IEA INTERNATIONAL ENERGY AGENCY

PHOTOVOLTAIC POWER SYSTEMS PROGRAMME

# PVPS annual report 2006

IMPLEMENTING AGREEMENT
ON PHOTOVOLTAIC POWER SYSTEMS

PHOTOVOLTAIC POWER SYSTEMS PROGRAMME

# ANNUAL REPORT 2006

# CHAIRMAN'S MESSAGE

I am pleased to present the annual report of the IEA Photovoltaic Power Systems Programme covering the year 2006. Interest in PVPS activities and results has once again increased with the outcome of further outreach towards new countries, networks and stakeholders. The network was systematically extended towards new target groups, new members as well as new work items and accompanied by increased communication efforts; both on the Executive Committee level as well as on the Task level.

As the topic of energy in general and renewable energy in particular is gaining worldwide momentum, PVPS and its members have had stronger interaction with other renewable energy areas and their organisations. The G8 Gleneagles Plan of Action of the IEA has placed additional emphasis on the technology networks and their outreach activities through the NEET initiative (Networks of Expertise in Energy Technology) in which PVPS participates.

The European Photovoltaic Industry Association (EPIA) continued its membership in the PVPS Programme as a sponsor. PVPS is open to further industry associations from other regions in order to intensify our relationships and co-operation with this sector. In 2006, contacts for potential country participation in IEA PVPS have taken place particularly with Turkey, Greece, Poland and Malaysia.
With the support from EPIA and the United States, a new Task 12 on "Environmental Aspects of Photovoltaics" was established during 2006. The work of this new Task, which is covering an increasingly important topic, will commence in 2007.

The overall communication efforts were continued through systematic distribution of PVPS products (flyer, newsletter, annual report and topical reports) at conferences, workshops and by means of direct mailings. In particular, the buildings community, media and finance sectors have been in the focus of our broader communication efforts through dedicated workshops. Communication was further supported by the PVPS website www.iea-pvps.org. Moreover, a booth at the industry exhibition of the 21st European Photovoltaic Solar Energy Conference in Dresden, again attracted a large number of visitors and provided an excellent forum for dissemination purposes.

With many new results from the various ongoing projects, 2006 was another productive year for PVPS. The detailed results are given in the Task reports of this annual report and all publications can be found at the PVPS website. I would like to congratulate all Tasks on their progress and achievements.
The current status of photovoltaics in the PVPS member countries is described within the country section of this annual report.

To my great regret, our Executive Committee member Michel Viaud, representing EPIA, passed away at the end of 2006. Michel has been a strong supporter for the case of photovoltaics and IEA PVPS and we have lost a dear friend to whom we remain most grateful for his contributions and his dedication.
A number of Executive Committee members have left us during the year, heading for new responsibilities or horizons. I would like to thank them for their strong support and valuable contributions. With this, I take the 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

# TABLE OF CONTENTS

# PHOTOVOLTAIC POWER SYSTEMS PROGRAMME

## IEA

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

Collaboration in research, development and demonstration of new technologies has been an important part of the Agency's Programme. The IEA R&D activities are headed by the Committee on Research and Technology (CERT), supported by a small secretariat staff, with headquarters in Paris. In addition, four Working Parties on End Use, Renewable Energy, Fossil Fuels and Fusion, are charged with monitoring the various collaborative energy agreements, identifying new areas for co-operation and advising the CERT on policy matters. The Renewable Energy Working Party (REWP), chaired by the first PVPS chairman, Mr. Roberto Vigotti, oversees the work of ten renewable energy agreementsand 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 2006, twelve Tasks were established within the PVPS programme, of which one was completed in 1997 (Task 6), two were completed in 2001 (Task 5 and Task 7), one was completed in 2004 (Task 3) and one is not operational (Task 4). A new task began in 2006 (Task 11) on PV Hybrid Systems within Mini-Grids, which is a follow up to Task 3. The draft Workplan for a new task was approved in 2006 (Task 12).

