV for Rural Electrification in Developing Countries – Programme Design, Planning and Implementation," was published in September 2003.

Activity 32: Proposal Preparation

Activity 32 is compiling information for project developers on the potential sources of finance for PV deployment programmes and the processes involved in accessing this finance. The Activity is preparing a guideline document, titled "Sources of Financing for PV-Based Rural Electrification in Developing Countries," which identifies and summarises the procedures of potential financing sources from multilateral and bilateral donors, to utilities, foundations and others. The final draft of the document is under preparation and is due to be published in early 2004.

Work Planned for 2004

The document, "Sources of Financing for PV-Based Rural Electrification in Developing Countries," will be published in early 2004 and will be disseminated alongside all the other guideline documents on the PVPS and Task 9 websites and at the planned Task 9 workshops.

Task 9 Extension and New Workplan

Over the course of this first Phase of Task 9, a need for additional work on aspects of PV deployment in developing countries has been identified by Task 9 Experts and the target audience of Task 9. This has been partly due to the valuable feedback received from the support and co-operation actions undertaken up till now and from the process of guideline document preparation. At the ExCo Meeting of October 2002, a mandate was given to Task 9 to develop a Workplan for the extension of the Task. The draft Workplan for Phase 2 of Task 9 sets out a new programme organised into four main Subtasks, each of which will be led by a Task 9 member:

- Subtask 20: Support and Co-operation (continuation of the existing Subtask)
- Subtask 40: PV energy services for rural electrification and poverty alleviation
- Subtask 50: Market penetration activities
- Subtask 60: PV and the Kyoto Mechanisms

Task Meetings

1st Experts' Meeting, 14-16th October 1999, Utrecht, The Netherlands.
2nd Experts' Meeting, 8-9th February 2000, Washington DC, The USA.
3rd Experts' Meeting 2-3rd October 2000, Marrakech, Morocco.
4th Experts' Meeting, 26-27th March 2001, ASEAN Centre for Energy, Jakarta, Indonesia.
5th Experts' Meeting, 12-13th September 2001, Ottawa, Canada.
6th Experts' Meeting, 25-28th February 2002, Oaxaca, Mexico.
7th Experts' Meeting, 3-5th October 2002, St.Gallen, Switzerland.
8th Experts' Meeting, 25-26th April 2003, Lyon, France.
9th Experts' Meeting, 2-3rd September 2003, Ulaanbaatar, Mongolia.

Future Meetings

10th Experts' Meeting, 8-10th March 2004, Stockholm, Sweden.

TASK 9 PARTICIPANTS

COUNTRY	NAME	AFFILIATION
Australia	Gordon Thompson Geoff Stapleton	CASE GSES
Canada	Fayez Malek	CIDA
Denmark	Peter Ahm Jean Paul Laude	PA Energy A/S DANIDA
Finland	Heikki Neuvonen	NAPS Systems Oy
France	Bernard Chabot Anjali Shanker Lara Bertarelli	ADEME IED IED
Germany	Rolf Posorski	GTZ
Italy	Francesco Groppi	CESI
Japan	Tetsuzou Kobayashi Junichi Honda	Showa Shell Kyocera
Switzerland	Alex Arter	ENTEC
Sweden	Anders Arvidson	Stockholm Environment Institute
United Kingdom	Bernard McNelis Jonathan Bates Rebecca Gunning Katerina Syngellakis	IT Power
USA	Mark Fitzgerald Roger Taylor	ISP NREL

TASK 10 – URBAN SCALE PV APPLICATIONS

Fig. 1 - Task 10 Kick-Off Meeting, Vienna, Austria.

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. The final planning for Task 10 occurred during 2003, with final approval to start the task 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 relatively independently from all the other deliverables, the relationship between deliverables will be cross-referenced or databased 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 circumstances which combine all stakeholder values to the PV system investor through sustained policy-related market drivers. Activities wil include:

- developing 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;
- deriving recommendations to stakeholders for removing barriers to mass market uptake of PV;
- building upon existing lessons learned with financing, policy, environmental and rate structure issues by analysing the economic contribution of these market drivers and developing best practice scenarios;
- promoting trans-boundary transfer of lessons learned; and
- identifying participating country industry roadmaps and produce guide for roadmap development.

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 by:

- developing 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.
- 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.

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. Activities include:

- 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. 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;
- identifying existing codes and standards applicable to urban scale PV and the needs for developing new codes and standards. 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;
- analysing electricity network effects, benefits, impacts, and issues. Interconnection, operational effects, and market issues will be included;
- expanding the market-driven approach to research and development 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; and
- reviewing certification practices and defining harmonized standard test procedures transferred to the relevant stakeholders and standard committees.

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.

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 PV education tools. An innovative deliverable will involve holding a marketing 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.

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. In addition to coordination and inclusion of other multidisciplinary implementing agreements, the Task will include stakeholder expertise from participating countries to develop deliverables. Every Task meeting will include a stakeholder workshop.

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.**

KEY DELIVERABLES (PLANNED 2004)

- A workshop targeted at Architects and Students, Vienna, Austria, Feb 2004.
- Oral Paper presentation at the Paris PV Conference June 2004.
- Architects and Builders workshop for French stakeholders during the Paris Conference, June 10, 2004.
- Brochure/flyer for outreach to stakeholders.
- Task 10 website with front end for stakeholder outreach and Task 10 participants password accessible working platform.

TABLE 1 LIST OF PARTICIPANTS AND THEIR ORGANISATIONS

COUNTRY	PARTICIPANT	ORGANISATION
Australia	Mr. David Crossley	Energy Futures Australia Pty Ltd.
Austria	Mr. Reinhard Haas Mrs. Assun Lopez-Polo	Institute of Power Systems and Energy Economics Energy Economics Group Vienna University of Technology
Canada	Mr. Josef Ayoub	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.
Portugal	Mrs. Maria João Rodrigues	Center for Innovation Technology and Policy Research Instituto Superior Têcnico (Technical University of Lisbon)
Swedan	Mr. Mats Andersson	Energibanken AB
Switzerland	Mr. Peter Toggweiler	Enecolo AG
USA	Ms. Christy Herig	Segue Energy Consulting/Subcontractor to National Renewable Energy Laboratory

TABLE 2 – MEETING SCHEDULE (2003 AND 2004 PLANNED)

TASK 10 MEETING	DATE	PLACE
Planning Meeting	20-21 March 2003	Feusisberg SZ, Switzerland
Planning Meeting	18-19 September 2003	Copenhagen, Denmark
1st Technical Experts	12-13 February 2004	Vienna, Austria
2nd Technical Experts	Week 41 October 2004	Florence, Italy

AUSTRALIA

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS
DR HARRY SCHAAP, ENERGY SUPPLY ASSOCIATION OF AUSTRALIA

Fig. 1 - DSC façade on CSIRO Building, Newcastle. Photo: STI

GENERAL FRAMEWORK

The use of photovoltaic power systems (PV) in Australia continues to grow, with installed capacity increasing by a relatively constant 16,5 % (up from 15 % the previous year) to reach a total installed capacity of 39 130 kW by the start of 2003. Although not largely targeted by government programmes, off-grid non-domestic applications continue to dominate Australia's cumulative installed capacity (about 58 % by 2003, which is similar to the previous year and down from about 75 % in the mid 1990's), with an annual growth rate that increased significantly during 2002 to approach 19 % (up from 12 % in 2001 and 4 % in 2000). Off-grid domestic applications have enjoyed strong growth over the last decade and are now benefiting from the government support programmes aimed at increasing the use of BIPV and replacing diesel use with renewables. These applications accounted for 31 % of the cumulative installed capacity by 2003, slightly lower than the figure for the previous year.

Twice as much PV was connected to the grid in 2002 compared with 2001 and the grid-connected market segment is now approaching 11 % of the total installed capacity compared with less than 1 % six to seven years ago. The national BIPV support programme (which commenced in 2000 and which has recently been extended) and the renewable energy target for electricity retailers and major energy users (implemented in 2001 and recently reviewed), both discussed later in this report, are widely perceived as important factors in keeping this market segment growing strongly.

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 mainly with the retailing 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.
The public is generally supportive of PV and interested in its use – however, even with rebates, PV is still an expensive option for grid-connected households and community applications.

NATIONAL PROGRAMME

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

Mandatory Renewable Energy Target (MRET) – this target seeks to increase the contribution of renewable energy sources in Australia's electricity mix by 9 500 GWh per year by 2010. 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 September 2003.

Supporting the Use of Renewable Energy for Remote Power Generation (RRPGP) – this programme commenced in 2000 and is expected to make over 200 million Australian dollars available over the life of the programme for the conversion of remote area power supplies (including public generators and mini-grids) from diesel to renewable energy sources, and for new renewable installations that would otherwise have been fueled by diesel. The RRPGP may provide up to 50 % of the capital value of the replacement or new renewable generation for off-grid users of diesel-based power generation.
The programme is administered by state governments and a number of states also provide additional financial support for off-grid renewables.

Supporting the Use of Solar Photovoltaic Electricity on Residential and Community Buildings, the PV Rebate Programme (PVRP) – this programme commenced at the beginning of 2000 with 31 million Australian dollars available over four years. The programme has now been extended until 2005 with a further 5,8 million Australian dollars 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 PVRP extension, householders are eligible for a rebate of 4 AUD/W (previously 5 AUD/W), capped at 4 000 AUD per residential system (previously 7 500 AUD). Rebates are also paid for extensions to an existing system. Community buildings attract the same rebate except it is capped at 8 000 AUD (previously 10 000 AUD).
The Australian Government has also made available one million Australian dollars to fund projects by residential housing developers, through a competitive bidding process.

Renewable Energy Equity Fund (REEF) – venture capital can be made available by the fund manager to small innovative renewable energy companies that can demonstrate that they have an innovative development that is being commercialized. Although the Government

Fig. 2 - Pitjantjara power station.
Photo: Solar Systems

is not directly involved in making investment decisions, along with the fund manager and private investors they can share in any profits from REEF.

State government policies are emerging that may have a positive impact on PV market growth. In particular, 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 (such as electricity retailers) are called benchmark participants. Each year, the Scheme sets individual benchmark reductions of greenhouse gas emissions for each benchmark participant based on their contribution to the supply of electricity in New South Wales. Each benchmark participant then has to reduce the average 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). One NGAC represents one tonne of carbon dioxide equivalent that would otherwise have been released into the atmosphere in generating electricity. NGACs are transferable certificates that may be freely traded between any parties. NGACs may be created by any eligible electricity generators (such as grid-connected PV systems) which reduce the average greenhouse intensity of electricity generation.

R&D, D

Australian Government annual funding for PV R&D, D (and including the market incentives) was about 20,3 million Australian dollars during 2002 (compared to 16,7 and 24,6 million Australian dollars for the two previous years). Funding from the state governments for the same period was around 0,3 million Australian dollars, significantly less than for the previous year.

The University of New South Wales (UNSW) Centre for PV Engineering continues its world leading research into high efficiency wafer and thin film silicon cells. Other areas of research include buried contact cells, silicon light emission, silicon-based quantum wells and super-lattices, new energy up- and down-conversion concepts and energy collection using optical-frequency antennas.

BP Solar 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 continues its development of automated production equipment.

Pacific Solar is developing and commercializing a thin film PV technology called Crystalline Silicon on Glass (CSG) based on initial research at the UNSW. In addition to its R&D on CSG modules, Pacific Solar has developed and commercialized its own module inverters and roof mounting systems.

The Centre for Sustainable Energy Systems at the Australian National University (ANU), in conjunction with energy utility Origin Energy, has developed a new thin film PV technology to be known as "Sliver cells".

The ANU team is also developing parabolic trough and paraboloidal dish PV concentrator systems, and a Combined Heat and Power Solar System.

Murdoch University is developing methods of producing low cost silicon from a number of new sources for both wafer based and thin-film silicon solar cells. Sustainable Technologies International (STI) is demonstrating its world-first titania dye sensitized solar tiles and panels after many years of research.

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 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.

IMPLEMENTATION

Installed PV capacity in Australia rose by 5,5 MW in the year up to the beginning of 2003 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.

While more than 2,2 MW in over 1 500 household / community building systems have been connected to the grid as a result of almost four years of operation of the PVRP, the programme has also resulted in more than 3,1 MW and over 3 200 off-grid installations during the same period. It is worth noting that industry reported a severe cut in sales early in 2003 as a result of uncertainty surrounding the extension of the PVRP.

Fig. 3 - Solar Water Pump, WA.
Photo: Tony Martin, Solar Energy Systems

In contrast to implementation of grid-connected systems, the off-grid market is also helped by the RRPGP sub-programmes – which have mostly supported PV and have seen 1 MW installed by 2003, with only a small fraction of the allocated funds having been spent. RRPGP implementation is different in the various States and Territories and sub-programmes include: 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; Bushlight (Indigenous Renewable Energy Services Project) which aims to both increase industry capacity to service indigenous communities and to build greater understanding of renewable energy issues within communities; and RRPGP sub-programmes in NSW and South Australia.

Green Power sales from twelve Green Power retailers were recorded at about 123 GWh in the third quarter of 2003 (compared with 106 GWh in the third quarter of 2002) and with about 33 % more customers than 2002. However PV electricity accounts for less than 0,15 % of total green electricity purchased by the retailers. Energy retailer EnergyAustralia's PureEnergy product accounts for about 60 % of the Green Power PV electricity sourced nationally.

Similar to the situation for Green Power, the recent review of MRET found that the 'lowest cost' approach to renewable energy implementation under the scheme has done little to stimulate the PV market. In fact, less than one per cent of RECs so far created under MRET have been generated from PV systems, and only about 170 PV systems have been registered as 'eligible generators'.

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. It could be argued that the human resources that were available to promote technology innovation and manage demonstration are now non-existent or are too busy dealing with energy policy issues and regulations.

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 doubled in Australia in 2002 and production capacity trebled. Of the 20 MW of cells produced in Australia during 2002, approximately 13 MW were exported to the rest of world.

In addition, of the 7 MW of modules manufactured 1,5 MW were exported. Imported cells and modules are also used in the Australian market.

There was a focus in 2002 on large area modules and laminates (140 W). Approximately 80 % of local production was large area modules. This reflects the market demand for lower cost per watt compared to the traditional 75 and 80 watt panels. About 1 % of production is for special building modules such as custom glass-glass atrium panels and PV roof tiles. However, there is increasing interest in this area as the grid-connect market increases. Special modules are manufactured to specification for Telstra, Australia's telecommunications utility company.

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.

Meanwhile, Pacific Solar continues the development of its thin-film CSG product, but has been forced to sell its business handling the Plug&Power™ ac module system for grid-connected rooftop applications.

Solar Systems is continuing to expand the installation of its successful CS500 solar concentrator PV dishes in remote communities. These parabolic solar tracking dishes consist of 112 mirrors concentrating to the equivalent of 500 suns onto 24 kW water-cooled upgradeable receiving modules. All up cost, including all remote infrastructure costs, is less than 10 AUD per watt. A 220 kW plant is now operating in the Pitjantjatjara Aboriginal community and several other plants are planned for other remote communities currently reliant on diesel power, with production expected to reach 2,5 MW.

Origin Energy is constructing a Pilot Plant to commercially demonstrate the potential of the Slivers TM technology. The plant is being constructed in Adelaide, and is designed to be expandable to approximately 10 MW p.a. capacity.

Fig. 4 - Shellharbour Workers Club refit with PV.
Photo: SEDA

There are several Australian manufacturers of inverters and controllers. Their products cover both grid and off-grid markets and range in size from less than 1 kVA to over 100 kVA.

MARKET GROWTH

Growth in the local Australian market saw annual sales expanding by 27 % during 2002.

Australia's vast size and sparse population have made effective remote area telecommunications, power supplies, water pumping, navigation aids and transport route signaling critical and expensive. PV continues to provide an important commercial alternative to diesel and central grid supplies for such applications. 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.

With its relatively low electricity tariffs, PV remains an expensive option for grid applications in Australia and with government grants for grid-connected systems set to cease within a year or so, there is continuing concern that this market sector may well stall. The MRET review has 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. While stopping short of recommending many of the PV specific changes to MRET that were flagged by various parties, the review panel has proposed some fine-tuning that will remove some of the recognized institutional barriers. MRET is not seen as a vehicle for achieving cost reductions or improving international competitiveness.

FUTURE OUTLOOK

Work being done for the Australian PV Industry Roadmap suggests that PV in Australia is at a crossroads. The mid-term outlook for PV applications remains healthy, but the near-term may be more problematic especially for the relatively expensive grid-connected applications. Interest and initiatives are increasing at all levels in the community, but Green Power schemes and MRET are not delivering the anticipated levels of 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. The installation of PV systems is becoming more of a straightforward and accepted practice in Australia and work is ongoing to develop uniform installation and connection guidelines, straightforward contracts and financial arrangements that more positively encourage PV use. Lastly, and inexorably entwined with the previous factors, Australian industry must consider its future business development options in an uncertain policy environment.

AUSTRIA

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

HUBERT FECHNER AND MICHAEL HEIDENREICH, ARSENAL RESEARCH

Fig. 1 - 22 kW PV System, Institute for Marketing, Upper Austria, KW-Solartechnik.

GENERAL FRAMEWORK

According to the Kyoto-Protocol, Austria had committed to ambitious CO2 reductions of 13 %. Since then, CO2 emissions have increased; so that today a reduction of 19 % would be necessary to reach this goal. However, photovoltaics is not seen to be amongst the main technologies to reach this short term goal in 2010. In a longer view, PV can significantly contribute to Austria's Electricity supply; a long term strategy - the Austrian PV roadmap – is just under development, coordinated by the Austrian PV Association "Bundesverband Photovoltaik."

In July 2002, the new *Green Electricity Act* (GEA, BGBl. I – Nr. 149/2002) was passed by the National Council and Federal Council (announced in mid-August 2002). Most of its clauses came into effect on January 1, 2003. The Green Electricity Act governs the aid for green electricity and combined heat and power generation throughout the country. It can be seen as an update of the former Electricity Act (ELWOG, 2000). In general, it provides a change of the legislative responsibilities (federal instead of provincial), which occurred as necessary – at least due to the fact that previous forms of aid and charges in the individual provinces varied greatly.
It sets the target to meet 4 % generated from new renewable energy sources as well as 9 % of the public national electricity demand from small hydropower by 2008, respectively. Those "new" RES are supported mainly via feed-in tariffs as well as additional investment subsidies to achieve the above mentioned political target quotas. Due to time and capacity limitations, public PV support in Austria is mainly characterized by discontinuity. PV research funds are nowadays mainly dedicated to support projects within international collaboration programmes such as the IEA PVPS programme or European projects.

NATIONAL PROGRAMME

For new PV installations, the feed-in tariff stated in the *GEA* is 0,6 EUR per kWh up to a capacity of 20 kW and 0,47 EUR per kWh for larger systems. The extra costs for the network operators will be compensated by additional supplements on the customer invoices. However, the limitation of 15 MW total installed capacities is stated in the law, up to which the high tariffs will be paid. The installed capacity of more than 10 MW at the end of 2002, and the new applications for new PV installations in the first two weeks of 2003 have shown the inefficiency of the regulation concerning continuity and investments with low risks. Since then, PV installers and module producers are facing a situation of extreme uncertainty as well as the fact that PV is currently only a side issue in solar architecture. To improve the situation caused by the 15 MW cap, some provinces

Fig. 2 - 13 kW PV at Vocational School Imst. Tyrol, Siblik-Elektrik.

have now reintroduced a direct subsidy system, based on grants; most of them financing about 50 % of the total installation cost. Hence again, the uniform PV supporting system is replaced by "regional puzzled" schemes. Since the revision of the Green Electricity Act is foreseen in 2005, it can be expected that the PV market will remain quite weak during 2004.

RESEARCH, DEVELOPMENT

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

- Organic Solar Cells based on thin plastic films have received increased attention due to their unique properties. These cell types are probably promising to become the cheapest solar cell in the future. A maximum efficiency of about 2,5 % has been achieved through the bulk hetero-junction cells.
- Encapsulation of solar cells, the development of new contact pattern for crystalline cells and coloured cells are being investigated at research departments of industry and at academic institutes.
- New concepts for PV-inverters and various aspects of grid-interconnection, not exclusively related to PV but more generally to distributed generation from RES, are the main focus of several EU financed projects, which are jointly carried out by research institutions, industry and utilities.
- New solutions for building integration of PV are investigated to reduce the costs and address the building industry by aiming to create a better understanding about chances and challenges of high integrated concepts for roofs, facades and other building elements.
- At arsenal research, besides inverter testing, a new module testing facility has been established for qualification testing of PV-modules according to international standards (IEC 61215), as well as research co-operation with industry for developing new PV products.

IMPLEMENTATION AND MARKET DEVELOPMENT

With an enormous increase of more than 50 % in 2003, installed PV power capacity reached roughly 17 MW by the end of the year.

Between 1995 and 2002, the mean growth of the total capacity was more than 30 % per year. Until the end of 1996, the off-grid sector dominated the Austrian PV market. However since 1997, the majority of new systems were grid-connected according to the overall trend in the IEA PVPS reporting countries.

As in most of the other countries, *Off-grid installations* were the first economic alternative for PV systems. Small stand-alone systems provide electricity to technical systems or for domestic use in Alpine households or mountain huts lying far away from the grid. However, they are not only appearing exclusively in remote areas. In urban sites, PV is increasingly used as an option to supply infrastructure systems such as parking meters or rail-greasing systems.

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

PV is becoming more and more visible on Austrian highways, supplying the increasing numbers of screens which inform drivers with actual information about the current traffic situation.

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

INDUSTRY STATUS

PVT Austria, the first manufacturer of PV modules in Austria, producing standard and semi-transparent crystalline silicon panels (production started 2002), continued to produce successfully; even though in 2003, the housing market was limited because of the unsatisfactory support situation.

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

FRONIUS, a power electronics company has been engaged in solar electronics for many years and is now Europe's second largest producer of inverters for grid connected and stand alone PV systems. They started selling their new IG series inverters in Europe in 2002. Fronius is expanding their market to the U.S. in 2004. More than 90 % of their production is exported to other countries.

ISOVOLTA is manufacturing coloured back sheet laminates for PV modules for the majority of the module manufacturers, worldwide.

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

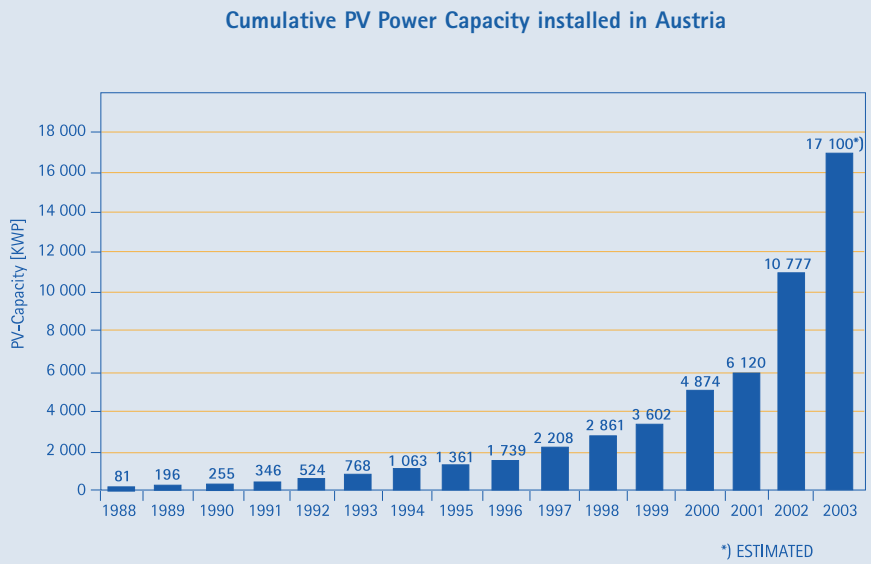

Fig. 3 - PV capacity installed in Austria between 1989 and 2002, source: Faninger, PV market in Austria.

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

MARKET DEVELOPMENT

The long time existing National Photovoltaic Association has restarted by continuing to work with the employed staff, in spring 2003. Since then, a lot of awareness raising activities were performed and a network for dissemination of information was created.

About 30 PV industries are members of the Association. The formulation of the national roadmap, a PV marketing Concept for Austria and the biannual "Youth Solar Award" are parts of its work.