The twenty-one PVPS members are: Australia, Austria, Canada, Denmark, EPIA, European Union, France, Germany, Israel, Italy, Japan, Korea, Mexico, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom and the United States. Turkey has shown an interest to revive its membership. The European Photovoltaic Industry Association (EPIA) joined PVPS in 2005.

## 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 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

## 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.<br>• To share the knowledge and experience gained in monitoring selected national and international PV projects.<br>• To provide guidelines for improvement of the design, construction and operation of photovoltaic power systems and subsystems.<br>• 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;<br>• Recommended practices for improved design, construction and operation and maintenance of PV systems and subsystems, in an accessible form;<br>• Recommendations concerning remaining technical issues for the interconnection to the grid of small-dispersed systems as well as large and very large PV systems;<br>• 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;<br>• To present/publish the reliable and relevant parts of this information in appropriate forms (brochures, reports, books, internet etc.);<br>• To disseminate these information products, relevant for the deployment of PV systems, to target groups;<br>• To monitor the use of this information and the effects on the awareness among target groups;<br>• To bring actors of different groups together, and to encourage the creation of national and international networks;<br>• To identify the most successful policy mechanisms leading to a self-sustained market growth;<br>• To provide objective policy advice to governments, utilities and international organisations;<br>• 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;<br>• PVPS fact sheets covering the development of key parameters and issues, e.g. industry shipments, installed capacity, potential, cost, etc. ;<br>• The Trends In Photovoltaic Applications Report 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 Trends report is to present an accurate, comprehensive and useful description of the PV products, applications and markets in the reporting countries. The Trends report is published in printed form on an annual basis;<br>• 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;<br>• 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;<br>• An overview of the activities, available information such as reports and contact points of the PVPS programme on the Internet;<br>• 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;<br>• 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;<br>• 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;<br>• Input to national workshops is provided by the participation of PVPS experts; |
| 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;<br>• To conduct occupant surveys and gather key market data on targeted projects managed within participating countries;<br>• To evaluate the inclusion of PV within the standard design and construction process in selected communities worldwide;<br>• To assess the buildability, saleability, pricing and financing options for BIPV rooftop products and providing feedback to industry and manufacturers;<br>• 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;<br>• To develop material that will assist in the development of standardised net metering contractual agreements between homeowners and utilities;<br>• To address mortgage and insurance issues;<br>• To identify steps in streamlining installation procedures and electrical inspections. | • Summaries of the outcomes of the PVPS programme in national information networks and media are encouraged.<br>• Compilation of jurisdiction within participating countries where net billing and net metering has increased the accessibility;<br>• Compilation of homebuilders providing solar home options to customers;<br>• Overview of PV financing methods in OECD countries;<br>• Planning methods to evaluate and maximise the benefits of grid-connected photovoltaic systems to the electric grid and to the customers; |
| 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;<br>• To stimulate co-operation between IEA PVPS members and selected non-IEA countries;<br>• To increase awareness on the opportunities of PV systems amongst targeted groups in developing countries via workshops, missions and publications;<br>• To stimulate PVPS membership of selected non-IEA countries;<br>• To identify opportunities and provide best practice for emerging applications (non-domestic systems, community systems, hybrids, mini-grids, weak grids);<br>• To promote adequate measures for quality assurance and standards;<br>• To identify the opportunities and conditions to implement adequate mechanisms of the Kyoto protocol as well as WSSD initiatives. | • Specific studies on important issues (e.g. non-technical barriers, financing, potential assessments, PV in competitive energy markets, etc.).<br>• Collation and analysis of relevant existing publications on PV in developing countries;<br>• 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;<br>• A regular electronic newsletter containing an information update on the CDM process and latest news on Task 9 publications, workshops and other relevant events;<br>• Staff workshops for multilateral and bilateral agencies;<br>• Workshops in non-IEA countries, co-ordinated with bilateral and/or multilateral agencies and/or NGOs;<br>• Active participation of target groups in selected developing countries;<br>• Dialogue and contact point with staff of multilateral and bilateral agencies. |