A national PV-network, "PVPS.NET," was created. It was founded by the Ministry of Transport Innovation and Technology, and aims at supporting the implementation of PV in the building sector. PV installers and module producers, together with architects, are preparing tools for architects and the building industry; in order to integrate PV more and more as a part of buildings. It has been recognized that it is not only because of the costs, but also due to very practical reasons, that architects are often hindered in their attempts to integrate PV into their building concepts; as well as the lack of arguments to convince building owners to implement PV. By addressing these topics, various tools for argumentation and education in PV building integration were developed. These tools will be available at the Austrian PV Association's website, at the end of the project in late spring 2004. A national PV-Conference for the building industry, together with the PVPS programme based on the outcomes of Task 7, as well as the plans for the start up of Task 10, are further tasks to be carried out by this national PV-network.

FUTURE OUTLOOK

The favourable feed-in tariffs paid in some federal states and the *new Green Electricity Act* regulating the feed-in tariffs for electricity from renewable energy sources on a national level already led to an application boom for new PV installations. However, this development has stopped, due to the limit of 15 MW total installed capacity, up to which new PV installations are supported by the feed-in tariffs.

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 more that industry and research organizations contribute to innovative PV applications, the more that demands on training and educational services will arise. It is urgently necessary to develop up-to-date tutorials for growing interest groups in Austria.

Financial incentives and voluntary approaches remain the basis for a stronger PV market in Austria. Updated regulations for subsidizing PV installations and a certain time horizon for investors are essential for a sustainable development of the Austrian PV market.

CANADA

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

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

Fig. 1 - Solar PV installation (2,65 kW) at the Canadian Centre for Housing Technology, Ottawa, Ontario. (photo Sol Source Engineering)

GENERAL FRAMEWORK

On August 12th, 2003, the Government of Canada announced the details of 1 billion CAD of investment towards the implementation of the Climate Change Plan for Canada (CCPC)[1]. This investment is part of the federal Budget 2003 allocation and builds on 1,7 billion CAD the Government of Canada has invested in climate change over the past five years. The Canadian commitment target under the Kyoto Protocol to the United Nations Framework Convention on Climate Change is to reduce its greenhouse gas (GHG) emissions to 6 % below its 1990 level by 2008 and 2012.

The Government of Canada is supporting several new initiatives within the CCPC. One of these initiatives, the Technology and Innovation component, aims at reducing Canada's GHG emissions over the long term and positioning Canadian industry to maximize economic opportunities in new technology development in five key areas. PV and related activities have been incorporated into the implementation plans in two of these areas: decentralised energy production and advanced end-use efficiency technologies. Technology Early Action Measures (TEAM) Programme is another initiative that has been renewed under the CCPC with injection of new funding. 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 recognising the significant market growth opportunity that PV represents to the Canadian PV Industry, the Government of Canada in 2003 commissioned a study that looked into elucidating the barriers facing the large-scale deployment of grid-connected photovoltaic electricity generation in Canada, and to propose an action plan to make PV an integral component of Canada's energy future[2]. The findings of this study are being addressed by energy policy makers in the Government in consultation with the PV industry in Canada and industry associations. Highlights of Canadian PV Industry support of Canada's climate change objectives, include:

- Xantrex Technology Inc. in advancing the development and demonstration of a multi-energy source power control system, for distributed generation;
- ATS, Spheral Solar Power Inc.'s major investment in a novel technology that will significantly contribute to the cost reduction of solar power and establish in Canada a PV manufacturing capability;
- ARISE Technology and Cook Homes partnering in a pilot programme to market PV solar homes to residential customers;
- ICP Solar Technologies Inc. is developing state-of-the-art innovative solar power technology products (ICP is recipient of two 2004 Consumer Electronics Show Innovation Awards);
- Canadian Solar Inc. in developing and marketing PV products in developing country markets;
- Carmanah Technologies Inc. is developing solar-powered LEDs (light emitting diodes) that are extremely rugged and designed to withstand extreme environmental conditions with zero maintenance.

The Government of Canada continued its efforts to work with academic institutions to raise awareness of BIPV with the next generation of architects and building engineers. It partnered with

the University of British Columbia and the Royal Architectural Institute of Canada (RAIC) to deliver a one-day Workshop on building-integrated photovoltaics (BIPV). The workshop aimed at heightening the architectural community's understanding of solar photovoltaics as an emerging exciting renewable energy technology for integration into buildings, to demonstrate its successful application throughout Europe, Japan and the United States and to give visibility to the architectural and environmental opportunities of BIPV within a Canadian context. A report entitled "Mainstreaming Building-Integrated Photovoltaics in Canada" identifies the numerous benefits of BIPV and dispels the myths that surround its use, as well as presents a process by which BIPV can be incorporated in a variety of building types in Canada. This material will form the basis of a training course to be given by RAIC to Canadian architects.

Despite the relatively low price of conventional energy, many Canadians are contributing to the growth of the PV market and industry. A sustainable market for remote and off-grid applications has developed over the last 10 years in Canada. The installed power capacity is expected to reach 11,50 MW in 2003, compared to 10 MW in 2001 (see Table 1). This is an unsubsidized market that is growing because PV technology is meeting the remote power needs of Canadian customers particularly for transport route signaling, navigational aids, remote homes, telecommunication, and remote sensing and monitoring.

NATIONAL PROGRAM

The federal Department of Natural Resources Canada (NRCan) is responsible for energy policies and energy R&D in Canada. Within the framework of the Renewable Energy Strategy, NRCan's CANMET Energy Technology Centre-Varennes (CETC-V) is responsible for the management of the federal photovoltaic R&D and technology transfer programmes. This includes technical support for research on components and systems in collaboration with industry and major end-users, as well as the development of standards and codes. This photovoltaic R&D programme is financed by the federal fund allocation by the Programme on Energy Research and Development (PERD). In addition, the Renewable and Electrical Energy Division (REED) is responsible for policy support and is actively supporting PV training and marketing activities to promote the use of photovoltaic and other renewable energy technologies in Canada. The strategies of the Canadian R&D photovoltaic 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 and non technical barriers;
- Collaborate with key partners and stakeholders to increase the awareness of the potential and value of PV;
- Provide support to globally competitive PV manufacturers that can significantly contribute to Canada's Climate Change objectives.

R&D PROGRAM

The Canadian R&D 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. This work is conducted in collaboration with the industry at CETC-V, a national research facility located near Montréal in the Province of Québec[3]. On-going projects include:

- a comprehensive research programme to evaluate the use of small PV-hybrid systems in order to optimize their performance and reduce their life-cycle cost[4];
- a research project to increase the integration of renewable energy technologies in off-grid residences in Canadian climatic condition, in partnership with the Yukon Energy Solution Centre, the Arctic Energy Alliance and the Canadian Mortgage and Housing Corporation;
- evaluating the energy performance of commercial PV modules operating in Canadian climatic conditions and contributing to the development of international PV module standards;
- assessing the performance of PV products designed for building integration, in collaborations with Canadian manufacturers and system's integrators;
- conducting research to improve the efficiency and performance of inverters and balance of systems components used for utility interconnected PV systems;
- championing the development of a national guideline for the interconnection of small distributed generation systems, including PV, wind, micro turbines, and fuel cells, in collaboration with the Electro-Federation of Canada;
- supporting the development and adoption of performance and safety standards for use in Canada, including participation in the International Electrotechnical Commission working groups that aim to develop international standards.

TABLE 1: CUMULATIVE PV POWER CAPACITY INSTALLED IN CANADA

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
PV power (MW)	1,24	1,51	1,86	2,56	3,338	4,47	5,83	7,15	8,83	10	11,50 MW

Data - Natural Resources Canada

Fig. 2 - A BIPV façade (12,4 kW) at the Red River College Princess Street Campus, Winnipeg, Manitoba. (photo Corbett Cibinel Architects)

Fig. 3 - The Solar-Powered Rotary Dream Home, City of Waterloo, Ontario incorporated a 3 kW UniSolar metal roof as part of the first demonstration of community-scale PV rooftop systems in a neighbourhood in Canada. (photo ARISE Technologies Inc.)

DEMONSTRATION PROJECTS

Canadian Centre for Housing Technology

The Canadian Centre for Housing Technology (CCHT) is Canada's new advanced housing research and demonstration facility. The Centre has been created to accelerate the development and application of improved technologies for the Canadian housing industry and to facilitate world-market access to Canada's leading edge housing solutions. Built on a fully serviced six-acre site at the National Research Council of Canada (NRC), the Centre is a working partnership between NRC, NRCan and the Canada Mortgage and Housing Corporation (CMHC). The Centre currently features two fully monitored test homes and a unique demonstration and showcase facility. These buildings are highly instrumented and are used by industry to test innovative building products and heating systems. The Centre works with industrial partners to develop new research houses and explore specific test and research challenges. Recently 2,65-kilowatt grid-tied PV systems (1,32 kW each) were installed on the roof and as a canopy to the CCHT information centre (Figure 1). An additional 1,6-kilowatt using the next generation Spheral Solar™ product is planned in 2004.

Building Integrated Photovoltaics at the Red River College Princess Street Campus

Red River College (RRC) is the largest and most comprehensive institute of applied learning in the Province of Manitoba. It provides the highest quality education and training for 32,000 full and part-time enrollments each year. The Princess Street Campus is one of eight satellite campuses of the RRC. When completed it will be home to approximately 2000 students and staff involved in media and information technology programmes. It is located in the down-town core of the City of Winnipeg. The Princess Street Campus has incorporated energy efficiency and sustainable building processes in its design features that enabled it to place 5th in the world in the 2002 Green Building Challenge in Oslo. It includes three phases linked by a central atrium. Phase 2 of the project incorporates a row of historic facades of some of the oldest buildings in Winnipeg as well as a 12,4 kilowatt BIPV system integrated into building's the south facing façade (Figure 2). The project is the focal point or the revitalization of Winnipeg's historic exchange district.

Montréal Universities Participating in the Solar Decathlon Home Competition

In 2003, a team of engineering students from Concordia University in Montreal and design students from the Université de Montreal have teamed up with Alouettes Homes and ICP Solar technologies Inc. and entered the 2005 Solar Decathlon Competition. This competition, which is sponsored by the US Department of Energy, will feature 20 teams from the USA, Canada and Spain converging on the National Mall in Washington D.C. during the Fall of 2005[5]. Decathlon teams will compete to design and build a solar-powered house.
The teams will assemble their modular homes on the Mall. Contest rules require that each house generate enough energy to operate a household, a home-based business and related transportation needs. The teams demonstrating the most energy efficient and innovatively designed house wins. The Government of Canada is supporting the Canadian bid since it is an excellent opportunity to give architecture, engineering and other students hands-on experience in energy-efficient design and solar power technologies.

Canada's First Residential Solar Community Pilot Project

In September 2003, the Kitchener Conestoga Rotary Dream Home Lottery, Kitchener, Ontario officially opened the 2003 Solar Powered Rotary Dream Home to the public (Figure 3). The lottery was to raise funds for a local hospital. Four homes have been sold in the same neighborhood since the model home was displayed. The overall goal of this NRCan/TEAM funded project is to develop BIPV rooftop technologies and to demonstrate that PV solar homes can be designed built and marketed to the Canadian public. The emphasis is to demonstrate various PV technologies integrated to energy efficient homes, in order to gain a better understanding of the technical requirements, such as installation, performance, inspection, as well as non-technical barriers (educational, market information, financing etc.) in the design and construction of PV solar homes. The objective is to develop innovative novel components and integrated solutions that can build the Canadian capacity to package these solar home systems and sell them through normal residential housing sales channels. This is an ongoing project of ARISE Technologies Corporation, Cook Homes Limited, The City of Waterloo, Waterloo North Hydro, The University of Waterloo and the Canadian Imperial Bank of Commerce in partnership with CETC-Varennes aimed at advancing the development and demonstration of photovoltaic (PV) solar homes in Canada.

Fig. 4 - Canada's R&D programme is addressing the issues of integrating renewable energy in off-grid residences north of the 600 north parallel. This 600-Watt PV installation in an energy-efficient off-grid residence, Whitehorse, Yukon.

Demonstrating Renewable Energy Integration in Cold-climate Off-grid Residential Applications in the Yukon

As part of NRCan's coordinated research programme to foster the advancement of renewable energy technologies so that they become the preferred energy option in off-grid energy markets in the north, an integrated design charrette was held in Whitehorse, the Yukon territory in December 2003, to address potential opportunities and technical challenges involved with living off-grid using renewable energy. The Canadian PV Programme organized the three-day long design charrette in collaboration with the Yukon Energy Solution Centre. Thirty experts from the private and public sectors with experience in renewable energy and buildings energy technologies participated in this event. The participants were divided into three working groups, with expertise in computer simulations renewable energy technologies, architectural, building, construction as well as manufacturing and systems installations evenly spread out between the groups. The teams adopted an integrated approach to optimize the use of renewable energy, and provide an analysis of total energy use (incl. space and hot water heating) and electrical energy use in off-grid houses North of the 60th parallel (Figure. 4).

BIPV Atrium at the Waterloo City Hall

In November 2003, the City of Waterloo, Ontario, inaugurated 1,1-kilowatt grid-tied BIPV installation in the City Hall building atrium (Figure 5). This project was partially funded through the Green Municipal Enabling Fund established by the Federal Government and Federation of Canadian Municipalities with contributions from Arise Technologies Inc. This is a pilot scale project, which involves monitoring of the installation.

IMPLEMENTATION

Canada has developed and approved the Climate Change Plan for Canada, a National Implementation Strategy to reduce its green-house gas emission by 6 % from 1990 level. Within this framework, several climate change measures have been initiated that should benefit the PV industry and other stakeholders:

- *Technology Early Action Measure Programme* - This is a cost-shared programme between the federal government and industry for the development of innovative technologies and their demonstration in the market place. Several PV technology proposals were approved under this programme;
- *Sustainable Development Technology Canada* - This is a not-for profit funding organization developed through a national government initiative and set-up with an investment of 350 million CAD to foster the rapid development, demonstration and pre-commercialization of technological solutions, that deliver positive environmental and economic impacts to Canadians;
- *MicroPower-Connect Initiative* - This is an initiative that aims to develop and harmonize the requirements for the interconnection of emerging technologies, such as PV, wind, fuel cells, and micro turbines[6];
- *On-site Generation at Government Facilities* - As part of its climate change action plan, the government of Canada will support the installation of approximately 15 PV systems over the next three years. Projects include high visibility sites that demonstrate the application of building-integrated PV products;
- *Climate Change Technology and Innovation Programme* - As part of this measure, the Natural Science and Engineering Research Council will manage a research fund for novel next-generation energy technologies related to greenhouse gas mitigation. This programme targets early-stage and exploratory research in Canadian Universities and will enhance the knowledge base for longer-term solutions to climate change;
- *Federation of Canadian Municipality (FCM) Green Fund* - The federal government provides funding to the FCM to initiate green energy projects. By partnering with a local community champion, PV companies have an opportunity to propose PV deployment projects.

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. None of the Provinces in Canada are mandating net metering policies, although some have examined the issue[7].

INDUSTRY STATUS

The Canadian PV industry has grown steadily serving both its domestic off-grid market and the export market. There are approximately 150 organisations actively promoting PV power. Many of them are members of the Canadian Solar Industries Association or Énergie Solaire Québec[8].

ATS Automation Tooling Systems Inc., its subsidiary Spheral Solar™ Power and Elk Premium Building Products Inc.(Elk), a subsidiary of ElkCorp. based in Dallas, Texas, have entered into a memorandum

Fig. 5 - Atrium of the Waterloo City Hall building incorporating 1,1 kW of BIPV, Ontario. (photo ARISE Technologies Inc.)

of understanding under which they intend to work together to design, manufacture, test and commercialize a new generation of fully integrated photovoltaic roofing products, primarily for use in residential buildings. The new products will take advantage of Elk's extensive knowledge and expertise in the residential roofing materials market and the unique qualities of Spheral Solar™ Technology. The companies will bring considerable expertise to developing BIPV. Elk is a leader in building product technology and has developed numerous integrated solutions for the roofing industry as well as consumer goods. These products have served to reduce costs, increase safety and productivity. ATS and SSP are currently commercializing their proprietary Spheral Solar™ Technology and building their first 20-megawatt production facility in Cambridge, Ontario, Canada. This revolutionary new photovoltaic technology allows for solar cells to be manufactured using thousands of tiny silicon beads bonded in an aluminum foil. The resulting flexible solar cell is expected to dramatically reduce the cost of solar energy and open a broad range of new uses of solar power by industrial, commercial and residential users worldwide. The cells are lightweight, pliable and break resistant and can be formed into a variety of shapes and sizes.

Canadian-based Xantrex Technology Inc. and American-based Atlantis Energy Systems (AES) are offering a new inverter and solar panel combination designed to make it easier for homebuilders to install renewable energy systems. By combining a Xantrex SunTie XR Grid-tie Inverter with Atlantis Energy System's Sunslates® roofing product, the roof of a house can act as both a roof and a power plant simultaneously. The combined system is designed to make the installation of solar power systems easier and more affordable than ever before and enable homeowners to participate in the emerging small-scale green power market.

A network of systems integration companies has established distribution and dealer networks that effectively serve a growing Canadian PV market. These include distributors for BP Solar (acquired Solarex), Shell Solar (acquired Siemens), Kyocera, Photowatt, 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

The Canadian PV installed capacity in 2003 is estimated at 11,5 Megawatt with a sustained domestic market growth that has averaged 25 % over the last ten years. In 2003, the annual PV module market is estimated at 1,5 Megawatt per year compared to 1,17 Megawatt in 2002. Twelve manufacturers reported sales of. about 61,5 million CAD. It is estimated that the Canadian PV industry generated revenues of 100 million CAD and employed approximately 600 people in 2003.

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

FUTURE OUTLOOK

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

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

More significant effort will be required to encourage the development of the grid-connected market sector in Canada. Since CETC-V (footnote 4) released the study examining the benefits of on-site generation using photovoltaic technologies on buildings in Canada, several new activities have been initiated as part of an action plan that aims to build on Canadian Industry experience base and address some of the market place barriers that currently exist.
New government investments in R&D for Building-Integrated PV technology, support for the development of a technical guideline for the interconnection of small power supplies, and support for demonstrations of PV on building in high-visibility sites throughout Canada will contribute to facilitating the market introduction of PV technology for grid-tied applications in the medium to long term.

Footnotes with relevant web sites:

1 *Climate change web site: http://www.climatechange.gc.ca/english/publications/announcement/climatechange_investment.html*
2 *Industry Canada website: http://www.ic.gc.ca/*
3 *CETC-Varennes was formerly known as the CANMET-Energy Diversification Research Laboratory (CEDRL); web site: http://cetcvarennes.nrcan.gc.ca/eng/accueil.html*
4 *PV-Hybrid Programme newsletter, HYBRID-INFO: http://cetc-varennes.nrcan.gc.ca/eng/publication/2003-145e.pdf*
5 *Solar Decathlon web site: http://www.eere.energy.gov/solar_decathlon/*
6 *MicroPower-Connect Initiative: http://www.micropower.org*
7 *John J. Bell, A Survey of Canadian Policies to Compensate Small Power Producers for Electricity Fed to the Grid: Net Metering and Net Billing, Masters of Environmental Studies Thesis, Dalhousie University, Halifax, Nova Scotia, December 2003.*
8 *Directory of members and companies available from: the Canadian Solar Industry Association (www.cansia.ca) and Énergie Solaire Québec (http://www.esq.qc.ca)*

DENMARK

PV TECHNOLOGY STATUS AND PROSPECTS

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

Fig. 1 - 1,02 kWp PV system on a house from Friland, an experimental area in Denmark for alternative buildings.

GENERAL FRAMEWORK

Denmark has presently no national energy plan, but the governments 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.
The government wishes to strengthen the research community and the development of new and promising energy solutions.

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 to the base year 1990. The market for CO_2 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 end of 2003 about 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 this 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 during 2003, the Danish Energy Authority (EA) has elaborated a draft national strategy on PV in collaboration with the electricity sector, the industry and other key stakeholders. This PV strategy is expected to be finalised early 2004, and will include the fields of research, development and demonstration. Deployment activities in support of the PV strategy are expected to be developed during 2004, and thus, an overall framework for the coordination of PV development and deployment in Denmark is expected to be in place shortly.

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 are supported mainly by the Danish Energy Authority and via the Public Service Obligation (PSO) of Danish network operators.

Fig. 2 - 2,04 kWp PV system on a typical residential house located the northern Jutland.

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 2003, about 2 MW have been installed in the context of demonstrations plants. A 300 roof-top project, including 750 kWp, was launched early 1998 and was completed by end of 2001. A 1 000 roof-top programme was launched late 2001 as a follow up; this programme targets a mix of general cost reductions, increase in end-user payment and promotion of small roof-tops. Only a few weeks after the announcement of the programme, the SOL 1000, more than 3 000 house owners had registered their interest. However, uncertainty about the programme due to change 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 1 500 house owners expressing firm interest in the programme and by end 2003, about 250 kW have been implemented, stimulated by an investment subsidy of 40 % of the turnkey system cost; the average turnkey system cost being EUR 4,50/W.

A special support programme for PV applications in the commercial sector, funded by the CO2 tax on electricity, was set up 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.

In late 1999, a new three-year programme, 2000 – 2002, to promote building integrated PVs in apartment buildings and institutions was initiated. The programme included both the development of new integration methods and new components and demonstrations. By the end of 2001, six calls for proposals had been carried out resulting in 52 proposals, of which 23 have received support. The programme did create interest for PVs in the Danish building industry. However, programme funding was abruptly stopped primo 2002.

RESEARCH AND DEVELOPMENT, DEMONSTRATION

During 2003, the government 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.

R&D activities into PEC cells (Grätzel type cells) are ongoing at the Danish Institute of Technology. This activity has in 2002-03 been supported by the PSO of the Danish network operators. At 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; particularly 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 1 000 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, has implemented about 250 kW during 2003. 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.

A new utility initiative has been launched in 2003 by Copenhagen Energy: 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.

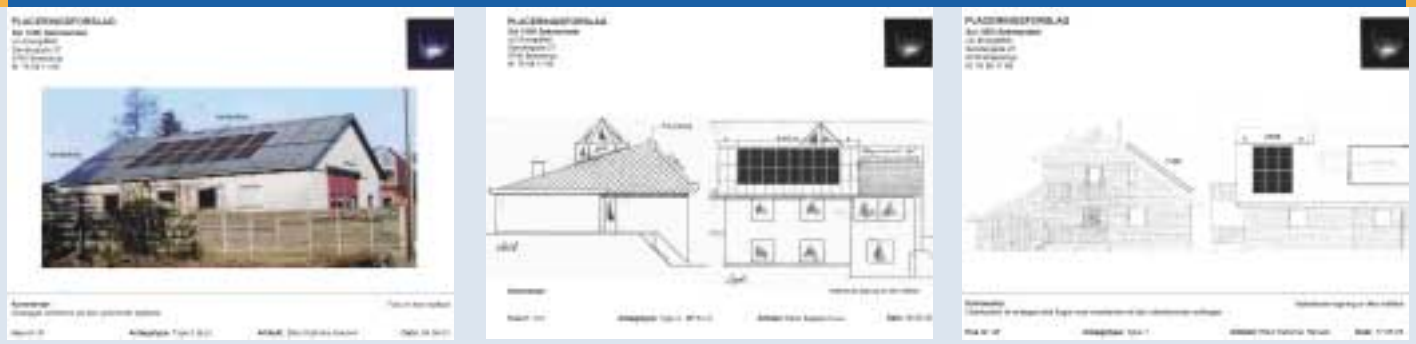

Fig. 3 - Achitects' drawings and visualization of the Sol 1 000 project.

INDUSTRY STATUS

The company Topsil, which by using 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. Initial efforts indicate that +20 % efficient cells based on the float zone Si may be competitive in the near future.

R&D efforts are beginning to exhibit commercial results in terms of export. A commercial break through was announced in 2003, also by Topsil. It is now seeing the first commercial results of its R&D into low-cost float-zone processing and shall supply float-zone Si for high efficiency PV cells, on a commercial basis.

Inverter technologies have been R&D' for some years for both fuel cell and PV applications. For the latter, a commercial break through was also announced in 2003, by the Danfoss related company Powerlynx, which reports to have received its first multi-million Euro order.

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

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

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

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

Total PV business volume in 2003 cannot be estimated with any degree of accuracy primo 2004, due to the above mentioned new business developments in the fields of Si feed stock and inverters, the details of which are not yet public. However, a rather sharp increase of the 2002 figure of 10 MEUR is expected.

By the end of 2003, the cumulative installed PV capacity in Denmark (including Greenland) is estimated to be about 2 MWp; an increase of almost 20 % when compared to 2002.

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 1 000 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. 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 unchanged development of the Danish end-users increasing willingness to invest in PVs, a commercial market for PV roof-tops in Denmark will emerge around 2009-10.

EUROPEAN COMMISSION

RESEARCH, DEVELOPMENT AND DEMONSTRATION ON PHOTOVOLTAICS WITHIN THE EUROPEAN UNION
ROLF ÖSTRÖM, SCIENTIFIC OFFICIER, EUROPEAN COMMISSION, DG RESEARCH
PIETRO MENNA, RESPONSIBLE FOR THE SOLAR SECTOR, EUROPEAN COMMISSION, DG ENERGY AND TRANSPORT

Research in the Photovoltaic sector is supported by the European Commission both for short to medium term and medium to long term activities.

5TH FRAMEWORK PROGRAMME (1998-2002)

In total around 100 projects were started between 1999 and 2003. They cover both actions with an expected impact in the short to medium term as well as medium to long term.

The projects with an expected impact in the medium to long term can be divided into the following categories: PV cells and modules, PV systems, building-integrated PV and projects related to ERA networks and pre-standardisation. This corresponds to more than 60 projects with over 65 MEUR EC contribution.

The main areas of medium to long term PV research funded by the European Union in the fifth Framework Programme (FP5) 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 (such as tandem and concentrator cells and systems, new materials).
- Research on reducing the cost of other new and innovative components and systems.

In the short to medium term timeframe, the research and demonstration projects supported by the EU under FP5 can be grouped under the following headings:

- Demonstrating the economies of scale;
- Technology innovation to integrate PV in the buildings;
- Large, grid-connected, demonstration plant;
- BOS & measurements;
- Education, dissemination, studies.

More than 40 projects have been launched in Europe for short to medium term actions, 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 demonstrate the economies of scale which are achievable by grid-connected PV systems for single family homes, when developers, utilities and building industry work together from the beginning of the project. Projects like *SunCities*, *Hip-Hip*, *Mediterraneo*, and *PV Enlargement* belong to this first category. The second most important component (more than 19 %) has been for demonstrating innovative concepts for better integration of PV into buildings. 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 EC contribution.

6TH FRAMEWORK PROGRAMME (2003-2006)

Under the 6th Framework Programme (2003-2006), the focus has been put on the development and demonstration of integrated approaches for new system design options and concepts, with a strong emphasis on cost reduction, as indicated below:

Short – Medium Term:

- Innovative production concepts for high efficiency PV cells/ modules to be integrated into larger scale (multi-MW) photovoltaic production facilities in order to lower the Wp 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 (BIPV) 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.

Medium – Long Term:

- Innovative concepts and fundamental materials research for the next generation of PV technologies (e.g. organic or hybrid solar cells);
- 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).

We have already selected 10 PV projects from the first FP6 Call, for a total cost of 78 MEUR and an EC contribution of nearly 42 MEUR.

FINLAND

PV TECHNOLOGY STATUS AND PROSPECTS

LEENA GRANDELL, MOTIVA OY

Fig. 1 - In 2003 a new office of Solpros, a consultant company working in the field of solar energy and environment, was opened. The building is a low energy house utilising photovoltaic power and passive solar energy. The estimated need for purchased energy is 50 kWh/m² annually.
(photo Solpros, 2003)

GENERAL FRAMEWORK

The photovoltaic sector in Finland is still fairly small, providing work to approximately less than 100 employees. The main actors consist of several companies (importers, retailers and consultant companies), a number of research institutes and two associations.
Within the government, the Ministry of Trade and Industry has the main responsibility for enhancing renewable energy sources, including photovoltaics. During 2001, a network called FSI, Finnish Solar Industries, was established consisting of companies and other entities. The purpose of the network is to enhance the opening of the PV markets through collaboration.

The Ministry of Trade and Industry launched an Action Plan for Renewable Energy Sources in 1999, in which focus is set on the domestic market development. The Action Plan is one crucial part of the National Climate Strategy, which has been formulated to achieve the goals of greenhouse gas reductions set for Finland by the Kyoto Protocol. During 2002, the Action Plan has been evaluated and revised.

NATIONAL PROGRAMME

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

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

RESEARCH AND DEVELOPMENT

A few institutes and companies are actively working on research and development of photovoltaics. The most important ones are the Helsinki University of Technology, Jyväskylä University and Fortum Ltd. Also, the Technical Research Centre of Finland and Rautaruukki Ltd. are active in the field.

Tekes, Technology Development Centre, administrates the public funds for photovoltaics. During 2003, funding was given mainly for the development of new materials, initiatives related to manufacturing technology, as well as performance optimisation.

The Helsinki University of Technology and Jyväskylä University focus on dye sensitized solar cells. Here, the goal is to concentrate on manufacturing technology aspects with the aim of understanding factors critical to the performance of the cell and development of new manufacturing methods applicable to large scale production. Additionally, the Helsinki University of Technology is working on the ageing phenomenon of thin film solar cells (CdTe and CIS).

INITIATIVES FROM GOVERNMENT AND UTILITIES

Investment subsidies are granted for solar energy systems for up to 40 % of the expenses. The subsidies are given only to companies, organisations, enterprises, etc., and not to private individuals. Since 2003, subsidies for renovation sites are more focused on the energy system of the site, also including the change of the energy source towards renewable energies.

Various eco-labelling systems for energy exist on the market at the moment. Finland takes part in the European Renewable Energy Certificate System (RECS). Over ten utilities and other energy companies provide green electricity on the market, which is certified according to the RECS system.

Norppa eco-label is monitored by the Finnish Association for Nature Conservation. The utility can apply for the Norppa eco-label, if the electricity generation fullfills the needed criteria.

Helsinki Energy provides electricity generated by wind and old hydropower. The customer pays monthly, "ympäristöpenni," a so called environmental cent, for receiving green electricity. The funds are used for new projects enhancing green electricity generation.

INDUSTRY STATUS

The Finnish PV market is characterised by some 10 importing companies with retailers. No domestic PV cell production exists but on the other hand, a number of companies are active in technology development of components and on system level. Thus, several innovations of Finnish companies are on the market.

MARKET DEVELOPMENT

The photovoltaic markets consist of three main segments:

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

The domestic markets are dominated by small solar home systems for vacation houses; representing approximately 90 % of annual sales. Building integrated applications is an increasing market segment. The most important demonstration installations over the last couple of years have been building integrated systems. Telecommunications base stations, weather stations or the some 20 larger stand alone hybrid systems operated by the Finnish Coast Guard, are examples of applications in remote areas.

FINNISH PV SYSTEMS 2003

	Power (kWp)
Solar Home Systems	3 022
Stand-Alone Systems	238
Grid-connected (Utility)	118
Grid-Connected (Roof-Top)	32
TOTAL	3 410

(the cumulative installed capacity)

FRANCE

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS IN FRANCE

ANDRÉ CLAVERIE, CÉDRIC CAMEZ
FRENCH AGENCY FOR ENVIRONMENT AND ENERGY MANAGEMENT (ADEME), RENEWABLE ENERGIES DEPARTMENT

GENERAL FRAMEWORK

The French Agency for Environment and Energy Management (ADEME) is the organisation in charge of the implementation of the national sustainable development policy in the five following fields: waste management, soils conservation, air quality, noise abatement and energy management; the latter includes energy efficiency and the renewable energies. One of the centres of activity of this policy is solar photovoltaic electricity.

In the first half year 2003, the Government and the Ministry of Industry launched a national debate on energy. Safety of supply and environmental conservation are the two main basic requirements. On 7 November 2003, the Minister in charge of the Industry has presented the White Book on Energies (www.industrie.gouv.fr). The conclusions and the proposals put forward are in favour of energy management and renewable energies. Solar photovoltaic energy is mentioned in the research actions to be undertaken on par with hydrogen and carbon dioxide sequestration. Two parliamentary reports by MPs J. Besson (www.debat-energie.gouv.fr/site/pdf/rapport-besson1.pdf) and S. Poignant (www.assemblee-nat.fr/12/rap-info/i1153.asp) have taken an in-depth look into the renewable energies policy. The *energy guidelines* Act should be passed by the Parliament in 2004. It is at this stage that the requirements in connection with renewable energies will materialise through regulatory and tax measures.

NATIONAL PV PROGRAMME

ADEME combines and funds research projects which come within its strategy and intervenes, through its 26 regional delegations, in field projects funding. The national support programme is built around two sections: research and technological development aimed at reducing the costs of components and systems. In addition there is a programme meant for opening up markets, which includes support for investment geared to the implementation of photovoltaic systems. The regional delegations of ADEME are responsible for the investment support procedures while the Renewable Energies Department of Sophia Antipolis provides technical and strategic backing.

ADEME is also a body in charge of information dissemination (www.ademe.fr) as well as the organisation of training: training of installers, of those arranging projects, and of engineers for research. At the Sophia Antipolis headquarters, ADEME is thus running, in conjunction with Métrol Consultancy, two training sessions per year in photovoltaic systems. Training is designed for rural electrification and pumping applications. An additional training programme focusing on systems connected to the grid should be launched in 2004. Concerning training through research, ADEME co-finances PhD students on a grant, who for three years, participate in applied research projects in public or industrial laboratories. Additionally, ADEME is sponsoring events of international scope such as the 19th European Photovoltaics Conference that will be held in Paris in June 2004.

Fig.1 - Pic Saint Loup School (Hérault dpt). European Universol project. 5 kW grid-connected PV canopy. (photo courtesy of Hespul and Apex)

RESEARCH AND DEVELOPMENT

Regarding research and technological development, ADEME's four-year programme which stretched over 1999 – 2002, ended mid-2003. An assessment of the results of projects, which were sponsored, has been presented during the national research seminar on 18-19 November 2003 at ADEME's Sophia Antipolis headquarters. This seminar on materials and processes brought together about one hundred researchers and specialists. ADEME's committee of PV R&TD experts, as well as external consultancies, have assessed research contracts. Fruitful cooperations forged with the industry and the research laboratories have been highlighted. The strategic choices made on materials, processes and the systems components have not been questioned. However, crystalline silicon and the thin film-based materials such as Cu-In-Ga-Se remain the preferred industrial options; while the thin film-based hydrogenated amorphous silicon and their polymorphous variations should be subjected to a fresh review. Among the recommendations made are the studies of combinations of this thin film-based silicon with bulk crystalline silicon.

Based on the recommendations made by the experts, new projects have been submitted to ADEME from these industries covering the 2004 – 2007 timeframe. The CEA-GENEC Laboratory of Grenoble has installed a new technology platform in 2003, which will allow developing innovative manufacturing techniques of crystalline silicon cells, which could reach 20 cm x 20 cm in size. The objective of these new projects is to demonstrate the feasibility of conversion efficiencies of 20 % with processes that can be transferred to the industry at a competitive cost. The new industrial RTD projects are considering a 30 % reduction in production costs over 4 years.

Among the stakeholders of the crystalline silicon industry, there are: the industrialist Photowatt, the EMIX company and public research organisations such as CEA, CNRS and the universities. Regarding the thin film-based materials, the following are the major players:

Fig. 2 - Réunion Island (French overseas department). Private house. 4 kW grid-connected PV . (photo Courtesy of Apex-Bp-Solar)

Free Energy Europe (amorphous silicon) and the consortium of partners backing the project dubbed CISEL (Cu-In-Ga-Se): EDF, Saint Gobain Recherche and the CNRS. Last 18 December 2003, a new research platform bringing together CISEL partners has been inaugurated in Chatou (Paris area). Other CNRS teams have joined and brought more muscle to the CISEL consortium in place since 2000. Research projects such as the organic materials sectors, which were launched in 2002, will be subjected to assessment in 2004. For the components industry outside the PV modules sector, financial support provided by ADEME has been devoted to research on lead-acid storage batteries' ageing, on inverters with multiple management and monitoring functions and related also to technical and financial management systems for off-grid rural electrification projects. The main industrial players involved in the development works sponsored by ADEME are Apex-Bp Solar and Total Énergie.

As part of the call for proposals 2003, "Preparing the construction industry for 2010," was launched by ADEME in association with the town planning, construction and architecture Plan (PUCA) three projects were selected. One concerns innovative work undertaken on the curved tiles by Lafarge-Couverture and Apex-BP Solar and the remaining two are aimed at demonstrating the interest and the feasibility of the photovoltaic/thermal hybrid collector (Clipsol, Cethil and Locie; Cea, Cstb and Photowatt). For their own part, Armines and EDF have developed two tools for thermal simulation of a building integrating thermal and photovoltaic solar collectors.

IMPLEMENTATION

Over the year 2003, ADEME has maintained its position on the market of grid-connected PV and integrated into the built with the objective of optimising public funding including ADEME, and regional councils. Regarding the individuals, the recommendations tend to limit to an electrical output of 2 kW while recalling the interest of a general energy efficiency approach. For more ambitious projects, ADEME is favouring solutions involving integration into the building envelope associated with architectural quality. In 2003, public subsidies were on an average of 4,6 EUR per watt; among which 3,4 EUR from ADEME (including the contribution provided by the European Commission) and 1,2 EUR from regional councils.

Partnerships forged with the local authorities have allowed the emergence of new quality projects in the Western Pyrénées, Chambéry, Grand Lyon, and so on.

The SER (Renewable Energies trade group), the industrial and association groups as well as ADEME have made great strides regarding the implementation of a technical, regulatory and legal framework for the connection of photovoltaic systems to the electricity grid. All the stakeholders have thus adopted a standard (www.edf.fr/index.php4?coe_i_id=159). Two documents have received the approval of the Energy Regulating Committee (CRE):

- The connection contract;
- The distributor buy-back contract.

The construction industry's scientific and technical research organization (CSTB) has implemented technical approvals (Atec), of which the requirements have to be met by the photovoltaic modules designed for integration into the built. Apex-BP Solar is currently undergoing the qualification procedure. In order to launch this procedure, CSTB and ADEME have provided the necessary funds.

On the other hand, the Guide for Project Supervisors: "Drafting Grid-Connected PV Systems Technical Specifications" which had been published in 2002 was revised; which has resulted in a more practical and useful guide.

The European projects benefiting from ADEME's co-financing continued their course in 2003. The HIP-HIP Project ended with the installation of 450 kW in continental France[1] and the publication of a brochure highlighting the results of the demonstration operation "Photovoltaic Solar Energy for the Construction Industry – "Field Experience of the European HIP-HIP Project in France."
The PV-STARLET Project developed in partnership with HESPUL Association and the Imerys–Toiture company, plan the installation of photovoltaic systems based on SUNSAT solar tiles on about 300 houses: work is currently under way on 25 sites. The UNIVERSOL Project (www.universol.org and www.universol-France.org) co-ordinated in France by HESPUL is planning the installation of 345 kW on 15 buildings of an educational nature, of which two installations have already seen the light of day. In September 2003, the European project, PREDAC (www.cler.org/predac) run by CLER Association led to the gathering of about one hundred architects and construction industrialists in order to get them better acquainted with photovoltaics and fuel exchanges; while taking into account their experience and their motivation.

INDUSTRY STATUS

Production of PV cells by Photowatt International has slightly increased in 2003. Photowatt was the first company to obtain the PV GAP Quality label (www.pvgap.org) for its crystalline silicon modules certified under the IEC 61 215 international standard. On the other hand, Photowatt has decided to come back to PV systems after several years during which the company was focusing on the manufacture of PV cells and modules. The company's approach is to offer standardised systems of 1,6 kW, 3,2 kW and 4,8 kW. Photowatt has been associated to a sister company Spheral Solar Power, based in Canada, which is developing a new type of PV modules based on tiny silicon spheres.

EMIX Company is about to start the production of crystalline silicon ingots manufactured through the continuous casting technique via an electromagnetic cold crucible. Other research companies under contract such as Apollon Solar and Solarforce have launched new pre-industrial development projects (silicon materials, PV modules, etc.).

Concerning the photovoltaic components designed for roofing, Imerys-Toiture has presented its new solar tile, which will be marketed as a 1 kW kit (inverter, wiring and modules).

MARKET DEVELOPMENT

The domestic photovoltaic markets are dependent upon aid in investments provided by ADEME, the regional councils, the European Commission, EDF and the FACE (the rural electrification fund).

Good development has been demonstrated in the grid-connected photovoltaic applications. In 2003, public investment aid covered 2,8 MW among which 1,5 MW in mainland France. Investment aids provided by ADEME, the regional councils and the European Commission can reach up to 80 % of the investment. These aids were on average of 4,6 EUR per watt in 2003.

Until now, the off-grid domestic applications on isolated sites accounted for an important market share and have registered a 20 % decrease when compared to 2002: 940 kW have been installed in 2003. An 8 % decrease had already been registered in 2002. Market saturation in the French overseas departments is to blame for this decline, as these installations can benefit from aid to the tune of 95 %. However, concerning the overseas departments, the installations that come under the tax exemption measures for investments benefited from aid (granted by EDF, ADEME and the regional councils) up to 7,2 EUR per watt in 2003.
These measures have allowed installing in France, in 2003, 3,7 MW of photovoltaic systems (outside the professional applications such as telecommunication relays).

FUTURE OUTLOOK

In the field of research and technological development, ADEME will back targeted specific projects in line with technology choices validated by its experts committee and will do so in conjunction with the industry and the public laboratories.

Regarding the market for the installation of off-grid electrification systems, the slowdown registered in 2003 should continue all the more, since the aids provided to the installations benefiting from tax exemption measures will be cut by 24 %.

For the market of grid-connected installations, in 2003, ADEME, the regional councils and the European Commission have contributed funds for 2,8 MW, which represents a significant increase against the previous year. Technical, regulatory and contractual conditions of connection of the photovoltaic systems officially published in 2003 underpin the basis of a good level of development for 2004.

Footnote:

[1] *France includes mainland France, Corsica and the overseas departments: Guadeloupe, Martinique, Réunion and Guyane.*

GERMANY

PV TECHNOLOGY - STATUS AND PROSPECTS
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FORSCHUNGSZENTRUM JÜLICH GMBH

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. In the meantime, a first analysis carried out in spring 2003 shows that a share of roughly 8 % in electricity production has been reached.

While currently photovoltaic (PV) does not significantly contribute to this development – despite its strong growth rates - it is expected that PV will do so 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 2003, federal support for R&D on PV amounted to about 29,7 MEUR shared by 141 projects in total. The distribution of the budget shows that funding is concentrated on silicon technologies (see Fig. 1). In doing so, long-term options and activities to create a technological basis for small and medium enterprises play a major role.

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 347,5 MW were granted. Overall, this marks a clear success of the programme.

In addition to the "100 000 Rooftops Solar Electricity Programme," the **Renewable Energy Sources Act (EEG)** works guaranteeing a favourable feed in tariff. With the background of the termination of the "100 000 Rooftops Solar Electricity Programme," at the end of 2003, it was decided to adjust the EEG feed in tariff for PV: From 2004 on, there will be a basic tariff of 0,457 EUR / kWh. On top of this, there will be a bonus for small systems and building integration. For example, for systems smaller than 30 kW on buildings, there will be a bonus of 0,117 EUR / kWh; resulting in a net feed in tariff of 0,574 EUR/kWh. As before, these rates will decease by 5 % annually for newly installed systems.

R,D&D

Overview

As part of the 4th Federal Programme on Energy Research and Energy Technology the so-called, **"Way Paving Programme Photovoltaic 2005,"** with a time horizon of ten years has been formulated. Three main goals are set:

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

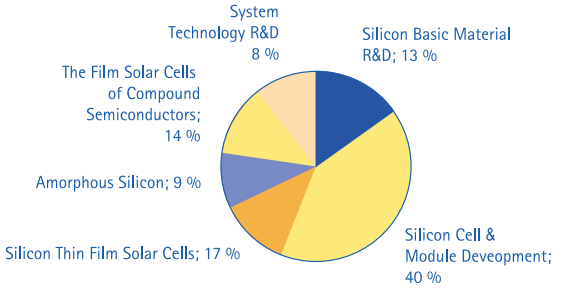

Fig. 1 – Funding of R&D 2003 by BMU (29,6 Mio. EUR in total).

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. The following outline will only concentrate on the Way Paving Programme Photovoltaic 2005, described above.

Research and Development

The following describe selected topics of important R&D-activities which were started in 2003. Most of these projects are co-operative R&D projects where industry and research institutes collaborate.

Crystalline silicon is still the most important material for manufacturing solar cells. Currently, emphasis is put onto efficient manufacturing techniques. Therefore, in 2003 some projects directly related to new production concepts of silicon wafers and cells were realised:

- NEON – methods to fabricate thin multicrystalline silicon wafers which have a large area of 200 x 200 mm^2,
- PLATON – plasma technologies for dry surface structuring of multicrystalline solar cells,
- INKA – cheap inline processes for metal contacts of high efficiency silicon solar cells.

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

Thin Film Technologies have the potential to combine low material and energy consumption with simple process technologies resulting in a cost-effective large area production. Today, several materials are used and numerous cell concepts with different maturity exist. One important project set out in 2003 deals with the development of a textured TCO (transparent conductive oxide) for thin film PV especially amorphous silicon.

In order to evaluate new technologies and new cell concepts, a project on organic solar cells was initiated. The long term target is the production of cost efficient large area solar cells by using an industrial organic vapour phase deposition process.

While the R&D on the integration of decentralised small power systems connected to the public grid as well as the evaluation of PV-systems (carried out under Task 2 of the IEA-PVPS programme) are continued, a new activity deals with off grid systems. Within the UESP – Project (see www.uesp.de), a flexible, reliable and cost effective solution for the management of autonomous power supply systems based on distributed intelligence and standardisation will be developed.

Demonstration

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

IMPLEMENTATION

In the last years, Germany has executed important programmes in the field of PV which have triggered remarkable results in market development and technology progress. Complementary to the R,D&D- programme, 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 new law rules the input and favourable payment of electricity from renewable energies by the utilities. For PV systems built in 2003 a feed in tariff of 0,46 EUR per each kWh fed into the grid is guaranteed for an operation period of 20 years.
- From January 1999 until the end of 2003 the Federal Government executed the **"100 000 Rooftops Solar Electricity Programme."** With a total granted capacity of 347,5 MW, this soft loan programme is a real success story. In 2003 alone, approximately 148 MW were approved (see Fig. 2).

Status of 100 000 Rooftops Solar Power Programme

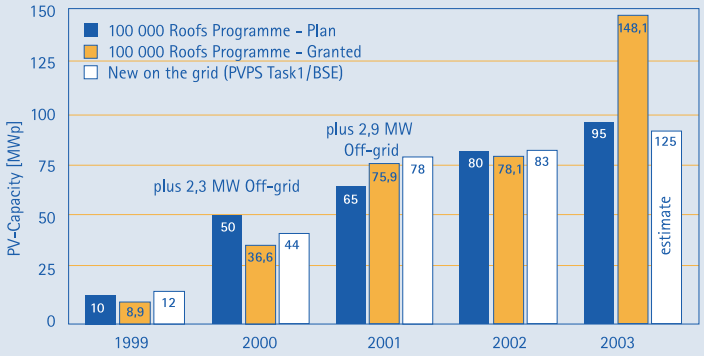

Fig. 2 – Grid connected PV power supported by the Federal "100 000 Rooftops Solar Power Programme."

- 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 which provides soft loans or subsidies. From 2000 until mid 2003, approximately 535 PV systems for educational purposes were supported.
- 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 a growing number of cases, financial support for the rational use of energy and for renewable energies is provided. **Cost-effective payments** for every kWh of energy fed into the public grid from PV and other renewable energy systems is offered by some utilities belonging to cities and communities.

INDUSTRY STATUS

Due to the German 100 000 Rooftops Solar Electricity Programme and the EEG, the German PV-industry has experienced a period of strong growth over the last three years. The German capacity in solar cell production has grown from 12 MW in the year 2000 up to a level of 100 MW in 2003 and a volume of 165 MW in 2004, is to be expected. The share in the worldwide production capacity has risen during this period from 4,2 % to 16,5 %. Therefore, Germany is the strongest market for PV energy in Europe, with a yearly demand of approximately 125 MW in 2003 and an expected demand of 165 MW in 2004. The German market share in Europe amounts to more than 80 %.

The range of industries supporting photovoltaic power generation is expanding along the whole value chain. In the last 4 years, equipment and production companies became the most experienced ones beside Japan. Thus, the PV-industry influenced and gave new impact to suppliers of feedstock for PV-cells, manufacturers of production equipment, of PV-components and power systems, housing constructors and other products necessary to install PV-systems.

The crystalline silicon technology has dominated the market in the last 4 years and there is no doubt that this technology will also be dominant during the next couple of years. The market share of different solar cell technologies worldwide is shown in table 1, emphasizing the champion to be crystalline silicon with more than 92 %.