*IEA PVPS Executive Committee, Busan, Korea, October 2006.*

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

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

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

## IEA-PVPS TASKS

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

- Task 1. Exchange and Dissemination of Information on PV Power Systems;
- Task 2. Performance, Reliability and Analysis of Photovoltaic Systems;
- Task 3. Use of PV Power Systems in Stand-Alone and Island Applications (concluded in 2004);
- Task 4. Modelling of Distributed PV Power Generation for Grid Support (not operational);
- Task 5. Grid Interconnection of Building Integrated and other Dispersed PV Systems (concluded in 2001);
- Task 6. Design and Operation of Modular PV Plants for Large Scale Power Generation (concluded in 1997);
- Task 7. PV Power Systems in the Built Environment (concluded in 2001);
- Task 8. Very Large Scale PV Power Generation Systems;
- Task 9. PV Services for Developing Countries;
- Task 10. Urban Scale PV Applications. Begun in 2004. Follow-up of Task 7.
- Task 11. PV Hybrid Systems within Mini-Grids. Begun in 2006. Follow-up of Task 3.
- Task 12. Environmental Health and Safety Issues of PV. Draft Workplan approved in 2006.

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

# TASK STATUS REPORTS

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

### OVERALL OBJECTIVES

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

All countries participating in the PVPS Programme are members of Task 1. To meet the Task 1 objective and deliver the expected outcomes, Task 1 participants focus on understanding the needs of their stakeholders and target audiences for the various Task 1 deliverables and establishing mechanisms for communication both within and outside the PVPS Programme.

Task 1 activities are organized into the following subtasks:

#### SUBTASK 1.1: Status Survey Reports

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

Trends reports were initially produced every two years but are now produced annually to provide more timely information. The first issue was printed in March 1995 and a further ten issues had been published by the end of 2006.

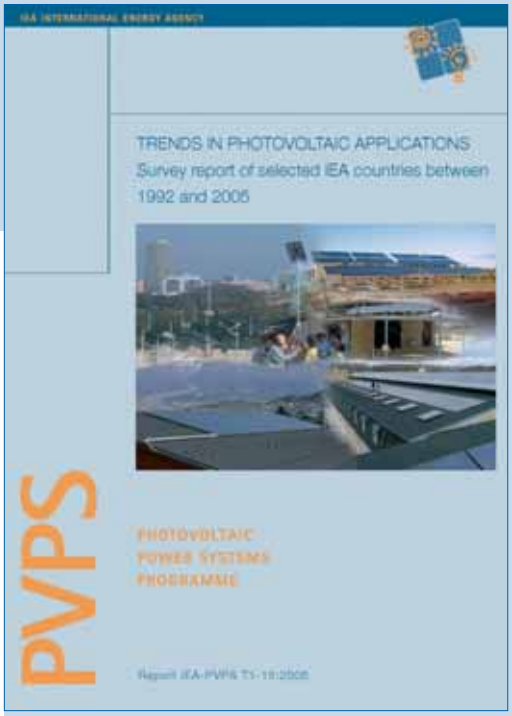
#### SUBTASK 1.2: Newsletter

A printed, colour newsletter, PVPower, is prepared and distributed to stakeholders by post and also via the website each six months to present highlights of the IEA-PVPS Programme as well as general features of interest about PV systems and components and market applications. Task 1 participants provide material of interest to the newsletter editor and ensure that the newsletter reaches its target audience in the respective countries.

Twenty five issues of the newsletter had been published by the end of 2006.

#### SUBTASK 1.3: Special Information Activities

A range 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,




*Trends in Photovoltaic Applications. Survey Report of Selected IEA Countries between 1992 and 2005.*

Added Values of Photovoltaic Power Systems, PV Industry Roadmaps, Environmental Safety and Health issues, International PV Collaboration and Market Developments, and Finance and PV. Other activities include Buy Back Rates for Grid-connected Photovoltaic Power Systems; Photovoltaic Components and Systems: Status of R&D in IEA Countries and Photovoltaics in Cold Climates.

The matters of interest to Task 1 participants are increasingly being incorporated into existing activities – such as the newsletter, the survey reports, the website and as input to other tasks except where dedicated activities such as workshops might be supported.