TABLE 1 - SOLAR CELL TECHNOLOGIES WORLDWIDE IN PERCENT:

Technology	Percentage
Poly Crystal	52
Single Crystal	36
Ribbon & Sheet	4,7
Amorphous Silicon	6,4
Cd Te & CiS	0,9

German PV-companies are represented in all fields of technology; having RWE Schott Solar in ribbon and sheet production using the EFG-technology, as well as Würth Solar and Shell Solar producing CiS-modules in pilot plants.

The main players in the field of crystalline PV-business in Germany entering into the production chain are:

Wacker; with a clear commitment to produce silicon for wafer production companies in an amount of 2 000 t per annum out of the existing capacity and being in a position to increase capacities if the market growth proves to be reliable and prices adequate. Besides this business, Wacker is developing a new route for granular solar grade silicon by decomposing Trichlorsilane in a fluid bed reactor, thus reducing cost by using less energy and reaching a higher output per volume during the decomposition. Apart from Wacker, there is a JV between Degussa and SolarWorld which is looking for a better technology for Silan decomposition to reduce the cost of solar grade feedstock and increase capacities, while the demand for silicon is growing.

In 2003, the wafer production capacities were increased to 120 MW on mono- and multicrystalline wafers, beside a 7 MW increase of EFG-Si-ribbon produced by RWE Schott Solar. The main producer of multi- and monocrystalline wafers is Deutsche Solar; with a 78 MW production in 2003 and a capacity of more than 100 MW in 2004.

Since PV Crystalox is not disclosing their production capacity, it has been estimated at 30 MW in 2003. AS Industries, a newcomer, producing monocrystals and wafers at Arnstadt, started the wafer business with estimated 5 MW.

Cell production in Germany was boosted, nearly doubling to 100 MW from 58 MW the year before. The production capacities of the six players: Deutsche Cell, ErSol Solar Energy, Q-Cells, RWE Schott Solar, Shell Solar and Sunways are still increasing and could reach 165 MW in 2004, if the announced investments are realized. The biggest jumps in production were made by Deutsche Cell to 17 MW from 2 MW in the year before, also Q-Cells and RWE Schott Solar increased their capacities with new production lines.

Module production in 2003 was increased to 80 MW from 40 MW the year before and the involved companies announced another doubling to 160 MW in 2004. Companies with a production of more than 5 MW are: RWE Schott Solar, SMD (SolarManufaktur Deutschland), Solara, Solarfabrik, Solar Factory, Solarwatt Solar Systeme and Solon.

There are another 18 companies running production lines with small scale capacities or special products; for example, for the automobile industry or boat-energy supply.

In 2003, the marketing of 2 to 4 kW residential PV-systems expanded to 80 MW. A dozen of larger companies are creating the markets for PV-systems also in the sectors of public facilities and commercial buildings, standardizations of PV-systems of 10 to 500 kW scale and the development of novel type PV-systems is being promoted. SolarWorld, for instance, has developed a roof integrated PV-system certified by the German TÜV, that is reducing the cost of PV-systems by saving classical roofing tiles.

The inverter industry has created new systems with higher reliability and efficiency. In particular, SMA and Sunways are the leading companies in producing this equipment. The strong demand for all PV-systems in Germany will lead to a market of more than 1 Billion Euro including exports of silicon, wafers, cells, modules, components and whole systems. This turnover is equivalent to more than 20.000 jobs and shows the growing importance of renewable energy, especially photovoltaic, for the German economy.

Some of last year's highlights are summarised below (data based on companies' communiqués):

- In spring 2003, the first production line of RWE Schott Solar's SmartSolarFab™ went into full operation. Until end of 2004, a capacity of 60 MW solar cells based on the EFG film technology will be realised. This engagement results in a creation of 400 additional labour places.
- SOLON AG, a producer of PV modules, opened a new production line in May. In 2003, the production of 11 MW modules is expected. SOLON AG employs 100 workers.
- Q-Cells opened a new cell production line in October and by that, doubled its production capacity to 48 MW annually. 200 labour places were created within the last 3 years.

Fig. 1 - Cell Production Line of Shell Solar at Gelsenkirchen.
(Photo and copyright: Shell Solar)

- In October, Shell Solar increased its cell production capacity in Gelsenkirchen from 10 to 25 MW when opening the second pilot production line (see fig. 3). Upon achieving full production, 55 co-workers will be employed. This second line is an important step towards a 100 MW production capacity in Gelsenkirchen.
- In November, Solar Factory, a 100 % subsidiary of Solar World AG started operation. PV modules are manufactured using full automatic production equipment. In total, the Solar World group employs 500 people in Freiberg in the areas of wafer, cell and module production.
- Until January 2004, ErSol Solar Energy is going to double its cell production capacity to 25 MW annually. By doing so, the number of employees will rise from 100 to 120.

MARKET DEVELOPMENT INCENTIVES

The programmes described above have significantly accelerated the installation of PV-systems in Germany significantly. Following a first estimate there could be roughly 385 MWp on the grid at the end of 2003. In addition to the market of grid connected systems, there is an increasing demand for stand alone systems used; for example, for repeater stations along motorways.

FUTURE OUTLOOK

With the termination of the "100 000 Rooftops Solar Electricity Programme" at the end of 2003, the EEG was adjusted accordingly. Connected with those increased feed in tariffs, there is the hope for a steady growth of PV markets in the future.

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ISRAEL

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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.

About 500 kWp have been installed so far; 30 kWp were installed in 2002. Nearly all the applications are off-grid remote electrification systems. Most installations were made on an economic basis, the PV system being the most economically viable alternative (because of its distance from the electric grid).

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

A resolution adopted by the Government in November 2002 mandates that at least 2 % of total electric energy be generated from renewable sources by 2007, rising to 5 % by 2016. The decision might 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 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 are involved in photovoltaic R&D, most of them from academe, spread over most research areas (with no concentration of effort on particular subjects). Many of these teams cooperate with leading teams worldwide (both in academe and in industry).

Fig. 1 - One of eight irrigation-control stations operated by a PV system, near Natanya. (photo SolarPower Ltd.)

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

- A novel thin-film solar cell from carbon, in its new form of buckminsterfullerene(C_{60}), is being investigated at the National Solar Energy Center in Sde Boker.
- Scientists at the Weizmann Institute of Science have tackled the problem of the questionable stability of CdTe/CdS thin film solar cells, and are confident that they have solved the problem. The issue was and is a vexing one as these are the first truly thin film polycrystalline cells for which plants of several MW production capacity have been built.
- R&D activities at the Solar Energy Laboratory of the Jerusalem College of Technology are oriented toward industrial production together with efficiency improvement. They have been conducted in the framework of a EU 5th FP project and in cooperation with the PV Group of ENEA at Casaccia in Rome. Efficiencies achieved are in the range of 17,5 -20 %, depending on the quality of the starting Si material. Design and fabrication of bifacial cells are also emphasized.
- Long-term performance of various photovoltaic modules under desert conditions is being monitored at the National Solar Energy Center in Sde Boker.

Fig. 2 - 600 W PV system providing electricity for lighting, computing and medicine refrigeration at a bedouin community. (photo SolarPower Ltd.)

DEMONSTRATION AND APPLICATION

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

- Tel Aviv University is planning a 45 kW grid-connected system on the facade of a new building.
- Traffic and billing on the new Cross-Israel Highway is monitored by Traffic Probe Readers (TPRs) powered by PV panels. TV cameras read the car plate numbers and the system reports the information to the control center for billing the driver. 51 TPRs will be installed eventually. The system is the first of its kind in the world, and consists of a 220 Wp solar panel and a 400 Ah battery bank that can provide four days of autonomy. It was designed and built by Millennium Electric Ltd.
- The Israel Electric Corporation (IEC) is investing 1 million USD in a 30-home grid-connected demonstration project in the Negev. Each home will have a 3 kWp PV array, and the system will include inverters, meters and data-collection units. Through this project, called the "Solar Village," the IEC will investigate the operating regime, the impact on the local grid, the types of interconnections, the selection of suitable meters, etc.

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. Within its framework, the IEC is planning to erect a reverse-osmosis desalination unit powered by a PV array. In addition, the IEC will turn four single-family homes into grid-connected solar homes, each with a 2 kWp PV array. These installations will be a test bench toward the "Solar Village" project.

GOVERNMENT ACTIONS

As mentioned above, it is expected that the recent Government resolution establishing a minimum quota for electricity from renewables will 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 145,000 USD in 2003; however, additional funding is available in this area from other research foundations.
- Supporting grid-connected demonstration projects by up to 30 % of investment.

ITALY

PV TECHNOLOGY STATUS AND PERSPECTIVES

S. CASTELLO, ENEA
S. GUASTELLA, CESI

Fig. 1 - 9 kW installed under the roof-top Programme in northern Italy.

GENERAL FRAMEWORK

The Italian development and diffusion photovoltaic programme covers both all the main aspects of the technology, from the study of new materials up to plant operation and the dissemination programme implementation. Up to now, this context has led to such relevant results as:

- Approximately 26 MWp of PV power installed. rural electrification, off-grid non domestic application, on-grid centralized systems and on-grid distributed systems constitute the most important sectors of the Italian market, which is still showing a behaviour strongly dependent on subsidized projects;
- Two Italian manufactures, with a capacity production of about 5,5 MWp of both single-crystal and multi-crystalline modules and several small and medium size companies mainly involved in the design and the construction of photovoltaic plants;
- A continuous effort in research, development and demonstration. ENEA (the Italian Agency for New Technology, Energy and Environment) is the main operator, while CESI (Institute for research and certification of electric components and systems) and some universities are focussed on specific items;
- An ambitious dissemination programme (the Italian Roof-Top Programme), devoted to the realisation of grid connected photo-voltaic systems installed or integrated on buildings, financed and managed by the Ministry of Environment and the Italian Regions;
- A condsiderable budget for photovoltaics, that during the last year has reached the sum of about 25 MEUR (5 MEUR for R&D and 20 MEUR provided by both the Ministry of Environment and the Italian Regions in the framework of the Italian Roof-Top Programme);
- A growth of the popular acceptance for this attractive technology and of the real interest of end-users, photovoltaic operators and local utilities.

IMPLEMENTATION OF SYSTEMS

The cumulative installed power in Italy is, at present, about 26 MWp, of which 4 MWp was in the last year. Four different primary applications for photovoltaic power systems can be identified:

- Off-grid domestic systems (6,4 MW): this kind of application has been mainly promoted through an 80 % incentive in the period 1983 – 1990;
- Off-grid economic industrial applications (6,3 MW), which still dominate with a share of about 30 % of Italy's cumulative installed capacity;
- On-grid centralized systems (6,7 MW), sharply increasing at the beginning of 1990's in order to validate satisfactory solutions, for utility applications;
- On-grid distributed PV systems (7,6 MW), which have recorded a strong growth over the last year as benefiting incentives of the Italian roof-top Programme.

Fig. 2 - Rimini: 20 kW on a public building.

NATIONAL PROGRAMME

During these last years, the Roof-Top Programme represents one of the most significant measures in support of photovoltaics in Italy. In the first phase, launched in March 2001, a total budget of 40 MEUR has been provided by the Italian Ministry of Environment and the Regions, to finance:

- A National Programme, managed by the Ministry of Environment, concluded with the installation of 1,8 MW;
- Regional Programmes, managed at local level, still ongoing, with an expected capacity of about 5,5 MW.

Following the great success recorded by these initiatives, a second phase of the Programme has been officially approved and additional commitments are foreseen, funded by the Ministry of Environment and Regions; mainly:

- About 55 MEUR (July 2002), to continue financing the Regional Programmes (12 MW). In this context, priority is given to fully integrated roof-top applications while a decrease of the economic incentive and of the maximum cost allowed is foreseen. This phase of the programme has already started in 10 Italian Regions.
- 20 MEUR (March 2003), to support the realization of all the projects submitted in the framework of the National Programme (5,4 MW).

On the whole, the Ministry of Environment and Regions' incentives are activating an investment amount of about 175 MEUR, to install a total capacity of about 23 MW. Nevertheless, it is worth mentioning that despite very high public demand, the Programme is experiencing rather slow growth due to ongoing bureaucratic issues.
As a consequence, at the end of 2003, only about 6,5 MW out of the anticipated 23 MW have thus far been installed. In this perspective, ENEA is providing the technical support to the Ministry of Environment in the definition of plant technical features and in data monitoring. In addition, ENEA is carrying out R&D activities on distributed generation, in order to contribute to reaching the long term objectives of the whole initiative.

R&D AND DEMONSTRATION

The Italian R&D programme supports the development of new materials, devices and system components, as well as the performance evaluation of photovoltaic systems. These activities are mainly conducted by ENEA and CESI, while some topics are carried out in cooperation with the PV industry.

ENEA is the main research organisation operating in Italy. Its most significant R&D activities concern laser assisted processes, buried contact and selective emitter technology, advanced screen-printing, and the setup and optimization of fabrication processes of several kinds of innovative cells.

In the near future, a-Si based multi-junction thin film devices are still a main line of activity which aims to improve the stabilised efficiency of integrated large area modules. A new cluster tool was recently installed to begin a new investigation on poly-Si thin films; Hot Wire CVD and VHF PECVD will be utilized to obtain device quality poly-Si with low process temperature and high growth rate. ENEA is also involved in the a-SiNET and the European project, PV-EC-NET.

Moreover, in the field of a-Si/c-Si heterojunction, a cooperation between Eurosolare, ENEA and some other European operators, is currently carried out in the framework of the "MOPHET" Programme; which is 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."

In the systems and components sector, activities on small grid-connected plants, as prototypes of roof mounted systems are carried out by ENEA in the Monte Aquilone test facility, in Portici Center and on some pilot plants installed all over Italy. Performances of these plants are analyzed in terms of energy output, energy losses, power quality, operation and maintenance procedures. Analysis and tests on medium and large power plants have been carried out by ENEA on Delphos 600 kWp and Casaccia 100 kWp grid-connected plant. Last, but not least, ENEA is working on a new programme based on concentration, the PhoCUS (Photovoltaic Concentrators to Utility Scale) Project, aimed at investigating concentrators technologies and assessing the technical and economical feasibility of this application in Italy, for the centralised generation of electricity.

Concerning the demonstration and testing aspects of this project, it is expected that 5 standard units (5 kW each) will be installed in the Enea Monte Aquilone test facility in the early 2004.

CESI is an institute for R&D and services in the electric sector, which belongs to the Italian electrical operators (institutions, utilities and electromechanical manufacturers). In the year 2000, with the liberalisation of the Italian Electrical System, the research department of ENEL (formerly the National Electric Utility) was incorporated in CESI. Since then, CESI, supported by Italian Government, is strongly involved in the technological innovation of the electric sector and consequently, also in development and testing of advanced renewable energy sources for the Italian Electric

System. Within this field of activity, photovoltaic conversion plays an important role. Basically the following types of activities are carried out by CESI in this field:

- Development and industrial manufacturing of high efficiency solar cells for space and terrestrial applications, based on GaAs compounds;
- Analysis and testing of PV modules based on advanced solar cells (thin films, amorphous silicon, etc.) and innovative components (e.g. inverters);
- Analysis and testing of hybrid systems;
- Support to the clients for installation, management and cost analysis of PV systems.

In the frame of GaAs space solar cells, CESI is one of the leader companies in Europe having supplied bare solar cells for 24 small and medium size satellites, worldwide. Single junction GaAs solar cells are presently manufactured using metal-organic chemical vapour deposition (MOCVD) large size industrial equipment. 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 at investigating the expected cost of the Wp using advanced high efficiency solar cells derived from space technology and is suitable for converting sunlight with an efficiency close to 30 % at concentrator values above 300 suns. Several concentrator PV test modules are being manufactured using composite Fresnel lenses.

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 the systems field, CESI has been involved in the development and manufacturing of the main PV installations in Italy, for many years. Present activities in this field are the PV roof projects as well as the manufacturing of faced and stand alone systems. CESI is currently involved in development and evaluation of innovative RE hybrid systems for electrification of remote villages. An experimental test field is available at CESI outdoor laboratories in Milan, to evaluate different components for hybrid systems, whereas the installation of an experimental plant is in progress in a mountain area of North Italy. Furthermore, performance evaluation of photovoltaic components and plants are currently carried out by CESI on several PV plants in order to assess long term behaviour of PV technology in different climatic conditions and in different electric configurations.

INDUSTRY STATUS

The Italian PV industrial system consists of two module manufacturers, some inverter manufacturing firms and several operators in the field of design, construction and commercialisation of PV plants.

The major PV module manufacturer is Eurosolare. Its manufacturing facilities have a production capability of 3 MWp/year per shift. Both single-crystal and multi-crystalline silicon cells are currently produced; in particular, the multi-crystalline module manufacturing process is completely integrated starting from the ingot fabrication, while single-crystalline modules are based on wafers bought on the international market. Moreover, the Eurosolare production also includes specially designed modules for roof-tops and facades.

The other module manufacturer is Helios Technology with a production capability of 2,5 MWp/year. Helios Technology module manufacturing process comprehends the fabrication of cells and modules from mono-crystalline silicon wafers.

Additionally, other small companies are assembling and encapsulating tailor-made modules, especially designed modules such as windows, integrated cells and the use of coloured cells can be found in Italy.

In the field of BOS components, about 15 companies manufacture inverters for on-grid and off-grid applications. Some of these have experience in inverters for large PV power plants, while others have produced 1,5-10 kVA inverters under Electric Utilities specifications. There are four main Italian battery manufacturers with a specific experience in the PV sector. All of these manufacturers produce stationary lead-acid batteries with a low content of antimony, in order to reduce the self-discharge. The rated capacity range from a few Ah to about 3 000 Ah.

Finally, an estimation of the number of companies that install PV systems in Italy now reaches 100 units. These are specialist PV companies offering consultancy, installation services and component delivery. These include the ENEL 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 unfavourable situation, experienced in Italy during these last years, mainly due to the electrical market liberalisation and the privatisation of ENEL, is eventually moving towards a new positive cycle. Some indications come from the initiatives of the European Union, the renewed interest in PV of some Italian operators, as well as the strong involvement and commitment of both the Ministry of Environment and Local Authorities in supporting the Italian Roof-Top Programme. However, in any case, there is strong expectation in the PV Italian market, due to the very recent approval by the Italian Government of a decree, concerning the implementation of the European Directive 2001/77/CE, which foresees also the feed-in tariffs.

JAPAN

PV TECHNOLOGY STATUS AND PROSPECTS
YUKAO TANAKA
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DEVELOPMENT ORGANIZATION (NEDO)

Fig. 1 - 45-kW PV system and the rooftop garden of the Central Governement Building No. 4, Tokyo.

GENERAL FRAMEWORK

The promotion and deployment of photovoltaic (PV) systems have been implemented through the foresight for new energy in "Long-Term Energy Supply and Demand Outlook" prepared by the Advisory Committee for Natural Resources and Energy. Japan's target volume for PV system introduction by FY2010 was set to 4 820 MW. The Ministry of Economy, Trade and Industry (METI) has been actively driving forward the promotion measures and policies 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 energy. "The Renewables Portfolio Standard (RPS) Law," newly established in 2002, which obliges energy suppliers the use of certain percentage of renewable energy, was thoroughly enforced in 2003. In addition, the Japanese Government 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 addition to these, the "Law Concerning the Promotion of Measures to Cope with Global Warming" and the "Law on Promotion of Green Purchasing" were enacted.

NATIONAL PROGRAMME

The Japanese Government has implemented R&D, demonstrative projects, dissemination measures, and law enactment towards the achievement of targeted introduction capacity of 4 820 MW of PV systems by FY2010. In the field of R&D, technical development for cost reduction of PV systems, development for PV promotion and research of innovative next generation technologies have been carried out. Regarding demonstrative research, a new programme, Field Test Projects on Advanced Photovoltaic Power Generation Technology, has started to demonstrate the effectiveness of PV systems employing new PV modules, new components, advanced system technology and newly developed installation methods, etc. and enlarges the application area of PV systems. As for dissemination policy, Residential PV System Dissemination Programme was 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 FY2003 are as follows;

1. Research and development of photovoltaic power generation technologies: 7 420 MJPY
2. Residential PV System Dissemination Programme: 10 500 MJPY
3. PV Field Test Programme for Industrial Use: 260 MJPY
4. Field Test Projects on Advanced Photovoltaic Power Generation Technology (New): 3 500 MJPY
5. Demonstrative Research on Clustered PV Systems: 2 370 MJPY
6. Project for Supporting New Energy Operators: 38 810 MJPY
7. Project for Promoting the Local Introduction of New Energy: 12 710 MJPY
8. Project for Establishing New Energy Visions at the Local Level: 1 320 MJPY
9. Project for Promotion of Non-profit Activities on New Energy and Energy Conservation: 1 140 MJPY
10. Project for Supporting Regional Activities for Prevention of Global Warming: 590 MJPY

The budgets for items 6), 7), 8), 9) and 10) include ones for PV and other new 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, the "5-Year Plan for Photovoltaic Power Generation Technology Research and Development (FY2001-FY2005)," was launched in FY2001, based on results obtained thus far. The programme aims at: early establishing PV technology for realization of approximately the same generation cost as the electricity rate; developing common basic technologies necessary for full-scale deployment of PV applications; and developing essential technologies of PV cells and PV systems based on new concepts. The development areas of the programme are classified into the fields as stated above. The specific programmes in progress are as follows; the short- and medium-term targets are (i) technological development of advanced PV cells (thin-film Si solar cells, thin-film CIS solar cells and InGaP/InGaAs/Ge solar cells), (ii) development of technology focused on PV promotion (large area a-Si solar cells, thin-film mc-Si solar cells, mc-Si substrate, etc.) and (iii) development of common base technology necessary for mass dissemination of PV applications (performance evaluation of solar cells, PV modules and PV systems, recycle and reuse technologies of PV systems, etc.). The long-term targets are research and development of innovative next generation technologies for

Fig. 2 - PV systems installed in the curtain wall (8,5 kW) and the rooftop (31,5 kW) of the Tsuzuki Post Office, Yokohama City, Kanagawa Prefecture.

Fig. 3 - 160-kW PV system installed in the upper part of the exhibition all and 20-kW window-integrated PV system in the Disaster Reduction and Human Renovation Institute, Kobe City, Hyogo Prefecture.

PV systems (Cat-CVD process, nano-structure silicon solar cells, dye-sensitized solar cells, spherical microcrystalline silicon solar cells, carbon-based thin-film solar cells, organic thin solid film solar cells, chalcogenide solar cells and III-V-nitride thin-film solar cells).

DEMONSTRATION

Main demonstration programmes implemented by METI in FY2003 were "PV Field Test Programme for Industrial Use," the "Demonstrative Research on Clustered PV Systems," and the "Field Test Projects on Advanced Photovoltaic Power Generation Technology," which was newly started in FY2003.

PV Field Test Programme for Industrial Use

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 at schools, medical facilities, welfare facilities, factories, office buildings and private-sector facilities by the end of FY2002. Collection and analysis of the data has been conducted since FY2003.

Demonstrative Research on Clustered PV Systems

This programme started in FY2002 for a 5-year scheme in order to conduct demonstrative testing of large-scale and the intensive introduction of grid-connected PV systems equipped with storage batteries. It aims at establishing grid connection technologies for centralized grid-connected PV systems intensively installed in one area. The specific research objectives are 1) development of technology to avoid restriction of PV system output, 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. The demonstrative researches will be carried out by installing residential PV systems and batteries to 200 residences in FY2003 400 in FY2004.

Field Test Projects on Advanced 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 a trial basis and promoting improvement of performance and cost reduction of the PV systems. This programme is regarded as a succeeding program of PV Field Test Program for Industrial Use. 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 the programme. A total of 157 projects with 4 820 kW were selected in FY2003.

IMPLEMENTATION

The Ministry of Economy, Trade and Industry (METI)

The main implementation programmes that were carried out in FY2003 were the "Residential PV System Dissemination Program," the "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 the "Residential PV System Dissemination Program" in FY1997, in order to develop the initial residential PV system market. The programme continues to be actively promoted. The total number of PV systems installed under these programmes exceeds 150 000 systems. This programme aims at reducing the installation cost of 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 who is going to install PV system to his own house, ii) a ready-built house supplier of housing developments and iii) a local public organization that is going to introduce PV systems to public housing. PV systems

Fig. 4 - Residential PV systems intensively installed in a housing development, Sapporo City of the Hokkaido Prefecture.

with 9,99 kW of the maximum output capacity, connected to low voltage grids and allowing reverse power flow qualify for the programme.
The amount of the subsidy in FY2002 was 100 000 JPY/kW, but it was decreased to 90 000 JPY/kW in FY2003.
Residential PV systems have been installed to 77 503 houses, a total of 280,0 MW from FY1994 to FY2001. In FY2002, for 42 837 houses, a total of 161,8 MW were installed. In FY2003, 42 811 applications for the programme were accepted, as of December 26, 2003.

Project for Promoting the Local Introduction of New Energy

This programme aims at accelerating new energy introduction by supporting the regional projects that local governments developed for introducing new energy. Subsidy is provided for local public organizations that are going to introduce and promote 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 waste fuel, clean energy vehicles and energy conservation measures.
PV systems with 150 kW output capacity and over are qualified under the programme. Half of the installation cost is subsidized. 118 systems in total were subsidized from FY1998 to FY2001. Out of these, 52 systems were PV systems. The total capacity installed was 7 039 kW. In FY2002, 57 systems in total were qualified and out of these, 21 systems were PV systems. Total capacity installed was 2 391 kW. In FY2003, 101 systems in total were qualified and 70 systems out of them were PV systems. Total capacity installed was 3 311 kW. The programme allows local governments to understand the benefit of the introduction of renewable energy and then introduce PV systems intensively to school buildings and public facilities 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, 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 businesses are eligible for guaranteed debt or subsidization. A third of installation costs are subsidized, and 90 % of the debt is guaranteed. The capacity of eligible PV systems is 100 kW and over. 110 systems in total were qualified from FY1998 to FY2001, and 3 of these systems were PV systems with 356 kW in total. In FY2002, 25 systems were qualified and one of these systems was a 25-kW PV system (installed with other new energy systems). In FY2003, 39 systems were qualified; 2 systems were PV systems and the total installed capacity was 217 kW.
Besides these programmes, support has been offered to local governments for the projects to develop their own visions for the introduction of new energy and to nongovernmental organizations (NGOs) supporting activities to introduce new energy at local level.

The Ministry of Land, Infrastructure and Transport (MLIT)

Under the "Guideline for Planning Environmentally-Friendly Government Building (Green Building)," construction of green government buildings with PV systems has been promoted. The introduction of PV systems with 455 kW in total was completed in 13 central government office buildings as of June 2003.

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

The Ministry continues its "Eco-school Promotion Pilot Model Project" initiated in partnership with METI in FY1997 and is promoting the introduction of PV systems to elementary schools, junior high schools and kindergartens in Japan. 244 schools all over Japan were designated as pilot model schools by FY2002, and each of the 161 schools among them installed PV systems with 10 kW and over. In FY2003, 97 schools were designated as pilot model schools and PV systems are to be installed to 68 of these schools.

The Ministry of Environment

The Ministry is promoting projects of CO2 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 the "Law on Promotion of Green Purchasing" in April 2001, and commodities procured by the national and local governments have to be replaced with 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 started the Community-Based Eco-House Project to demonstrate various types of technologies to prevent global warming, while suitable for specific regions and introduced PV systems to the Eco-Houses.

Local Governments and Municipalities

The movement to actively work on environmental issues has been spreading among the local governments and municipalities. Some prefectures began to set their own target for the introduction volume of new energy following the national target for PV system introduction (4 820 MW). More and more local authorities began to develop their own new energy introduction visions and plan

Fig. 5 - 10-kW PV system installed as a canopy over the entrance of the Jin-ikai Hospital, Sankyokai Medical Corporation, Oita City of the Oita Prefecture.

the introduction of PV systems into public facilities and public housing. Some local governments and municipalities also provide their own additional subsidies to the national subsidy for residential PV systems and the number of these local governments has been increasing, year by year. Promotional supports to PV systems are enhanced at local governments and municipalities. In 2003, a total of 262 local governments provided subsidies for residential PV systems.

Utilities

Electric power companies 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. As of the end of March 2003, the PV power generation capacity installed in their facilities was 4 511 kW and the power bought by buy-back contract was 182 136 MWh in total.
Electric power companies in Japan established the "Green Power Fund" in October 2000; which aims at introducing and promoting PV systems and wind power generators. The utilities bill an additional charge as a contribution at 500 JPY/share/month to their supporters among their customers, and contribute the same endowment as the amount of their supporters' contribution for the installation of PV systems and wind power generators. From 2001 to 2002, 126 public facilities across Japan including schools were subsidized through the Fund. The total capacity installed was 2 260 kW. In 2003, 159 public facilities were selected, and installation of PV systems with 2 856,1 kW in total are underway.

Financing Institutes

Some banks and other financing institutes provide preferential financing at a low interest rate, for the introduction of residential PV systems for private use.

INDUSTRY STATUS

The PV industry has been rapidly growing toward achieving 1 000 MW of annual installed capacity of PV systems in 2003. The annual production of solar cell and PV modules in Japan reached the 100 MW level in 2000, and it increased to a 300 MW scale in 2003. 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 from the user's point of view, 5) new entry to the PV business in the domestic market, 6) advancing the establishment of overseas PV module plants and 7) the acquisition of international certification of PV modules in the overseas market. Among these movements, it should be noted that new activities which correspond to the growth of the PV market mainly pushed by the expansion of residential PV systems, have been carried out one after another. This includes enhancement of the production capacity and the construction of new manufacturing facilities by PV manufactures, new entry to the PV market by several companies, etc. As for the activities of PV manufactures in 2003, the following points are noteworthy.

Sharp raised its production capacity to 248 MW/Year from 200 MW/Year, and constructed a PV manufacturing plant with 20 MW/Year of production capacity in Tennessee, USA. It also plans to construct a 20 MW/Year scale of PV module manufacturing line in the UK in 2004. Kyocera started operation of a PV module manufacturing plant with 12 MW/Year of production capacity in Tianjin, China. It announced that it would increase the production capacity of mc-Si solar cells and PV modules to 120 MW/Year in 2004 from 72 MW/Year. Sanyo Electric newly constructed a manufacturing plant for a-Si/sc-Si PV module with 33 MW/Year of production capacity, and increased the total production capacity from 30 MW/Year to 63 MW/Year. It also started operation of a 10-MW/Year PV module factory in Mexico. Mitsubishi Electric also raised the annual production capacity of mc-Si solar cell from 35 MW/Year to 50 MW/Year and plans for further expansion to 90 MW/Year in 2004. It also provides original equipment manufacturing (OEM) solar cells for an overseas company. Kaneka and Mitsubishi Heavy Industry also increased the production volume, and plan to expand production capacity of a-Si/mc-Si solar cells. Showa Shell Sekiyu, a PV module manufacturer, enhanced their partnership with Shell Solar GmbH more closely and decided to spin off its PV division into Shell Solar Japan, in order to increase its share of the market. MSK expanded its PV module line and established a production system with 100 MW/Year of production capacity.

As for new entrants, Hitachi started to operate a 6 MW/Year manufacturing plant of bifacial PV modules. Fuji Electric started the business of flexible a-Si PV modules. Honda Motor advanced its business of Cu(In,Ga)Se2 (CIGS) solar cells. Sekisui Jushi plans the business of highly efficient sc-Si PV modules in cooperation with Sunpower of the USA. Moreover, Aishin Seiki, Showa Denko and other various companies are developing dye-sensitized solar cells, and consider establishing the solar cell business. In addition, venture companies appeared to enter the business of silicon wafer manufacturing for solar cells.

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

Sub-market application	1998 kW	1999 kW	2000 kW	2001 kW	2002 kW
off-grid domestic	450	500	550	600	650
off-grid non-domestic	52 300	56 200	63 000	66 227	71 997
on-grid distributed	77 750	149 000	263 700	383 086	561 295
on-grid centralized	2 900	2 900	2 900	2 900	2 900
TOTAL	133 400	208 600	330 220	452 813	636 842

MARKET DEVELOPMENT

New opportunities and application areas of solar cells, PV modules and PV systems have been created through the Residential PV System Dissemination Programme and field test projects initiated by METI. The PV market in Japan consists of following 5 market segments: 1) residential 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 PV market with 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 annual sales of 50 000 to 60 000 systems. Thus, PV manufactures place great importance on development of PV modules for houses and released PV modules with higher conversion efficiency, small-sized PV modules which can increase installation areas on roofs, lead-free PV modules, etc. Leading housing manufacturers are creating a new market for residential PV systems by developing all-electrified houses equipped with PV systems and zero-energy 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. In the area of industrial and business facilities and 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 capacity have been increasing. To correspond to these movements, inverter manufacturers commercialized 100 kW inverters and small-sized 10 kW inverters, which 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 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. Flexible type modules, lightweight modules, light-transmitting modules, bifacial power generation modules, roofing material-integrated modules and wall-material integrated modules are used as well as conventional ones.

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, and lighting. Recently, lighting fixtures combining light emitting diodes (LEDs) and solar cells and small-scale hybrid power generation systems combining wind power generators and PV systems have been commercialized one after another.

As for new developments of the PV system market, development of power supply systems for communities utilizing distributed power generation systems was started. Demonstrative projects to intensively install on-grid PV systems to houses in one area and other demonstrative projects to install 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 to each community were started. Table 1 shows the cumulative PV power installed by the end of 2002 in 4 sub-markets.

FUTURE OUTLOOK

With the Government's support 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 promoted the introduction of PV systems. With the growth of the PV market, PV manufacturers make an effort to expand their production capacity and to 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. In addition, 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 sectors of residential houses, public facilities, industrial and business facilities, is expected to expand, to grow and to be a self-sustainable market in the near future by achieving cost reduction with the Government's support for research, development and the introduction of PV systems.

METI has started to revise the Long-Term Energy Supply and Demand Outlook with an eye to FY2030 and deliberate the policies on energy and environment, as they ought to be. The future of new energy is also discussed under the revision; and the long-term energy supply and demand outlook of new energy will be plotted out in FY2004.

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 a 3 % share of New and Renewable Energy by year 2006; with 5 % by year 2012. In order to achieve this target, an aggressive approach must be taken to create the market and to expand market size. With the limited amount 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 large potential in the reduction of environmental pollution has been selected as a high priority programme.

NATIONAL PROGRAMME

The first and most significant instrument for the promotion of renewable energy was the "Promotion Act for the New and Renewable Sources of Energy (NRSE) Development," enacted in December 1987. This act aimed at concerted action at the national level in order to diversify energy sources available and to reduce the air pollution caused by the use of fossil fuel.

In January 1997, the Government formulated the "Ten-year National Plan for Energy Technology Development (1997-2006)" which included New & Renewable Energy, Energy Conservation and Clean Energy Technology. This plan aimed to supply 2 % of the total primary energy demand with New and Renewable Sources of Energy at the end of 2006. To legally support and realize this plan, the "Promotion Act for NRSE Development" was amended to the "Promotion Act for NRSE Development, Utilization and Dissemination," which put greater emphasis on enhancing the utilization and dissemination of developed technologies than the previous version. Photovoltaics has always had a high priority among various New Renewable Energy technologies.

During the last 15 years under this framework, a steady investment in PV has been made, as shown in Figure 1. The total R&D funding during this period amounts to 27,4 MUSD (16,2 MUSD from government and 11,2 MUSD from industry). In particular, R&D funding has been increased very sharply since 2001, which shows the Korean Government's strong willingness to materialize technology development and market expansion.

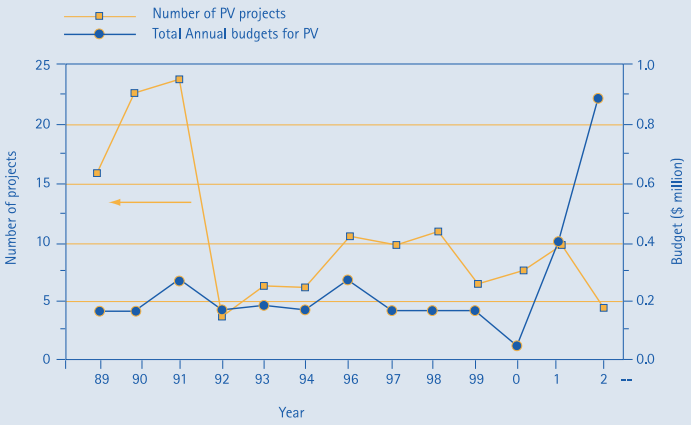

Fig. 1 – PV budget over the last 15 years.

The new plan for the technological progress is divided into three different steps, while focusing on developing the technology for mass distribution and commercialization of PV.

Step 1 (2001-2006)

Development of technologies for promoting the distribution of PV:

- 3 kW PV system for residential homes (2001-2004).
- 10 kW PV system for public and commercial buildings (2004-2006).
- Mass production of inexpensive and reliable products.
- Core technology for the next-generation thin-film solar cell.

Step 2 (2006-2009)

Development of technologies for mass distribution of PV:

- Unit process for ultra-thin crystalline Si solar cells.
- Solar modules for ultra-thin crystalline Si solar cells.
- Standardized PV system units for commercialization.
- Technology for commercializing the next-generation thin-film solar cells.

Step 3 (2009-2012)

Development of technology for inexpensive products:

- Commercialization of the ultra-thin crystalline Si solar cells.
- Mass production and commercialization of thin-film solar cells.
- Enhancement of the value and the potential performance of PV system.
- Technology for commercializing the standardized PV system packages.

In the short-term, PV cell R&D is focused on crystalline silicon. The target is to increase the 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, we will commercialize developed technologies with targets by the year 2012.

In terms of the technical aspect, Korea is also preparing the certification system for PV components and systems. Under this framework, the Korea Institute of Energy Research (KIER) was designated as the official center for performance testing and evaluation. During the period 2002-2004, certification systems for PCS, PV modules and PV cells are to be set up.

In addition, the MOCIE has been supporting "Green Village" project for the demonstration and field-test of PV systems. Currently two cities (Gwangju, Daegu) are involved in this project, and two more local authorities are expected to take part in this project within this year. The local authorities, in cooperation with the Government, play the leading role in the design, construction and monitoring of PV rooftop systems and other solar application facilities.

In addition to the projects listed above, there are three representative and supportive activities for technical development to be introduced here. One is a standardization activity to comply Korean Industrial Standards (KS) with the IEC; which represents international standards. International collaborative projects, such as field testing of PV power systems implemented in developing countries such as Mongolia and Vietnam, are another. Activities both to strengthen the IEA/PVPS programme and to found a cooperative scheme with neighboring countries, is the third.

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, as a collaborative project, named DURE-Gobi Project with Mongolia.

Moreover, the "Renewable Energy Forum in North-East Asia" has been established and held in Seoul, in November 2003, in order to realize actual cooperation among Korea, China, Japan and Mongolia.

Fig. 2 - PV - Wind hybrid system in Mongolia.

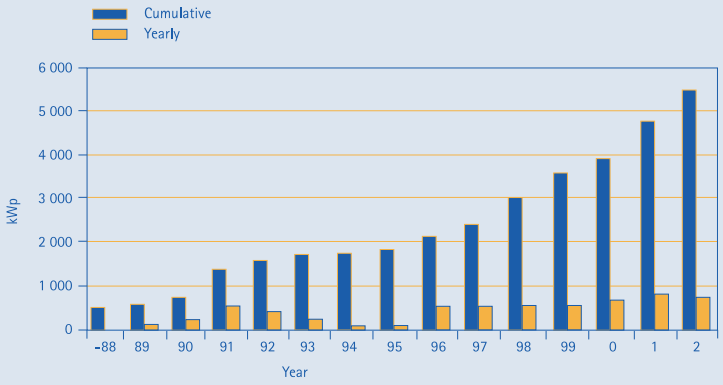

Fig. 3 - The total cumulative capacity of PV systems in Korea.

IMPLEMENTATION

The PV market was still dominated by the off-grid non-domestic sector that occupied about 77 % 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. In 2002, marine applications were the largest sector of application, followed by highway emergency call boxes and streetlight lamps. Other important applications include PV systems for the aviation warning lamps of high-voltage transmission towers, environmental monitoring equipment such as water-borne pollution, sewage, weather and traffic signaling and forest fire monitoring.

For off-grid domestic application, three PV systems with a total capacity of 85 kW were installed at remote islands in 2002. The share of this sector is about 9 % of the total cumulative installed PV power.

In 2002, more than 20 grid-connected distributed systems with a capacity in the range of 3 kW to 53 kW were installed. Among them, 16 systems were for public office buildings and 5 systems were rooftop systems for residential houses. The share of grid-connected distributed system was raised to 14 % of the total cumulative installed power. In 2002, the total installed power of this sector was 237 kW, representing 36 % of the total PV market. In 2001, only

Fig. 4 - PV - Wind hybrid system at Ieodo.

systems with a total capacity of 168 kW were installed. This sector has been intensively promoted under the framework of demonstration projects or local energy development projects supported by the government and local authorities.

Under the local energy development project, a wide variety of PV systems including off-grid domestic, non-domestic and grid-connected systems were constructed. The focus was put on grid-connected distribution systems owned by local authorities, public organizations and individuals. A 53 kW grid-connected system installed on the roof of the Chosun University's dormitory building and a 30 kW system installed on the roof of the Energy Pavilion at the site of the International Cave Exposition in the city of Samcheok, Gangwon Province, were representative examples. At the Cave Exposition site, a 107 kW system has already been constructed in 2001. In addition, two PV-diesel hybrid systems with a PV capacity of 60 kW and 22,5 kW, respectively, were constructed and began operating during 2002.

The total cumulative capacity of PV systems in Korea was 5,418 kWp at the end of 2002, and the installed capacity in 2002 was 475 kWp as shown in Figure 2.

INDUSTRY STATUS

There has been no major change in the status of PV cells and module production in 2002. Until 1999, High Solar Company (independent from former LG Siltron Co. in May 1999) continued to manufacture PV cell, but this company stopped its operation in the year 2000. In 2001, there was no PV cell manufacturer in Korea. However, two new companies, Neskor Solar and Photon Semiconductor & Energy after having completed the construction of PV cell manufacturing facility, started its operation in 2002. These companies with a production capacity of 1,2 MW produced 300 kW of single crystalline silicon PV cells in 2002. Over half of the products were exported and a part of the products were supplied to domestic PV module manufacturers. Recently, Photon Semiconductor & Energy has expanded production capacity to 6MWp and single crystalline silicon PV cells, since the end of 2003.

Five companies, including one which started its operation in 2002, produced about 780 kW of PV modules. The production volume was 10 % less than that of last year. Most of single and multi-crystalline silicon PV cells were imported from foreign countries. In 2002, the total production capacity was 2 000 kW(I shift). In the previous year the production capacity was also 2 000 kW and production volume was 850 kW.

S-Energy (Independent of former Samsung Electronics Co.) manufactured four types of modules with a peak output of 50 to 80 W using mc-Si PV cells imported from BP Solar. The 75 W has a dimension 1 204 L x 538 W x 38 mm D, and a structure glass/EVA/solar cells/EVA/tedlar. This company announced the completion of development of rooftop PV modules and started field testing of these modules in 2003. This company is planning to install large size laminator for the manufacturing of large size module. LG Industrial System Co. produced various types of PV modules with a peak output power in the range of 43 to 100 W using sc-Si PV cells imported from Siemens Solar Industries in USA. The module has a typical structure of glass/EVA/solar cells/EVA/back sheet, which is similar to that of S-Energy. Haesung Solar manufactures small PV modules with an output power ranging 1 to 50 W using PV cells; of which one part

is purchased from Neskor Solar, and some that are imported from abroad. The module manufacturing process is also similar to that of the former two companies.

Two companies manufacture the inverters for grid-connected systems: Hex Power Systems and Samwha Engineering. The former produced various products with a capacity 1 – 50 kW. These companies also produce the inverters for stand-alone systems. The price of inverters for grid-connected applications is shown in Table 5. In the case of inverters for stand-alone systems, Dongmyung Electric has manufactured several types of inverters for electrification, as well as Solar Home Systems, in developing countries. There is one PV battery manufacturer, Global High-tech Co., that produces lead-acid batteries of the tubular plate stationary type. The unit price of the battery with a capacity 2 000 Ah/100 hr is 910 KRW. Concerning the supporting structures, PV system installers used their own type of support structures made from anodized aluminum 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 changed to 100 000 roofs and 70,000 buildings. This means a total capacity of 1,3 GW by the year 2012. The total capacity is broken down in different sectors as shown in Fig. 3. 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. Figure 5 shows that an explosive growth of the market will occur between 2006 and 2012 once the foundation is set up by the year 2006. The Korea government recognizes that PV industry will grow and take up to 10 % of the world market by the year 2012, with exports amounting to $ 3 billion and the employment of 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 installing the 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.

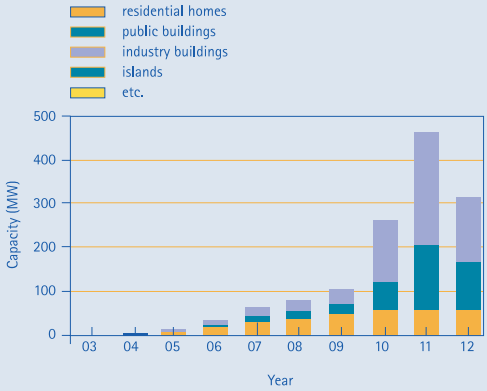

Fig. 5 - Dissemination of the PV systems over the next 10 years.

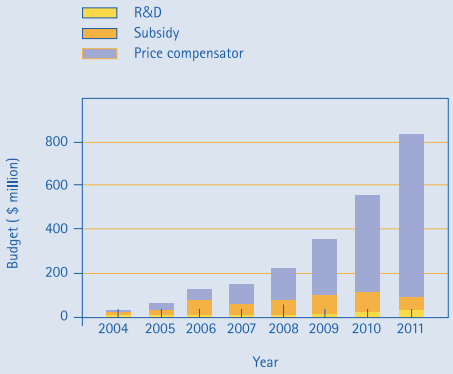

Fig. 6 - Budget for the national PV R&D and Dissemination.

To fuel the plans and strategies as mentioned above, Korea will spend about USD 2,3 billion during 2004-2012. (Refer to Fig. 6) The fund will be provided by the government. As the PV world market grows fast, the investment from the industry is expected to increase at a fast pace.

MEXICO

PV TECHNOLOGY STATUS AND PROSPECTS IN MEXICO
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ELECTRICAL RESEARCH INSTITUTE (IIE)

GENERAL FRAMEWORK

Rural electrification continues as the main but not the only PV use in Mexico. Professional installations within the national oil company to power non-manned oil rigs and telecommunications repeating stations at difficult access sites, are some of the applications where PV technology competes with traditional energy supplies. Small water pumps have been installed to irrigate small agricultural land, livestock watering and fence energizing. No further grid connected systems were set up during 2003, but performance monitoring continues.

NATIONAL PROGRAMME

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

RESEARCH AND DEVELOPMENT

Grid-Connected PV R&D activities continued during 2003. Systems' follow-up and monitoring were the main activities carried out. The research work in this area focused on inverter reliability and the impact of the grid tied PV systems on distribution transformers.

The research on PV-wind hybrids focused on the monitoring and data analysis of the San Juanico Hybrid system. This system provides energy to a fishing and tourism services provider community located on the Pacific coast of Baja California. The research work has been carried out by the Mexican national utility Comisión Federal de Electricidad (CFE) in collaboration with Arizona Public Service, a US-based utility.

During 2003, the Mexican Utility (CFE) supported a project to evaluate more than 100 Solar Home Systems installed over 10 year ago in three isolated communities located in the mountains of the western state of Nayarit . The relevance of the project resides in the fact that those systems are the first ones to be evaluated 10 years after their installation. The results from this study will help determine the effectiveness and usefulness of PV as an alternative for rural electrification, and will point out the problems arising both on the technical and non-technical side of the PV technology.

IMPLEMENTATION

No progress has been reported on the second stage of the PV Rural Electrification Programme announced by the Federal Government early last year. Nevertheless, installation of SHS continues its historical trend; which is now carried out mainly by municipal governments and the private sector. State governments continue using PV to provide energy to remote schools and rural clinics in areas where the national grid is not available. In the telecommunications sector, PV continues to be used to energize remote links, repeaters and satellite telephone services. The Shared Risk Trust Fund of the Federal Secretariat of Agriculture and Livestock FIRCO

Fig. 1 - Los Sabinos Nayarit PV Rural Electrification Project.

Fig. 2 - Colorado de La Mora Nayarit PV Rural Electrification Project.

(as known by its Spanish abbreviation) is carrying out projects for water pumping, electric fences, and cold tanks for milk storage. FIRCO is also providing training courses on productive uses of PV. These activities are co-financed by the Global Environmental Facility (GEF), the Federal Government and the beneficiaries. Under this programme during 2003, around 400 PV water pumping systems were installed, with an installed power capacity of more than 200 kW. FIRCO also offered 20 training courses on PV water pumping or productive uses of PV.