### SUMMARY OF TASK 1 ACCOMPLISHMENTS FOR 2006

The key Task 1 priority is meeting the information needs of the various stakeholders and target audiences, within the context of the objectives of the PVPS Programme. The public website www.iea-pvps.org is a cost-effective means of communication and information dissemination for Task 1 members and the Programme as a whole, and is continually refined to best achieve these outcomes.

#### SUBTASK 1.1: Status Survey Reports

The 11th issue of the Trends in Photovoltaic Applications report was published in August 2006 and analyzed data collected between 1992 and the end of 2005. The 2006 report include information on national market frameworks, public budgets, the industry value chain, prices, economic benefits, new initiatives, electricity utility interests, standards and codes and RD&D / technology overviews. The 32 page report was prepared by a small group from within Task 1 on the basis of the annual National Survey Reports prepared by all Task 1 participants and was funded by the IEA-PVPS Programme. Copies are distributed by post by Task 1 participants to their identified national target audiences and are provided at selected conferences and meetings. A paper on the 2006 Trends report was written for the European PV Conference in Dresden, Germany and presented in an oral session by Japanese Task 1 participant, Izumi Kaizuka.


*Newsletter PVPower issues 24 and 25.*

*Mr. Osamu Ikki, Chairman, RTS Corp, Japan, speaker at the IEA PVPS Workshop, Zurich, November 2006.*

*IEA PVPS workshop, Solar Photovoltaic Electricity: A Wealth of Investment Opportunities Under the Sun, held in Zurich, November 2006.*

The National Survey Reports are funded by the participating countries and provide a wealth of information. The latest versions 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 including information on national market frameworks, public budgets, the industry value chain, prices, economic benefits, new initiatives, electricity utility interests, standards and codes, and an overview of R&D activities.

### SUBTASK 1.2: Newsletter

Editorial policy for the newsletter continued to emphasize that projects and products –both PVPS and other - must be tangible to be included. PVPower issue 24 was published in June 2006. PVPower issue 25 was published in October 2006. The back page contained a listing of PVPS reports and books between 2003 and 2006. This complements an earlier listing that was published in PVPower issue 18. Current and back issues of PVPower are available on the public website.

### SUBTASK 1.3: Special Information Activities

In conjunction with the European PV Conference in Dresden, Germany, Task 1 organized a closed workshop, The PV Bubble: Behind the News, on September 8th 2006. The workshop was targeted at media, industry and analysts and presented the latest Trends and other work and sought feedback from the participants. Task 1 participants from Australia, Japan, Malaysia, Switzerland and the US contributed to the workshop.

A finance and PV workshop, Solar Photovoltaic Electricity: A Wealth of Investment Opportunities Under the Sun, was held in Zurich, Switzerland, on November 14th 2006. The event was organized by Task 1 participants Nova Energie GmbH of Switzerland and RTS Corporation of Japan, and received support from the Swiss investment and finance sector through INRATE AG, and the Swiss PVPS Pool. The audience of fund managers, PV industry representatives, investment institutions, utilities and policy advisers heard a variety of presentations and then debated a number of the questions being asked of PV: Can the current PV technology deliver on its promises? Are there sustainable markets for the products? Are the costs (and prices) competitive and in line with potential returns? Could the 'PV bubble' burst? And where exactly do the risks and opportunities lie?

## SUMMARY OF TASK 1 ACTIVITIES PLANNED FOR 2007

Task 1 activities will continue to closely reflect the broader strategy for the PVPS Programme. Market implementation is an important focus for PVPS activities, as is a close working relationship with the PV industry and other stakeholders (including non-IEA-PVPS countries).

### SUBTASK 1.1: Status Survey Reports

The target date for publication of the 12th issue of the Trends in Photovoltaic Applications report is August 2007, with electronic versions of the information to be made available on the public website in July 2007. National Survey Reports will be completed before the end of May 2007, based on the revised template, so that the information can be incorporated in and analyzed for the Trends 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. It is planned to develop strategies during 2007 to more fully capture the newsletter's full potential for PVPS information outreach, both within and outside the IEA-PVPS countries.

PVPower Nos. 26 & 27 are planned to be published in March 2007 and September 2007 respectively, maintaining current editorial policy.