INDUSTRY STATUS

Mexican companies continue leading the PV installations and sales in the country, but joint ventures between foreign and local companies are taking place in order to respond to the market needs. PV modules continue to be imported from abroad, while BOS for off-grid systems is manufactured in the country.

Fig. 3 - Rural Health Clinic powered by PV.

MARKET DEVELOPMENT

The Mexican PV market for 2003 was close to 1 000 kW. The market segmentation was as described. Rural Electrification remains the main application for PV in Mexico, with an installed capacity of 620 kW; professional applications (telecommunications, off shore oil platforms and cathodic protection) 240 kW; water pumping 80 kW; and others 8 kW. The cumulative PV installation in Mexico by the end of 2003 was 17.1 MWp. The numbers reported here do not include the sales of PV modules and systems taking place along the Mexico-USA border cities, where no record of imports is kept, due to the tax-free status of the region.

FUTURE OUTLOOK

Distributed generation is entering the scene in this country as an alternative to solve a number of problems facing the electrical sector. It is expected that grid-connected PV will have a role to play, so that current R&D efforts will have to move forward to tackle market penetration issues. Rural Electrification is also expected to regain its importance in the coming years. SHS will continue to be the preferred technical and economical alternative to provide electricity for the thousands of isolated communities in Mexico, still lacking this service.

THE NETHERLANDS

PV TECHNOLOGY STATUS AND PROSPECTS

JOB SWENS, NOVEM, WILLEM VAN DER HEUL, MINISTRY OF ECONOMIC AFFAIRS

GENERAL FRAMEWORK

In 2003, the investments in solar PV in the Netherlands were exceptionally high, especially by private house owners. This was due to several reasons. Starting January, no construction permits were needed for installing PV systems. Also, the dawn of the liberalised energy market and the green image of solar panels stimulated utilities to increase their subsidies for PV. Together with the Energy Premium Regulation (EPR) of 3,50 EUR/ Wp - 3,85 EUR/ WP, the total subsidy given could, in some cases, amounted to 5,35 EUR per Wp. At the same time, a drop of about 10 % in module prices and a strong competitive market caused the prices of small systems to drop below 6,00 EUR per Wp and even further in large projects. Although the EPR subsidy did not apply for most of the larger, professional projects, these subsidy schemes were so successful that, already in September, it became clear that the budgets of the EPR would be insufficient. The government subsequently announced that the scheme would be closed by mid October. For PV however, the result was a snowball effect: shortly after the government's announcement, the support budgets of the utilities were in danger of running out as well, causing the demand to rise even more. First estimates of Holland Solar from December 2003, based on PV panel import data from members, show that the annual volume turn out to be as high as 20-25 MWp (3 - 4 times the volume of 2002).

The reduction of the EPC (Energy Performance Co-efficient) threshold value by 20 %, which was projected for 2004, and which would have been favourable for BIRES (Building Integrated Renewable Energy Sources), and PV and solar heat in particular, was postponed towards 2006. This was done to allow the building industry, which is under pressure due to the economic set-back, to prepare for the extra efforts needed for this extra requirement.

NATIONAL PROGRAMME

Last year, the long-range Renewable Energy Programme (BSE-DEN), carried out by Novem, consisted of two calls, one in August and one in December. This programme supports R&D-, demonstration-, feasibility- and knowledge transfer projects for all forms of renewable energy. The main evaluation criteria for this programme are innovation and overcoming thresholds; expressed in the contribution of anticipated spin-off projects to the Dutch energy production in 2020. The first tender in 2003 showed an emphasis on biomass and wind (resp. 17 and 7 projects awarded), comparable attention for thermal solar energy, PV and heat pumps (average of 3 projects) and no support for geothermal and ambient temperature applications. Tender 6 (end 2003) is still under evaluation, but a similar distribution of support is expected.

For highly innovative PV research projects, the New Energy Research (NEO) subsidy scheme was reopened in April 2003. However, since this subsidy scheme has a relatively small budget for a wide range of energy research subjects, this will be a small inducement for PV research.

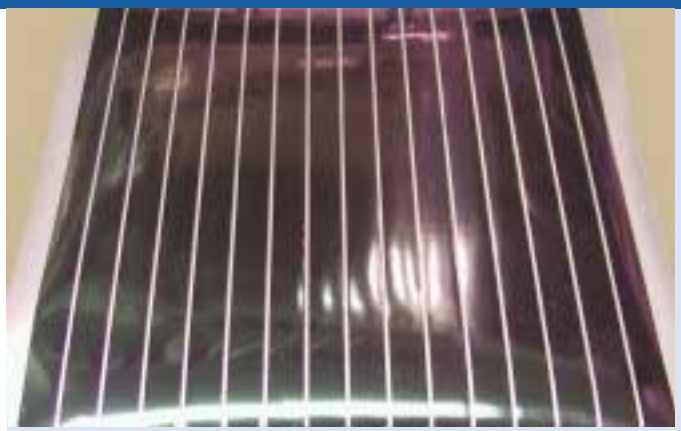

Fig. 1 - Laboratory role to role module from Heliantos project.

During 2003, the national priorities for government financed Energy R&D programme (EOS) were determined. This was done during a wide consultation amongst energy research and policy professionals. The main criteria in this evaluation were 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 main areas of interest, with specific strong positions for polycrystalline silicon and inorganic thin film technologies. The actual EOS programme will be formulated and implemented in 2004.

RESEARCH AND DEVELOPMENT

Solar cell research in the Netherlands continues to focus on improving polycrystalline and low temperature thin film silicon production. Within the flexible thin film silicon project Heliantos, in which the cell is built up on a temporary superstrate, Akzo Nobel Chemicals and Shell Solar constructed a role-to-role pilot line, which is due to be fully operational in 2004. Another important achievement in 2003 was the acceptance by the EU of the ECN co-ordinated project "Crystal Clear," in which several outstanding EU research facilities and the most important European PV industries co-operate in pre-competitive research with the objective of reducing module cost to below 1 EUR/Wp.

No new developments can be reported on the research of inverters. In the field of roof integration, the internationally well-received development of the mounting construction "PV-wirefree" (for both support and current conduction) resulted in a proof-of principle project that started January 2003. This project is to be followed up by field-testing in 2004, and a market introduction in 2005. Philips, ECN, Ecofys, Lafarge and Tyco are cooperating in the development of a new type of AC-module with flexible mounting. Econergy further improved its successful products InterSole and ConSole. Finally, Scheuten Solar expanded their research facility in Venlo, leading to 20 people working on CIS based thin film solar cells.

Fig. 2 - Thanks to the improved InterSole, integration of solar panels between the roof tiles is easier than ever.

INDUSTRY STATUS

With several new and extended activities and one large industry leaving, 2003 was a turbulent year for the Dutch PV industry. With the closing of the Shell Solar production facilities in Helmond, the Dutch PV module production was decreased to practically zero. The two small companies that are now responsible for the total Dutch PV module production are Logic and DOPT. On the other hand, new initiatives were taken up to start solar cell production and AKZO started the construction of a pilot line. While NKF stopped its activities in solar inverters, other inverter manufactures like Mastervolt and Philips succeeded in bringing new products on the market. Philips even decided to enter the market with full PV systems. The most important Dutch industrial activity was the acquisition of the former Flabeg factory in Gelsenkirchen by Scheuten Solar.

DEMONSTRATION PROJECTS, IMPLEMENTATION AND MARKET DEVELOPMENT

In the year 2003, most of the PV solar power, installed in domestic buildings, was a direct result of the Energy Premium Regulation. In just a few months, several housing companies realised large PV systems with a combined power of over 3,5 MW. A good example is the housing corporation "Patrimonium" in Veenendaal, where a total of 1,2 MW was installed on 35 apartment buildings in 3 months. The favourable subsidy conditions caused an interest in mid-sized PV systems. Systems ranging from 1-4 kWp in power were sold to private house owners, enabling a "zero electricity bill" at the end of the year. More attention was given to solar power by campaigns started up by municipalities and utilities, creating more blue coloured roofs in the Netherlands.

The market for PV systems, which are not subsidised by the EPR, such as the market for stand alone systems and large PV electricity generation plants was rather quiet: only a few systems were realised with EC subsidy or other financial support.

Most of the activity was generated in municipalities already known to actively support PV. The City of the Sun project made progress in it's goal of installing 5 MW in to be developed districts between Heerhugowaard, Alkmaar and Langedijk. In the Rotterdam Zoo "Blijdorp" a 500 kWp system was installed.

FUTURE OUTLOOK

At this moment it is unsure what the follow-up of the EPR will be. Almost certainly the new scheme will have a limited and closed budget. With the reduction of the EPR, the market for PV in 2004 may decrease significantly; which, according to market parties, could lead to difficult situations for some, especially smaller, companies.

In the Netherlands, tax is levied on the use of energy through the REB (Regulating Energy Taxes). In 2003 the consumption of green electricity was stimulated by a tax exemption, giving households a discount of 2,9 EUR ct per kWh. This tax incentive will gradually be shortened in 2004, to be ended in 2005. Although some utilities announced that they will decrease the prices of green electricity to compensate for the phasing out of the tax exemption, an increase of the price for green electricity is feared to decrease the use thereof in general. For PV however, this measure has no effect: the REB is only levied on electricity purchased from a utility. Moreover, the removal of the tax exemption will be compensated by an increase of the MEP funding. The MEP feed-in tariff is determined to be 6,7 EUR ct for PV systems that apply for MEP between January 1st and July 1st 2004, but will increase to 8,2 EUR ct for the second part of the year. In 2005, the feed-in tariff for solar-pv will increase further to 9,7 EUR ct per kWh. Since the MEP feed-in tariff seems only profitable for mid- to large sized PV systems, this scheme may become interesting for utilities, project developers and companies which may also benefit from tax deduction incentives like the EIA, but could also be available for cooperatives of private house owners.

Fig. 3 - At the Zoo "Blijdorp"in Rotterdam, a 500 kWp system has been realised. Siemens Nederland N.V. (the main contractor) will take care of the maintenance for a period of 20 years.

There is an enormous surplus of office buildings in the Netherlands, and a general shortage of private houses. Logically, best chances for PV in the Netherlands are thus expected in the housing development projects, which can profit from the MEP scheme.

The final step in the liberalisation of the energy markets will take place mid 2004, but the effects of this on the solar interest from utilities are difficult to predict.

Building on the successes in the domestic market in 2003, some larger companies announced to increasingly focus on the international market, starting in Germany.

NORWAY

PV TECHNOLOGY STATUS AND PROSPECTS

KNUT-ERIK MADSEN, ECO ENERGI

Fig. 1 - A typical PV installation for Norwegian cabins.

GENERAL FRAMEWORK

There are no governmental driving forces to support PV systems in Norway. PV enthusiasts are still hoping for targeted money for PV in the Norwegian energy system. Compared to other renewables, PV is still too expensive when compared to wind and small hydro.

PV (the sun, as well) is not an important energy source and the financial support is still negligible.

NATIONAL PROGRAMME

The research programme called EMBA (Energy – Environment-Buildings and Construction) (www.emba.no) in the Norwegian Research Council funds research within the energy field, and among these, renewable energy sources and energy efficiency. The total funds for PV-related R&D projects were appr. 10 MNOK for 2003. Most of the R&D projects are focused on the silicon chain from feedstock to solar cells.

RESEARCH AND DEVELOPMENT

There are three main R&D groups in Norway:

- **NTNU** (Norwegian University of Science and Technology) **Trondheim:** 4 PhD studies. Focusing on silicon feedstock, refining and crystallisation. Supporting Scan Wafer and Elkem.
- **Agder College:** 4 PhD on silicon in co-operation with Oslo University supporting Elkem.
- **IFE** (Institute of Energy Technology): 4 PhD studies; second hand pilot line for solar cells recently acquired and installed. Supporting industry (Scan Cell and others).

IFE is involved in a project called, "Market potential analysis for the introduction of hydrogen energy systems in stand alone power systems."

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

The project is running from 1. February 2002 to 31. January 2004, under the EU Altener programme. The partners are the Institute for Energy Technology, Norway, Trama TecnoAmbiental, Spain, Centre for Renewable Energy Sources, Greece, and Econnect Ltd, UK.

IFE is also running the following for the new Nordic Scientific Programme (2003-2006):

Solar Electricity, from Materials to System Integration (Nordic PV)

The objective of this scientific programme is to strengthen the commercial development of solar cells in the Nordic countries.

This will be achieved by:

- Strengthening the research effort undertaken by the individual partners, which all represent major national research groups in the field of solar cells.
- Establishing a formal Nordic collaboration between the major national research groups, and thereby establish a significant player in the international, fast-going solar-energy research arena.
- Establishing a programme which stimulates mutual technology transfer between the presently market dominant multi-crystalline silicon solar cells and new emerging solar cells close to commercialisation, such as CIGS, CdTe and photo electrochemical based cells.

The span in cell technology, the span in technical maturity of the products and the interdisciplinary project group, will establish optimum conditions for cross fertilisation and a unique potential for new innovative solutions – both critical factors for the enduring commercial success of Nordic enterprises involved in renewable energy.

The activity of this programme will be concentrated on further development of silicon solar cells, thin film solar cells, photo electrochemical solar cells and system integration of these solar cells. Partners in the project are University of Uppsala, Helsinki University of Technology, Danish Technological Institute, Norwegian University of Science and Technology and Institute for Energy Technology (IFE). The program is coordinated by IFE and has a total budget of 14 350 000 NOK.

Fig. 2 - Lighthouse installation - Lycklingholmen.

IMPLEMENTATION

No major installations were completed in 2003.

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) in this vast and sparsely populated country. Exceptions are demonstration projects, for which grid-connection, in some cases was performed.

Up to 1992, the leisure market, dominated by new installations in remote cabins in the forests and mountains of Norway, 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 repairing them.

The cabin market accounts for 80-90 % of the Norwegian market, with 85 W being a representative typical system size. Applications for leisure boats have also grown over the past years. In Norway, most of the systems used on leisure boats exceed 40 W.

During the 20 past years, size and comfort of the Norwegian cabins have increased significantly. Although modern cabins are often built in compact fields connected to the grid, thus offering the same comfort as permanent houses, surveys have uncovered that 70 % of cabin owners value surroundings that are mainly unaffected by human activities. Therefore, in many instances, while new cabins do not offer an opportunity for PV systems, this is not a universal trend. On the contrary, in the last few years we have seen the introduction of more ambitious systems in the leisure market for PV-systems. A few cabins have, on commercial terms, been equipped with comparably large PV systems, about 600 W. These systems have a 12 V installation for lighting and an inverter for supplying 230 VAC to conventional power outlets. They may also have a small generator for backup.

On the border between the leisure and professional market, installations at a couple of tourist cottages in the mountains were a notable feature in 2002. Also, these installations provide 230 VAC and have a generator as backup. As a continuation of this trend, one might hope that in the near future, the installation of PV systems will become fully integrated into the design and construction processes for cottages.

In the period after 1992, the slowdown in the market for cabins was partly compensated by the development of new markets. PV powered coastal lighthouses was 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 Coastal Guard in 1982 and was completed in 2000-2001. Approximately 2 350 installations serving lighthouses and coastal lanterns have been achieved. The smallest are equipped with one single module of 60 W, the largest with arrays counting up to 66 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 is 310 kW.

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 has 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. The market is estimated to be 5-10 kW on the average. In 2002, the actual figure was in the low range.

In marked contrast to many countries in Europe, Norway does not have any incentive schemes supporting the installation of PV systems. Therefore, there are very few grid-connected systems. The same may be said about building integrated approaches, although a few small systems have been installed on private initiative, and a 5 kW system is in the planning stage in Kristiansand. The latter project is sponsored by the EU–financed project PV-Nord.

There are plans for equipping a private home in Bergen with 3,8 kW PV in 2003. This project is being carried out on a completely private initiative, without any public incentives, and also comprises solar

heating and wood firing. The building is a single family house originally constructed in 1936. If realised, this project will be reported in the NSR for 2003.

INDUSTRY AND COMPETENCE

Elkem Solar was established in 2001 with its main objective is to develop a process for feedstock to solar cell production. As the world's largest producer of metallurgical grade silicon and with a long term experience in design of metallurgical equipment, the process development was based on metallurgical unit processes. No other producers are today producing silicon in a process specially designed for the solar market. Therefore, this new process represents an important milestone in the development of the PV industry. Up to now, most efforts have been put into the process development itself, but during 2003 the first wafers with Elkem Solar based feedstock were produced and tested in laboratory scale equipment. Part of this work was done in cooperation with Sintef in Norway and the University of Konstanz, Germany, and the first results were published during PVSEC-14 in Bangkok, January 26-30, 2004. Efficiencies of solar cells produced during this test work were in the same range as obtained for solar cells based on electronic grade Si, and above 14 per cent.

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 value chain from silicon feedstock to solar systems, based on multicrystalline silicon wafers, consists of 6 distinct production steps as illustrated in figure below.

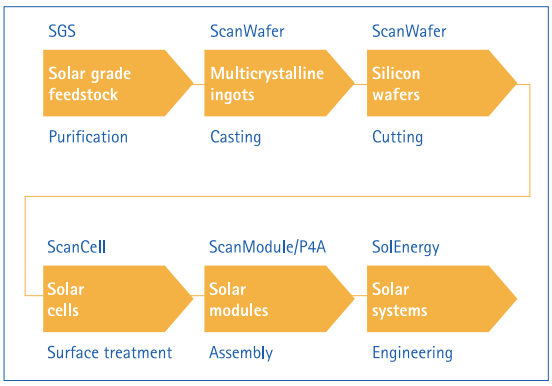

Fig. 3 - Companies within the REC group.

The research staff is now conducting experimental tests in a four-inch laboratory-scale fluid bed reactor (FBR) previously built by Advanced Silicon Materials LLC (ASiMI). The experiments will study reactor design 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; meeting the U.S. PV Industry goal of < $ 20 per kilogram.

A dedicated supply of low-cost feedstock has been identified by the industry as a technical barrier to continued reduction in solar panel costs. In 1995-1999, ASiMI designed several improvements in a process to develop semiconductor-grade granular polysilicon and holds several patents. SGS is now testing further modifications to reduce production costs for a solar grade granular feedstock.

Scan Wafer plant NR. 3 in south of Norway (Porsgrunn) started up 2003. Its capacity (silicon wafers) is 60-70 MW yearly.

PORTUGAL

PV TECHNOLOGY STATUS AND PROSPECTS

PEDRO SASSETTI PAES, LABELEC – EDP GROUP

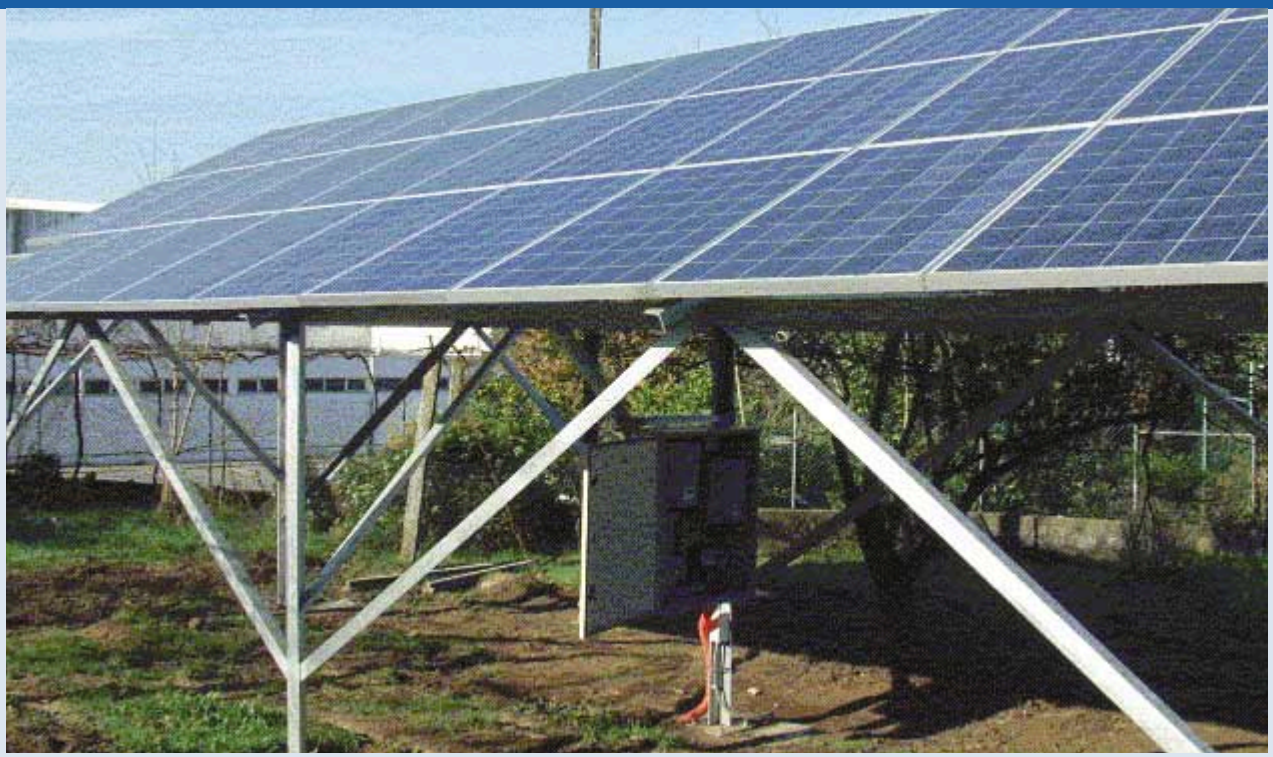

Fig. 1 - The first 5 kWp grid-connected PV system realized under the new legal framework for IPP. (photo S. Bras, Barcelos, courtesy of COEPTUM Engenharia)

GENERAL FRAMEWORK

In 2003, the government defined a new energy policy framework (Cabinet Resolution No. 63/2003), relying upon 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 guaranteeing adequate power generation);
- To promote the sustainable development (supporting the development of endogenous energy sources (renewables) and improving energy efficiency, in order to meet the Kyoto Protocol commitment).
- 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 former E4 Programme (Energy Efficiency and Endogenous Energies) launched in 2001, established goals concerning the exploitation of renewable energy sources (RES) for power (and thermal) generation, which were consistent with the EU Directive on renewable electricity (2001/77/CE), under which Portugal has to aim to deliver 39 % (including large hydro) of its gross electricity consumption by 2010.

The current energy policy framework is in line with the E4 Programme and, for some RES, the Portuguese government has set even more ambitious targets for 2010, namely:

- wind power: 3 750 MW (currently ~300 MW)
- photovoltaics: 150 MWp (currently ~2 MW).

The initiatives (legislation, incentive schemes) introduced in 2001/2002, aiming at stimulating the market (private investors), not only for RES electricity, but also for CHP, solar thermal use and building energy efficiency, are underway. These are namely:

- 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).
- National programme for supporting wide diffusion of solar water heating.
- National programme on building energy efficiency.
- Adapting or broadening the scope of financial incentives for energy efficiency and use of endogenous energies in the framework of the POE/PRIME Programme (Operational Programme for Economical Development).

RESEARCH, DEVELOPMENT AND DEMONSTRATION

Fundamental research activities are focused on amorphous and thin film crystalline silicon technologies and involve mainly by 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).

Applied R&D and demonstration is carried out by Universities and Public Research Laboratories (INETI – National Institute for Engineering and Industry Technology), as well as Energy Agencies (ADENE and regional agencies), utilities (EDP) and private research institutions (INEC Porto - Institute for Systems and Computers Engineering). Besides these institutions, associations such as SPES (National Solar Energy Society) and APISOLAR (manufacturer and installer association) are also involved in dissemination activities.

Demonstration systems concern mainly remote electrification and professional system applications (TV and telephone repeaters, parking meters, water pumping), as well as some of grid-connected systems realised by the utility EDP. More recently, Labelec (a company of the EDP Group) designed a small hybrid PV (3,2 kWp)-wind (0,9 kW) grid-connected system, to be installed early 2004 at its premises (campus of Sacavém); aimed mainly at demonstration and grid interconnection impact assessment.

IMPLEMENTATION

The most significant government initiative introduced in the framework of the E4 Programme and supported by the 2003 Cabinet Resolution, was the legislation promoting renewable electricity (higher feed-in tariffs, differentiated by technology). Under this legislation, which applies only to IPP, the current buy-back rates for PV are ~0,30 EUR/kWh (systems over 5 kWp) and ~0,52 EUR/kWp (systems under 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, the utility being obligated to buy the whole power.
The so-called "producer-consumer" law, aiming more at the residential and small industry markets, allows for micro-generators (microturbines, fuel cells, Stirling engines, etc., and also PV) to be connected to the low-voltage grid. Any individual or company may become an independent producer under this law, provided at least 50 % of the generated energy is self-consumed. Therefore, the utility is only obligated to buy half the generated power at a feed-in tariff depending on the technology. For PV, the buy-back rate is about 0,25 EUR/kWh, which, for small systems up to 5 kWp, is considerably lower than the IPP tariff, making this scheme considerably less attractive.

The technical regulation and licensing process already implemented under this legislation concern system ranging from 11 kW to 150 kW. For smaller systems, i.e., up to 16 Ampere per phase (3,68 kW single-phase or 11 kW 3-phase), a simplified process, in preparation, will likely be implemented.

Financial incentives for renewables and energy efficiency applications are available under the POE/PRIME programme (2000-2006) – III EC Framework Programme. Grants are provided on the basis of energy and environmental value of the projects, typically ranging from 20 % to 40 % of the total eligible costs, with a maximum grant of 150 kEUR per application.

Indirect market development incentives for renewables are also available: reduction of VAT rate from 17 % to 12 % on renewable equipment, custom duties exemption and income tax reductions (up to 700 EUR for solar equipment).

In spite of this favourable legal and incentive framework, especially in the grid connected domain, in 2003 only a few installations have been realised or are under preparation/negotiation. However, a high number of requests for grid interconnection points (mainly for systems up to 5 kWp) have been presented to the Directorate General for Energy, the government agency which is managing this process; which clearly indicates a growing PV awareness and attractiveness from IPP promoters.

TABLE 1- PORTUGAL'S TOTAL INSTALLED PV CAPACITY END 2003

Year	Stand-alone (kWp)	Grid-connected (kWp)	Total annual power power (kWp)	Cumulative power (kWp)
Up to 1995	324	12	336	336
1996	88		88	424
1997	98	5	103	527
1998	100	21	121	648
1999	132	146	278	926
2000	217	33	250	1 176
2001	115	51	166	1 342
2002	285	73	358	1 668
2003	396	5	401	2 069
Total by end 2003	1769	273		2069

The BP Harmony Project, formerly Sunflower Project, which consisted in the integration of PV modules on BP filling station canopies and was responsible for the installation of about 350 kWp grid-connected systems, has come to an end. The most significant new initiatives are:

- A 4,96 kWp grid-connected system installed in S. Brás (municipality of Barcelos, northern Portugal), designed by SunTechnics/COEPTUM Engenharia. The installation was licensed in November 2003 under the IPP law and is delivering all the generated power to the grid at a tariff of about 0,5 EUR/kWh.
- A building (facade) integrated, grid-connected PV system (12 kWp), designed by INETI, which will be installed early 2004, at the campus of INETI. The project is partly supported by the POE programme.
- The world largest centralised PV power plant (64 MWp) in the municipality of Moura, southern Portugal. The total estimated budget is about 300 MEUR. Negotiations are underway involving the promoter (Amper Central Solar, S.A.), the municipality, BP Solar, financial institutions and the government's Directorate General for Energy. BP Solar will do the turkey installation and will build a module factory nearby Moura, only if the project is approved.

INDUSTRY STATUS

Shell Solar signed an agreement with A. J. Lobo (Évora factory) to expand the module assembly capacity from the current 10 MW to 17 MW per year. According to Shell Solar, this factory will become its sole solar module assembly plant in Europe. In addition to monocrystalline modules, the factory will also manufacture muti-crystalline modules. Currently, the Évora factory employs about 90 people.

There are two solar type and stationary battery manufacturers (SPAT 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 (small charge regulators, ballasts, etc.).

MARKET DEVELOPMENT

The total installed PV capacity by the end of 2003 was about 2 MWp, of which 87 % are stand-alone applications and 13 % are grid-connected applications. The market continued to grow in 2003, mainly based on off-grid applications. The grid-connected market decreased significantly as a result of the conclusion of the BP's petrol station programme.

FUTURE OUTLOOK

The Portuguese strategy for the promotion of renewables, introduced by the E4 Programme in 2001 and reinforced by the Cabinet Resolution 63/2003, created a favourable legal framework and incentive schemes for their market development. Wind will form the bulk of the new installed power (3 750 MW by 2010), while PV's contribution is set to increase from the current level of about 2 MW to 150 MW by 2010. Without these contributions, together with hydropower, biomass and wave energy, Portugal will not be able to meet the targets agreed under the EU Directive on the promotion of electricity from RES in the internal electricity market.

As far as PV is concerned, in spite of this framework, the number of new initiatives in 2003 was insignificant, with the exception of the 64 MW power plant under planning in Moura. Nevertheless, there seems to be a growing interest in PV from IPP promoters, considering the high number of requests (about 50) for grid interconnection points received by the government's Directorate General for Energy, especially for small systems up to 5 kWp. There are still a few barriers to overcome for the widespread use of PV in the built environment, which is believed to dominate the future market in Portugal. These are namely: lack of regulations for grid interconnection of small systems at the low voltage level, lack of building codes for PV integration and the need to simplify the licensing process for PV installations, which is currently too complicated and time-consuming.

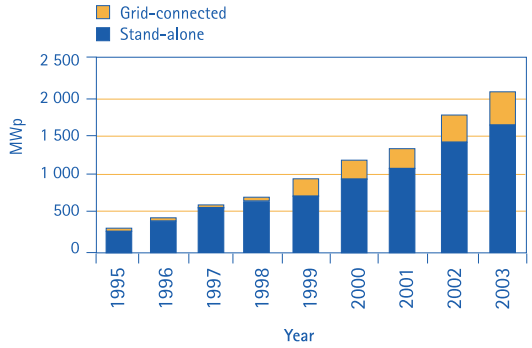

Fig. 2 – Cumulative installed PV power in Portugal (1995-2003)

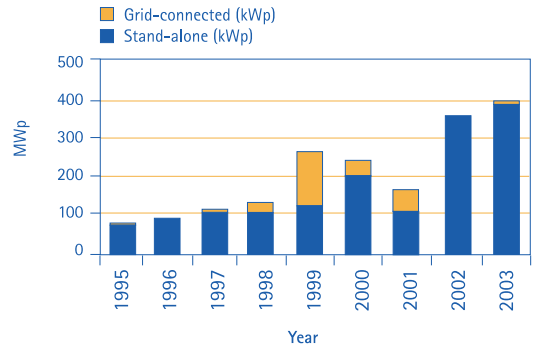

Fig. 3 – Yearly installed PV power in Portugal (1995-2003)

SWEDEN

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

Fig. 1 - Photo of the NCC project Holmen in Hammarby Sjöstad. Semi transparent modules with a total peak power of 17,6 kW distributed on façade, windows, balconies and a small system on a roof window. Naps Sweden AB supplied the system. (photo Energibanken, 2003)

GENERAL FRAMEWORK

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

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

The Swedish electricity supply system is largely based on nuclear and hydropower. Though growing rapidly, wind power and energy generated by PV still forms a minor contribution to the system. Whilst a few state-of-the-art grid connected PV systems exist, the bulk of PV plants are comprised of the domestic-off-grid systems.

As of today, Sweden still lacks market development initiatives and subsidy programmes such as feed-in-tariffs or roof-top-programmes that would lead to a direct promotion of PV in Sweden. However, in May of 2003 Sweden launched its system for the promotion of renewable energy via tradable electricity certificates. The system includes renewable energy sources like biomass, hydro, wind and PV. The short-term prices for the certificates are however too low to have an impact on the PV market in Sweden at current PV system prices. The Agency hence provides funding for Research, cost-shared Development and Demonstration projects.

NATIONAL PROGRAMME

In 1996 the Swedish Energy Agency together with the Swedish Foundation for Strategic Environmental Research, MISTRA, decided to start a new and merged programme for R&D on PV. The programme is called Ångström Solar Center (ÅSC) and is located at Uppsala University. The first phase had a total financing of 70 000 000 SEK, (1 000 000 USD) and lasted until the end of year 2000. The second phase started in the beginning of year 2001 and will last until the end of year 2004, with a total financing of 80 000 000 SEK (1 200 000 USD).
The overall goal of the Ångström Solar Center programme is to contribute to a sustainable energy system in the future, preferably contributing to the economic competitiveness of Sweden.

The approach is to depart from a leading scientific platform and evolve progressively toward applications by scale-up, prototype manufacturing, and eventually, commercialisation in three sub-programmes:

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

Furthermore, the Swedish national co-financed programme on PV systems and applications, PV 03-07 (SolEl 03-07) managed by Elforsk, started a new period during 2003 with financing for 2+2 years. It primarily involves the energy and building industry, but new participants from the manufacturing industry and property managers have also joined the programme.

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

RESEARCH

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

The technical achievements from CIGS thin film solar cell research in Sweden include cell conversion efficiencies up to 17 %, at the time making the breakthrough towards truly high performance thin film solar cells. In the year of 2000 a sub module consisting of four cells in series and having 16,6 % efficiency was fabricated. This is still the present world record for a solar cell module of any thin film material. This has resulted from R&D efforts where the focus has been on CIGS film fabrication by co-evaporation. The aim is that the CIGS technology developed at Ångström Solar Center should be ready to

Fig. 2 - Photo of Familjebostäders project Lysande in Hammarby Sjöstad. The total peak power of the system is 22 kW. Semi transparent modules with a total peak power of 9 kW as shading device in front of the façade and 13 kW standard modules on the south, east and west sides of the roof. Gaia Solar in Denmark supplied the system. (photo Energibanken 2003)

be taken over by the Swedish solar cell industry, which presently is the spin-off company Solibro AB. Utilising processes and materials that minimize the impact on the environment is of the highest priority but at the same time achieving performance and cost reduction. Thus, in research for a next generation technology, elimination of cadmium and minimization of usage of indium are main objectives. The group has recently filed a patent for manufacturing of a completely Cd-free solar cell.

Solibro AB was founded at the end of the year 2000 by four of the researchers at Ångström Solar Center. Following a fund raising period, industrial development commenced in September 2003. During the first phase the company will deal with scaling up of the active part of the solar cell, the CIGS layer. When scale-up of the CIGS fabrication process has been successfully demonstrated the plan is to expand to a complete line for fabrication of solar cell modules. The total financial frame of the first phase is 32 000 000 SEK (4 300 000 USD), out of which the Swedish Energy Agency contributes with 15 000 000 SEK (2 MUSD).

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

Smart windows can vary the transmission of solar radiation according to the buildings energy needs. Such windows have a large potential for energy savings and enhancement of the comfort in commercial buildings. The focus in the research programme is on electrochromic coatings on flexible foils. This foil can be retrofitted in existing windows and can also be used in new fabrication, thus further increasing market potential. Currently, commercialisation is pursued in niche applications.
In connection to the applied programme PV 03-07 a new research programme on building integrated PV research has been formed by the Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (Formas). The programme budget is 1 000 000 SEK (130 000 USD) a year. In addition, research and development in the application of solar cells systems in the built environment is covered in the Formas yearly open call, "Energy in the built environment."

DEVELOPMENT

The national programme on PV systems and applications, PV 03-07, focuses on system integration. It has switched somewhat from an energy perspective towards a PV in buildings perspective.

PV will expand from stand-alone applications to power production via grid-connected, building integrated and other decentralised PV systems. However, this expansion will largely depend on the level of knowledge existent among future industrial partners. To fulfil the vision and contribute to the reduction of critical PV system costs, the programme goal is to enhance knowledge about PV as an energy source and a building component, identify possible applications of PV and raise the commercial awareness of PV systems. During 2003 planning for a new strategic investigation commenced with the objective of establishing a future scenario of high-volume PV utilisation and manufacturing in Sweden.

The programme covers the rapid international development of PV systems in general and for grid-connected building integrated PV systems in particular. It also provides a basis for international exchange, such as Sweden's participation in IEA PVPS. In addition, the programme performs evaluations of procurement, installation and feasibility for Swedish PV installations. It defines and implements a monitoring process for existing and future grid connected Swedish PV-installations. Development of reflector and hybrid-concepts for PV-systems are also included the programme.

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

DEMONSTRATION

The new BIPV projects in Stockholm's Hammarby are reaching their completion. The two BIPV projects realised by JM have been in operation since 2002. The 17,6 kWp installation on the Island of Holmen (Figure 1) was commissioned in September 2003 and the 22 kWp project "Lysande" (Figure 2) will be connected to the grid in late January 2004. Hammarby Sjöstad is a new residential area in Stockholm with a strong environmental profile in which PV has a natural part to play. These new installations are among the first true BIPV projects in Sweden in which PV modules have been used as an integrated part of buildings in windows, façades and balconies.

Sweden is also co-ordinating a large EU-project called PV Nord. This project aims at paving the way for Building Integrated PV in Northern Europe. It combines demonstrations of nine building

integrated PV-installations with analyses of different aspects of the use of BIPV in the buildings. Sweden is also a part of the EU-network PV-EC-NET.

IMPLEMENTATION

The Swedish policies, which could indirectly promote the use of PV power systems, are taxes and fees related to traditional energy production as well as environmental protection and a system for the promotion of renewable energy through tradable electricity certificates launched during 2003. The current levels of such taxes and the short term price for the certificates are, however, likely to be too low to make a serious impact on the PV market in Sweden at average system prices. Instead, new installations will most likely be considered as part of a demonstration programme and receive support from governmental funds.

Sweden's strong industrial demand for low energy prices and poor financial support for PV projects leads to low interest levels amongst private investors and thus presents high barriers for the technology diffusion, market development and consequent price reduction alike.

Yet, as PV is recognised as a sustainable and renewable energy technology, the general attitude remains positive and has been expressed in form of increased consumer demand for green electricity and PV power. The solid and steady international progress, which has occurred over the recent years, not least in terms of socio-economic benefits, rapidly growing industries and employment opportunities, is receiving increased attention in Sweden.

INDUSTRY STATUS

The PV industry in Sweden consists of three main players, Gällivare Photovoltaic AB, ArcticSolar AB and Naps Sweden AB.
As a fully owned member of the international SolarWorld group, Gällivare Photovoltaic AB (GPV) is part of the fully integrated, in-house value chain of PV system production. In 2003, GPV tripled its annual manufacturing capacity of PV modules to 20 MW through the installation of a modern and fully automated production line including advanced cell testing and quality assessment methods. Arctic Solar AB produces and sells photovoltaic modules but depends on the purchase of solar cells on the world market.

Naps Sweden AB designs, markets and sells products and systems based on PV modules. Naps Systems has experience in consumer applications, industrial applications, rural electrification and on-grid distributed systems. Finnish Naps Systems Oy owns the company and is part of the Fortum Group.

MARKET DEVELOPMENT

The total installed power during year 2002 was 265 kWp, which is approximately the same as in 2000. The main volume of the Swedish PV market is in the domestic-off-grid sector. More than 80 % of the installations during 2002 were in this category. By the end of 2002, the total cumulative installed capacity in Sweden was about 3,3 MWp.

Fig. 3 - Photo of JM ABs and Fortum ABs architecturally buildning integrated PV-system in Hammarby Sjöstad. This is one of two similar buildings that have been equipped with semi-transparent modules in a glass-roof construction. The peak power of each installation is 5,7 kW. Naps Sweden AB supplied the systems. (photo Lars Hansson 2002)

Four major demonstration projects were installed during 2002. Two of these are grid-connected building integrated installations in Hammarby Sjöstad, Stockholm. A small system was also installed at the main railway station in Stockholm powering diode lighting inside the main station hall. The fourth system powers the pumps of a heating/cooling system gaining energy from sea water in a library in Visby.

Most of the system components in Swedish installations are imported. A dominant fraction, around 95 %, of the Swedish module production is exported.

FUTURE OUTLOOK

The high quality research and development that is carried out at Ångström Solar Center will continue on in its last year 2004. The ÅSC programme is highly relevant for the Swedish Energy Agency since it deals with important issues for a future sustainable energy system and potential commercial ventures beneficial to Sweden. A successful development of the thin film solar cells within Solibro AB is important and can bring PV forward in Sweden.

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

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

SWITZERLAND

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

Fig. 1 - 5,5 kWp Freestyle® thin film system on the roof of a single-family house in Lutry. (photo: Solstis)

GENERAL FRAMEWORK

During the entire year 2003, the main policy framework set by the *SwissEnergy* Programme (www.swiss-energy.ch) was the subject of difficult parliamentary discussions in the context of a wide-ranging government savings message for the period 2004 to 2006. This ongoing political debate throughout 2003 gave rise to large insecurities to all those involved in the field. Originally, it was proposed that the programme should come to an end by 2006 but support from a wide range of partners, including the cantons, led to the programme's survival, however at a reduced budget. *SwissEnergy* is focussed on market oriented support actions for energy efficiency and renewable energy; hence, this area will be most affected by the budget cuts. Further budget reductions are to be expected.

Another important decision regarding energy policy matters was the public referendum regarding the proposed abandon or moratorium for nuclear energy. The two initiatives were rejected by the voters, following strongly polarised public discussions. Both policy elements lead to a more stringent framework regarding the deployment of new, and in particular, renewable energy technologies. In the future, energy research will be affected in the area of market related activities, namely pilot- and demonstration projects. The stronger emphasis on relevance for climate policy goals is not favourable for the more short-term aspects of photovoltaics.

Based on strategic policy goals (energy & environment, science & education, industry & society), the Federal Commission for Energy Research (CORE), in cooperation with the Swiss Federal Office of Energy (SFOE), developed a new 4 year energy RTD master plan for the period 2004 – 2007, split up into programmes and sub programmes. This master plan establishes the goals and priorities for energy RTD. According to this master plan, RTD in photovoltaics remains a subject of priority for the considered period.

NATIONAL PROGRAMME

Switzerland has a dedicated national photovoltaic RTD programme which involves a broad range of stakeholders in a strongly coordinated approach (www.photovoltaic.ch). This national photovoltaic programme focuses on R&D,D in a system and market oriented approach, from basic research, over applied research, product development, pilot and demonstration projects all the way to market stimulation. 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.

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 incentive 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 energy efficiency and/or renewable energies. Support for photovoltaics through direct subsidy schemes is limited to a few cantons presently.

Fig. 2 - 70 kWp flat roof system at the exhibition centre Palexpo in Geneva. (photo: NET)

Through the bias of Task 9 of the IEA PVPS Programme, the subject of technology co-operation with developing countries has received increased interest. During 2003, the concept of a new interdepartmental platform for the promotion of renewable energy in international co-operation was developed. As a side-effect of the Swiss participation in PVPS Task 9, the Swiss engineering company Enecolo became involved in a GEF-supported project on building integrated photovoltaics in Malaysia.

RESEARCH, DEVELOPMENT AND DEMONSTRATION

The Swiss Photovoltaic RTD Programme is based on a 4 year RTD master plan, 2003 being the last year covered in the period from 2000 – 2003. A follow-up master plan will be published in 2004. Overall, 85 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). Transfer to industry of these RTD activities has continuously increased over the past years. The spin-off company VHF-Technologies is setting up a manufacturing plant of amorphous silicon solar cells on plastic substrates. Another technology transfer is occurring with the equipment manufacturer Unaxis. Building on the strong synergies with this company's expertise 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 placed on the application of building integration, both for new solutions involving thin film solar cells as well as for new mounting systems and structures for sloped roofs and facades.

With the ongoing market development, quality assurance of products and systems as well as standardisation continues to be of high priority. Three centres of competence have been established which evaluate products such as PV modules, inverters and components for building integration. Long term experience with the operation of photovoltaic power systems is carefully tracked for a number of grid-connected systems, ranging between 10 and more than 20 years of operation. Continuous development of system solutions has resulted in a number of industrial products which are increasingly being exported.

International co-operation continues to form a strong pillar of the R&D activities with about 25 projects running in the 5th framework RTD programme of the European Union during 2003. International projects are also carried out as part of programmes such as the European Union Altener Programme or the European Space Agency. The co-operation within the IEA PVPS programme has remained a further strategic activity for which target-group specific dissemination is crucial.

Fig. 3 - 9,7 kWp façade system at the cable-car station Piz Nair in St. Moritz. (photo: NET)

IMPLEMENTATION

The majority of the market implementation of PV systems continues to be driven by the campaign for "solar electricity from the utility". 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 utility of the city of Zurich. Increasingly, solar electricity is thus part of mixed green power products, according to naturemade star® labeled brands. The willingness to pay the comparatively high prices for solar electricity is typically around 5 % of the customers in the best cases and requires a strong and consistent marketing approach. With mixed products however, more customers can be attracted.

In the absence of broad national incentive schemes, this concept has enabled more than 7 MWp of PV systems installed with a high awareness effect among the public. The campaign has proved to be a successful approach, involving different stakeholders, provided that a strong and consistent marketing is undertaken. More than 5,5 GWh are annually subscribed under this model and another 0,7 GWh of solar electricity is part of mixed products. Benefits were identified also by the utilities in introducing new customer relationships. However, the total market volume under this scheme is presently saturated at about 1,5 MWp/year.

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 increased considerably.

In the inverter area, some products have achieved a high export rate. The Sputnik Company produces grid-connected inverters at a capacity of 50 MW/year and presently ranges as number 3 in the European market. The Studer Company produces stand-alone inverters and is very successful in the export too. On the PV industry supply side, different products count among the world leaders, e.g. for wire-sawing machines from HCT as well as Meyer & Burger and measuring equipment for PV module manufacturers from Belval. In addition to the solar plugging systems from Multi-Contact, another company, Huber & Suhner, has entered into this market.

More recently, industrial activities have started in the field of process equipment (see above, Unaxis solar) and small scale products based on thin-film technology (Flexcell® from VHF-Technologies). Furthermore, Swiss Sustainable Systems (3S) is building some of the world's largest PV module laminators.

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

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

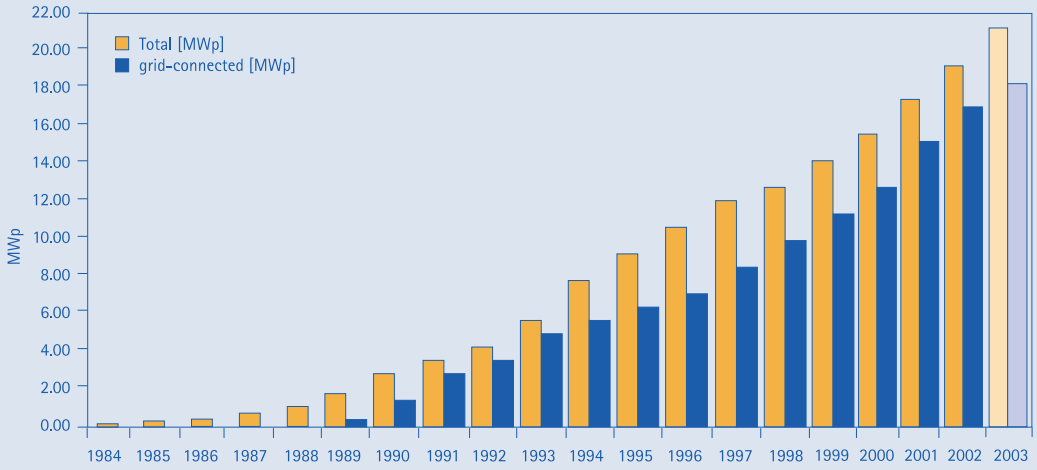

Fig. 4 - Evolution of the installed photovoltaic capacity in Switzerland between 1984 and 2003 (total and grid-connected, estimated values for 2003).

MARKET DEVELOPMENT

The market development has been mainly driven by the federal campaign "solar electricity from the utility," supported by promotional programmes and actions in some cantons as well as pilot & demonstration projects within the national programme. The annual market volume for grid-connected systems is estimated to about 1,9 MWp, similar to previous years. The total installed capacity thus rises to about 21 MWp (Figure 4), corresponding to about 3 Wp/capita. The PV energy statistics has been established tracking the energy produced by grid-connected PV systems and their statistical distribution since 1992 (Table 1).

FUTURE OUTLOOK

Regarding photovoltaic technology in Switzerland, the broad support of the national PV programme can be expected to continue with an ever-increasing 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.

In the next years, PV market implementation will increasingly 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.

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

TABLE 1: SWISS PHOTOVOLTAIC ENERGY STATISTICS FROM 1989 – 2002

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

(grid-connected systems)

UNITED KINGDOM

PV TEHCNOLOGY STATUS AND PROSPECTS

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

GENERAL FRAMEWORK

In the UK, the Department of Trade and Industry (DTI) is the lead Department dealing with energy issues. Other Departments with significant interests are the Department of the Environment, Food and Rural Affairs (Defra), the Office of the Deputy Prime Minister (ODPM), the Cabinet Office and the Treasury.
The increasing importance of renewable energy sources to the UK in terms of meeting emission reduction targets, contributing to diversity and security of supply and developing internationally competitive industries has been recognised and has led to a number of significant policy initiatives.

The Government has imposed an Obligation on electricity suppliers (the Renewables Obligation) which requires them to deliver a specified proportion of their supplies from electricity generated from specified sources of renewable energy, or to buy Renewables Obligation Certificates or to make a buyout payment. This will enable the UK to make progress towards its target of generating 10 % of its electricity from renewable energy sources covered by the Obligation by 2010.
The Government has an aspiration to reach 20 % of electricity from renewables in the UK by 2020. This forms the main element of the Government's strategy for renewables deployment but it has been supplemented by a number of other initiatives described below.

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, affordable energy for the poorest and competitive markets for businesses.

The Government has also recently undertaken a Renewables Innovation Review to:

Identify which are the key renewable technologies for the delivery of the UK targets and aspirations for renewables, the UK's wider carbon reduction aspirations and for the creation of UK economic benefit; to identify the barriers to the development and deployment of the key renewable technologies; to better understand better the innovation process in key renewable energy sectors; and to identify the most cost effective Government measures to facilitate delivery of the UK targets. The Review was published in February 2004 and can be found at: http://www.dti.gov.uk/energy/renewables/policy/renewables_innovation_review.shtml

NATIONAL PROGRAMME

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

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

Fig. 1 - 30 kWp glass/glass laminates at the National Marine Aquarium, Plymouth.

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

A Photovoltaic Government – Industry Group, set up at the request of the then Minister for Energy, Helen Liddell, made a series of recommendations to Government in its final report, dated 26 March 2001. These included the need for a market stimulation programme for housing and non-residential PV systems, simplified connection arrangements, planning guidance on PV, and setting up a national training and accreditation scheme for installers and service personnel. These and the other recommendations of the group have being taken forward by the Department of Trade and Industry and others.

RESEARCH, DEVELOPMENT AND DEMONSTRATION

The existing DTI Renewable Energy R&D Programme has been strengthened through the preparation of "Technology Route Maps" for each technology in consultation with industry. This has resulted in an improvement in the quality of proposals received as response to the periodic competitive calls for proposals. Funding of the PV element of the programme is running at about GBP 2 million per annum.

The current priorities for work supported under the R&D Programme are as follows:

- The identification, development and evaluation of novel materials and/or cell structures which offer significant improvements to current PV performance and costs;

Fig. 2 - 115 kWp roof-mounted and glass-glass canopy at Ford's Centre for Engineering and Manufacturing Excellence in East London - largest installation in UK at time of commissioning.

Fig. 3 - 99 kWp roof-mounted system on housing estate in Woking, Surrey.

- Innovative approaches to existing cell or module technologies with the goal of improving performance and/or reducing costs;
- Identification, development and evaluation of new production methods and processes which offer significant potential for cost reduction;
- Innovative approaches to balance of systems technologies such as power conditioning equipment, metering, wiring and installation systems with a view to significant improvements to the cost or performance.

The DTI is working with a number of industrial partners to pursue these objectives. Work includes development of amorphous silicon, high efficiency thin film silicon and organic cells.
The Field Trial of Domestic PV Systems referred to in the previous IEA PVPS Annual Report is underway. The budget of GBP 5,4 million is supporting around 30 projects with 500 dwellings totalling 750 kWp. A similar field trial for larger systems (non-residential) for public sector buildings, launched in November 2001, with a budget of GBP 4,2 million awarded grants to 18 projects above 20 kWp (covering areas of more than 200 m^2). 11 projects, totalling around 550 kWp, had been installed by the end of 2003, and monitoring has begun on half of these. Both the Domestic and Non-Domestic Field Trials are now closed to new applications.

IMPLEMENTATION

A Major PV Demonstration Programme was launched by the Secretary of State for Trade and Industry in March 2002. The programme will provide capital grants for the installation of domestic and non-domestic PV systems in the public and private sectors. The budget was increased by a further GBP 5 million in February 2004.

The programme aims to support some 1 200 small scale applications (less than 5 kWp), and 140 grouped domestic installations (comprising 1 300 roofs in total) and non-domestic buildings. The total capacity installed under the programme should be approximately 7,5 MW.
The programme has also put in place an installer accreditation scheme to ensure the quality of installations which are receiving grant funding. The quality of installers is also being underpinned by the establishment of training schemes for PV installers.

The process for obtaining network connection for small PV systems has been simplified and improved. Network connection guidelines (G77/G83) have been put in place following consultation involving the PV industry and utilities, and DNOs do not now require prior inspection of network connections for systems less than 3,7 kWp.

The Planning Policy Guidance annex specifically for photovoltaics applications was published in April 2002. This will be superseded by the Planning Policy Statement 22 and a series of Companion Guides on individual technologies in Summer 2004.

INDUSTRY STATUS

The UK's only indigenous producer of photovoltaic panels (ICP Solar, formerly known as Intersolar) has trebled its capacity to 3 MW using private capital. ICP is continuing Intersolar's major R&D programme covering both manufacturing process and product development with assistance from the Department of Trade and Industry. Crystalox has doubled its capacity, for the third year running, to maintain its position as one of the world's major suppliers of silicon ingots. In addition, 2003 saw the announcement of a 20 MW module assembly plant at Wrexham in North Wales by Sharp, and a 6 MW glass/glass lamination plant at Consett, County Durham by Romag. Both of these plants are expected to be in production by Spring 2004. Several roof tile products are under development, as well as roof mounting and cladding systems.

MARKET DEVELOPMENT

By 31 December 2002, the totalled installed PV capacity in the UK was 4 136 MW, of which 3 568 kW (86 %) was on-grid distributed. This represents a 50 % increase over the previous year.
This is expected to increase to around 6MW by the end of 2003, due primarily to commissioning of installations under the Field Trials and Major Demonstration Programme.
Solar Century, a solar solutions company has been very successful in building new business although BP Solar remains responsible for the lion's share of installations. Other significant installers are PV Facades, PV Systems, Sundog and Solar Energy Installations.

FUTURE OUTLOOK

The Major PV Demonstration Programme will provide a significant boost to PV in the UK. Installer accreditation and training, and grid-connection issues will become more important as the level of installed capacity begins to ramp up significantly. There has been a significant increase in the level of interest in the UK PV market from manufacturers across the world since the programme was announced.

Significant cost reductions together with steady improvements in the quality, reliability and service of systems will be vital to underpin the sustained growth of the sector.

THE UNITED STATES OF AMERICA

PV TECHNOLOGY STATUS AND PROSPECTS 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. The Office of Solar Energy Technologies refocused 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 leading funding source for PV research and development in 2003, and it utilized 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. Education, technical transfer, technical assistance and competitive contracts were used extensively to accomplish the work in 2003. PV-related activities funded by the DOE were allocated to PV cell and module development, manufacturing, balance-of-system and system technology categories. The U.S. Department of Energy web site http://www.eere.energy.gov/pv provides up-to-date information on and links to all aspects of the PV activities in the U.S.

The "Industry Roadmap," was updated in December 2002, but continues to unify the vision, long-term strategies and goals for the PV industry through 2020. 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 "U.S. DOE PV Technology Plan" (5-year plan) was revised, but remained in concert with the "Industry Roadmap" to help guide the national PV R&D activities to reflect the systems-driven approach.

The NCPV, an alliance of organizations, continued to serve as the focal point for the nation's capabilities in PV. The R&D goals and strategies were formulated in concert with the "Industry Roadmap" and through the NCPV "Annual Operating Plan.The "Annual Operating Plan" was coordinated with the solar energy technical plan called "U.S. DOE Solar Technology Program Multi-year Technical Plan for 2003-2007 and Beyond." It will be used to coordinate work in the long term for PV and Solar Thermal Technologies.

PV technologies for thin-film devices expanded its partnership program in 2003. The "Thin-Film Partnership Program" collaborated with manufacturers on technology issues that were common to all manufacturing processes and non-proprietary, with an added focus on reliability.

Fig. 1 - Moscone Convention Center, San Francisco, CA - 675 kW. (photo Courtesy of PowerLight Corporation)

The U.S. DOE Million Solar Roofs Initiative was earmarked for funding in 2003. The initiative sponsored state and local partnerships, financial tools, consumer awareness, and support with codes, standards, and certification programs.

NATIONAL PROGRAM

The U.S. Department of Energy is the principal source of funding for PV research and development. Research is focused on increasing domestic capacity by lowering the cost of delivered electricity and improving the efficiency of PV modules and systems. Non-conventional and breakthrough technologies were often accomplished as fundamental research at universities. 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 through 2006 have not changed and are:

- Reduce the direct manufacturing cost of PV modules by 30 percent to $ 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.

"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."

The National PV 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 remained 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 direction-related workshops for inverters and energy storage were held in 2003.
The National Solar Program shared the costs in areas of fundamental research, technology development and advanced materials and devices. The authorized funding for PV was categorized into three major areas for FY2003. They were as shown in the following.

PV Fundamental Research	39 % of the budget
PV Technology Development	19 % of the budget
PV Advanced Materials and Devices	27 % of the budget

The total FY2003 federal budget for the Photovoltaic component of the National PV Subprogram totaled $ 64 million dollars with additional congressional earmarks of $ 10,7 million dollars to fund the Million Solar Roofs Program, an inverter initiative, and various PV installations. Substantial funding for PV-related projects also came through state and local governments, partnerships, PV industry cost sharing, and utilities.

The NCPV relies on the core expertise of NREL and Sandia to create, develop, and deploy PV and related technologies. Other national PV resources that the NCPV draws on are Brookhaven National Laboratory, two Regional Experiment Stations (the Florida Solar Energy Center and the Southwest Technology Development Institute), and U.S. DOE Centers of Excellence at the Georgia Institute of Technology and the University of Delaware (Institute of Energy Conversion). In addition, more than 90 university, industry and utility research partnerships across the country are linked together to function in a unified way. The NCPV awards most of its federal funds through competitive procurements to industry, universities, and other research centers.

RESEARCH, DEVELOPMENT AND DEMONSTRATION

The U.S. National PV efforts included fundamental research, advanced materials and devices, and technology development. Critical PV program contributions were provided through national laboratory support to the industry through basic research; device characterization; and environment, safety and health activities. A web-based virtual laboratory allowed collaborators from universities and industry to access real-time data on test results related to their projects.

Research on Thin-film Photovoltaics

Thin-film devices and materials development were a major part of the PV program and were administered through the NCPV and the "Thin-film Partnership Program." Thin-film 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. Responding to sustained research efforts, the efficiency of thin-film devices continues to rise. New research to address failure mechanisms, reliability and long-term performance was initiated through a "Thin-film Module Reliability Team."

Photovoltaic devices using CdTe can be manufactured using potentially low-cost techniques such as spraying, electro deposition, and high-rate evaporation. Achieving high laboratory efficiencies using these low-cost techniques is an important objective of the National PV Program. To date, more than ten techniques have been used to grow CdTe. First Solar, LLC has continued to advance ultrahigh-rate vapor transport deposition through collaboration with the NCPV.

A major goal for CIS research is to transfer years of government-sponsored research to industry for pilot-scale manufacturing and to produce commercial modules. New performance heights have been reached for multi-junction solar cells of an unconventional lattice mismatched GaInP/GaInAs/Ge design, establishing this type of cell as a contender for the most efficient type of cell. The 31,3 % one-sun efficiency measured for such metamorphic cells is greater than the previous efficiency record, and would have been the highest one-sun efficiency yet measured had it not been exceeded by a 32,0 % lattice-matched 3-junction cell in the same fabrication run.

A new record concentrator cell efficiency of 35,2 % under (air mass) AM 1,5, direct, low-AOD (low aerosol-optical-depth) spectrum has been achieved at Spectrolab. Careful consideration of receiver design and the cell package assembly process has resulted in a robust concentrator system, allowing reliable outdoor operation of high-efficiency multi-junction concentrator cells under continuous illumination at high concentration.

Shell Solar and Global Solar sold non-concentrating commercial products using CIS alloys in 2003. Shell Solar produced 5- to 40-W PV modules made of CIS alloys. Global Solar continued to produce flexible modules for a variety of field applications.

Research and Development of the Balance-of-System

Research within the industry and the national laboratories continued to explore improved solid-state switching methodologies for inverters, new control firmware and software, new balance-of-system hardware designs, and entire PV systems that are cost effective. Inverter development included high reliability, universal/modular inverters and conformance with anti-islanding and code requirements. Three contractors were selected to complete a Phase I project aimed at determining designs, feasibility, and

Fig. 2 - Domaine Carneros Winery, Napa, CA - 120 kW.
(photo Courtesy of PowerLight Corporation)

market analysis for a high reliability inverter suitable for PV and other renewable energy applications. Issues pertaining to environment, safety and health remained an essential aspect of working with the balance-of-system industry and were included in all work sponsored by the National Solar Program. Phase II of the high reliability initiative was begun in 2003. Prototype hardware from this phase is scheduled for delivery in 2004.

Sandia National Laboratories' Distributed Energy Technologies Laboratory (DETL) performed numerous evaluations and performance studies of PV inverters ranging in size from 100 Wac to 100 kWac. Inverter evaluations involve two types of products. They were readily available hardware and developmental prototypes where the manufacturers are seeking assistance. Historically there has been no single document providing design requirements for utility-interactive photovoltaic (UIPV) inverters. Standardized test protocols were developed at the DETL in order to bring diverse requirements together. 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. The grid-tied test plan was designed to evaluate the performance and utility compatibility of UIPV inverters.

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.

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 %, and for modules toward 20 % and creating 33 %-efficient multi-junction concentrators. 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 I entitled "Identifying Critical Paths" continued to identify problems, approaches, and alliances. In 2003, the first HiPerf PV subcontract solicitation was completed.

Research on Crystalline Silicon

Fabricating record high-efficiency ribbon silicon solar cells with screen-printed and photolithography-defined contacts was completed in 2003. 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 "String Ribbon" (15,6 %) cells 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 developed.

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

Information on a new concept called the AC PV Building Block was disseminated to industry. This concept is expected to fill an important market niche for code-compliant, retrofit and building-integrated applications. One manufacturer began a feasibility study in 2003. Studies to determine inverter, materials, thermal-management and reliability requirements were initiated.

Demonstration Programs

No major national demonstration programs were active during 2003. Several programs were sponsored by various sectors of state governments and utilities, most notably California. Deregulation of the electric utilities and localized energy shortages have spurred several state programs that require installation of PV energy systems along with new R&D efforts aimed at fielded PV systems.

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.

Fig. 3 - Tuscon Electric Power's Springerville Generating Station Solar System (SGSSS). 32,280 photovoltaic panels in eastern Arizona. The array currently produces more power than any single photovoltaic installation in the world, 4,958 mega-watt-hours (MWh) in 2003 and expected 6,400 MWh in 2004. (photo courtesy of Dave Sanders)

Photovoltaic Manufacturing

To maintain 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 "Photovoltaic Manufacturing R&D - In-line Diagnostics and Intelligent Processing in Manufacturing Scale-Up." This solicitation encouraged teams to share the cost of high-risk research to develop intelligent processing for larger scale manufacturing that will be the foundation for achieving the goals set out in the U.S. Photovoltaic Industry Roadmap. A new solicitation, "PV Manufacturing R&D - Large-Scale Module and Component Yield, Durability, and Reliability," was announced and processed in 2003. Its goals were to continue to strive for manufacturing improvements with increased focus on systems and component reliability. Subcontracts are tentatively scheduled for 2004.

United Solar's roll-to-roll machine now simultaneously processes six stainless-steel webs at an annual manufacturing capacity of 25-30 MWp. The new machine is not only enhancing throughput capacity, but also has increased the power of each cell by 5-10 %. The most suitable application for United Solar's product may be in PV-shingle or metal roofing-integrated applications. The new factory in Auburn Hills is not only set up to produce solar cells, but also for the robotic assembly of large roofing laminates.

Energy Photovoltaics (EPV) operated a prototype manufacturing line in New Jersey. The device is a same-bandgap a-Si:H/a-Si:H double-junction module having an aperture area of 0,75 m^2 and a power rating of 40 Wp. This module has been reported as possibly the lowest-cost commercially available today, being offered at $ 2,25/Wp. Under the Thin-Film Partnership, EPV is also developing technology to manufacture a-Si:H/nc-Si:H ("micro-morph") cells and, later, modules to enhance the performance of the a-Si product.

Iowa Thin Film (ITF) manufactured a-Si cells using roll-to-roll deposition on polymer foils. It is established as a successful niche player making lightweight flexible PV generators for a variety of consumer applications.

BP Solar ceased operation of its 10-MW/year a-Si plant with enhanced throughput that produced tandem-junction modules. BP also closed its manufacturing facilities for CdTe in 2003. BP continued to manufacture its multi-crystalline PV modules.

AstroPower was developing an advanced photovoltaic module product based on thin-silicon on ceramic substrates throughout 2003. Recent results included an efficiency of 9,1 %, with a 1,0 cm^2, single element device and a 5,5 % efficient monolithically interconnected four segment, 5,6 cm^2, mini-module. This advanced product requires features such as silicon layers grown on a low cost ceramic, total silicon layers 100 µm thick, light trapping and back-surface passivation. These performance design features, combined with the use of low-cost continuous processing equipment, are expected to lead to high performance, low-cost photovoltaic panels. The thin-silicon device structure allows for the use of imperfect materials and increased doping levels, and lowers cost by minimizing the use of expensive feedstock material.

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. Improved reliability of inverters and required switchgear was also funded with Phase I of the high reliability inverter initiative begun in 2003. 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 module performance and durability studies for manufacturers based on data from several test sites. For new modules or for those that have operated in the field for years, researchers collect data on electrical performance, physical properties, integrity of solder joints, and properties of encapsulants. Tests 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.

An inverter test facility at Sandia provided for 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

Fig. 4 - 125 kW PV system using RWE Schott Solar's FS mounting and ASE-300 PV modules at the U.S. Coast Guard Training Center in Petaluma, CA. (photo credit RWE Schott Solar, Inc.)

that are resistive, inductive, and capacitive in nature. This DETL was used to study the effects of any distributed generation system (including PV and PV hybrid systems) on electrical utility operation, to verify proposed tests in standards and to help establish a certification test protocol for inverters.

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 are a major goal of the PV system activities. To reach that goal, the program is supporting research and analysis using field data and models to identify areas for further technical development. Sandia's "PV System Reliability Plan," drafted in consultation with industry, is guiding hardware and system development. The plan recommends continuation of several activities such as developing a reliability database to improve understanding of the performance of real systems; examining PV systems and components after extended operation in the field to identify sources of performance degradation or failures that could be prevented by changes in manufacturing; modeling system performance to identify fault-tolerant designs, sensitivities to component failure, and 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. An "Industry Forum" proposed 24 changes in Article 690 of the NEC for the upcoming 2005 Code. The 2005 code cycle input was completed in 2003.

The new IEEE1547 "Standard for Interconnecting Distributed Resources With Electric Power Systems" was accepted as an IEEE standard in 2003. Three additional tasks for the standard continued to be developed. Underwriters Laboratories began new updates for the UL1741 "Standard for Static Inverters and Charge Controllers for Use in Photovoltaic Power Systems" and expanded the standard to include inverters for all distributed generation.

The Arizona State University PV Testing Laboratory (PTL) conduced additional module certification tests based on the accreditation certificate they received from the American Association of Laboratory Accreditation. Module models have been qualified to IEEE1262/IEC61215 or IEEE1262/IEC61646 standards since the work began in 1996. The PTL continues to test module types to the UL1703 PV module standard to determine their suitability for listing and has a reciprocity arrangement with European testing organizations. The PTL plans to perform preliminary "Inverter and Systems Certification Tests" within the next year.

A "National Voluntary Certification Program" for PV installers was developed with the support of the U.S. DOE PV Program and was launched in 2003 with nearly 100 applicants in the first round of testing. State funding was also continued in 2003 with cost sharing by New York.

INDUSTRY STATUS

The quantity of PV modules produced in the United States in 2002 reached 120 MW and continued to grow at more than 10 % in 2003. Photovoltaic installations in the U.S. grew to more than 60 MW. The United States PV applications in 2003 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 35 MW per year of grid-connected systems. Approximately 20 MW of small, 2- to 4 kW roof-mounted systems are installed on private residences. The systems use all types of PV modules and are sometimes connected to a multiple mode inverter that permits the PV system to first serve the building's load and then to send excess power to the utility grid. When the grid power is not available, the inverter may be designed to switch to "standby" and power the local load from energy stored in a battery bank.

There are several inverter manufacturers serving the U.S. market. They all have complementary markets for inverters, and some export a large percentage of their product. Much of the U.S. inverter industry has been consolidated under Xantrex of Canada. Many new inverter manufacturers emerged in 2003. The new products are being listed and were commercialized in 2003. The new PV inverter manufacturers included Ballard, Solectria, Magnetek, OutBack Power, and others close on the horizon. In 2001 SMA (Germany) opened a sales office (SMA America) in the U.S. and now sells its UL-listed grid-connected residential inverters for U.S. applications.

MARKET DEVELOPMENT

The National Solar Program provided continuing support for state-supported PV applications using assistance through the Interstate Renewable Energy Council (IREC). Much of this work continued to provide PV applications and education for parks and public spaces through the "Photovoltaics for Utilities (PV4U)" program. The approach to removing barriers to PV for utilities is a network of State working groups that promote PV. Working with the states and supporting the North American Board of Certified Energy Practitioners for a "Voluntary National Certification Program for Practitioners" remained a focal point for the IREC program in 2003 featuring workshops and special sessions at conferences.

Sandia National Laboratories hosted a Solar Energy Technologies Systems Symposium in 2003 where 180 participants shared systems-related issues and developments. System performance, reliability, energy surety systems-driven approach applications and marketing were some of the key topics.

Barriers to the 50 MW rural electrification market for PV systems were addressed when NCPV personnel provide analysis and technical assistance to organizations such as the U.S. Department of Agriculture's Rural Utility Service, the U.S. Department of Defense, the U.S. Agency for International Development, the Florida Solar Buildings Program, the U.S. Bureau of Reclamation, Mexico's Agricultural Secretariat, the Salt River Project, and the Navajo Tribal Utility Authority.

International work included continuation of the Mexico Renewable Energy Program that is sponsored by the U.S. Agency for International Development (USAID) and supported by the U.S. 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 now serves as a model for increasing the use of renewables in other parts of the world. These projects were implemented in partnership with local Mexican organizations in each geographical or political area to purchase, finance, install and maintain the sustainable systems. This program is resulting in wide-scale system replication, through increased awareness of the benefits of renewable energy technologies, and improved private sector capacities to serve the market.

The NCPV support, such as training and technical assistance in Bolivia, Brazil, China, Ghana, Guatemala, Honduras, India, Indonesia, Kenya, Mexico, Morocco, Nigeria, Pakistan, the Philippines, Russia, South Africa, and Venezuela, has helped U.S. companies continue to make inroads into the international market.

The U.S. DOE Million Solar Roofs 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. Thirty-five MSR state and local partnerships received grants in 2003, totaling more than $ 1,6 million. MSR partners will use these grants to break down barriers to deploy more solar in the U.S. More than 70 proposals were submitted for the highly competitive grants.

FUTURE OUTLOOK

The U.S. Department of Energy, in partnership with its national laboratories, will continue with strong PV initiatives through the National Solar Program. The "Industry Roadmap" and an updated "DOE Photovoltaics Technology Plan" will guide the work using a "Systems-Driven Approach" to determine priorities based on market needs. The market development and expansion will include all of the components, interconnects, and materials needed for the PV industry. PV materials, manufacturing processes, balance-of-system hardware, fire and personnel safety, codes, standards, hardware certification and practitioner certification will remain vital elements in the program.

ANNEX A

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COLOPHON

Cover photograph
Reto Miloni
Task Status Reports
PVPS Operating Agents
National Status Reports
PVPS Executive Committee members and Task 1 experts
Editor
Mary Jo Brunisholz
Layout and design
Nuance, graphisme, web, communication, Givisiez, Switzerland
Paper
Normaset Puro blanc naturel
Type set in
Rotis
Printed in 1000 copies by
Imprimerie St-Paul, Fribourg, Switzerland