### SUBTASK 1.3: Special Information Activities

During the year Malaysia, Observer to Task 1, will manage a survey activity – Awareness and Capacity Building Programmes for PV. The objectives of this survey are to find out how member countries managed their awareness and capacity building programmes, the effectiveness of the communication strategies deployed, lessons learnt etc. This will provide valuable insights to assist those responsible for awareness raising and capacity building programmes.

Task 1 participants will organize or contribute to workshops being planned for Israel (part of the Sede Boqer BiPV workshop, February 2007), Mexico (Zacatecas, with the regional Government in June 2007), Malaysia (Kuala Lumpur as part of the MBIPV Project in August 2007), Italy (in conjunction with the European PV Conference in Milan, in September 2007) and Japan (as part of PVSEC-17 in Fukuoka in December 2007).

## LIST OF PARTICIPATING COUNTRIES, KEY TASK 1 PARTICIPANTS IN 2006 AND THEIR ORGANISATIONS

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

| COUNTRY | NAME | ORGANISATION |
|---|---|---|
| Australia | Greg Watt | Australian PVPS Consortium |
| Austria | Roland Bruendlinger | Arsenal Research |
| Canada | Josef Ayoub | Natural Resources Canada |
| Denmark | Peter Ahm | PA Energy A/S |
| European Union | David Anderson | DG Research |
| France | André Claverie | ADEME |
| Germany | Lothar Wissing | Forschungszentrum Jülich |
| Israel | Yona Siderer | The Ben-Gurion National Solar Energy Centre |
| Italy | Salvatore Guastella | CESI RICERCA S.p.A. |
| Japan | Osamu Ikki | RTS Corporation |
| | Izumi Kaizuka | RTS Corporation |
| Korea | Kyung-Hoon Yoon | KIER |
| Malaysia (Observer) | Wei-Nee Chen | PTM |
| Mexico | Jaime Agredano Diaz | IIE |
| Netherlands | Job Swens | SENTERNOVEM |
| Norway | Fritjof Salvesen | KanEnergi AS |
| Portugal | Luis Silva | ADENE |
| Spain | Javier Sanz | CENER |
| Sweden | Lars Stolt | Uppsala University |
| | Ulf Malm | Uppsala University |
| Switzerland | Pius Hüsser | Nova Energie GmbH |
| United Kingdom | Sarah Davidson | IT Power Ltd |
| USA | Ward Bower | Sandia National Laboratories |
| | Susannah Pedigo | NREL |

*Up-dated 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. The target audience for PVPS information has broadened considerably, with Task 1 now actively engaging the finance sector. Electricity utilities, particularly the network businesses, and non IEA-PVPS country parties need to be better engaged.

## KEY DELIVERABLES (2006 AND PLANNED)

The following were published and also made available on the public website during 2006:

*Trends in Photovoltaic Applications in Selected IEA Countries between 1992 and 2005.* Report IEA-PVPS T1-15: 2006;

Newsletter - *PVPower issues 24 and 25.*

Individual National Survey Reports are included each year under 'Country information' on the public website, with tables and graphs able to be downloaded. A template and data collection pro forma for the NSRs are produced and updated each year.

During 2007 it is planned to produce the twelfth issue of the Trends in Photovoltaic Applications report, PVPower issues 26 and 27, a report on various awareness and capacity building programmes and a range of country and workshop information.

## MEETING SCHEDULE (2006 AND PLANNED 2007)

The 27th Task 1 Meeting was held in Vancouver, Canada 27-28 March 2006.
The 28th Task 1 Meeting was held in Vienna, Austria 11-12 September 2006, immediately following the European PV Conference in Dresden and associated Task 1 workshop.
The 29th Task 1 Meeting will be held in Zacatecas, Mexico 4-5 June 2007, with an associated regional workshop.
The 30th Task 1 Meeting will be held in Tokyo, Japan 10-11 December 2007, immediately following PVSEC-17 in Fukuoka and associated Task 1 workshop.

# TASK 2 - PERFORMANCE, RELIABILITY AND ANALYSIS OF PHOTOVOLTAIC SYSTEMS

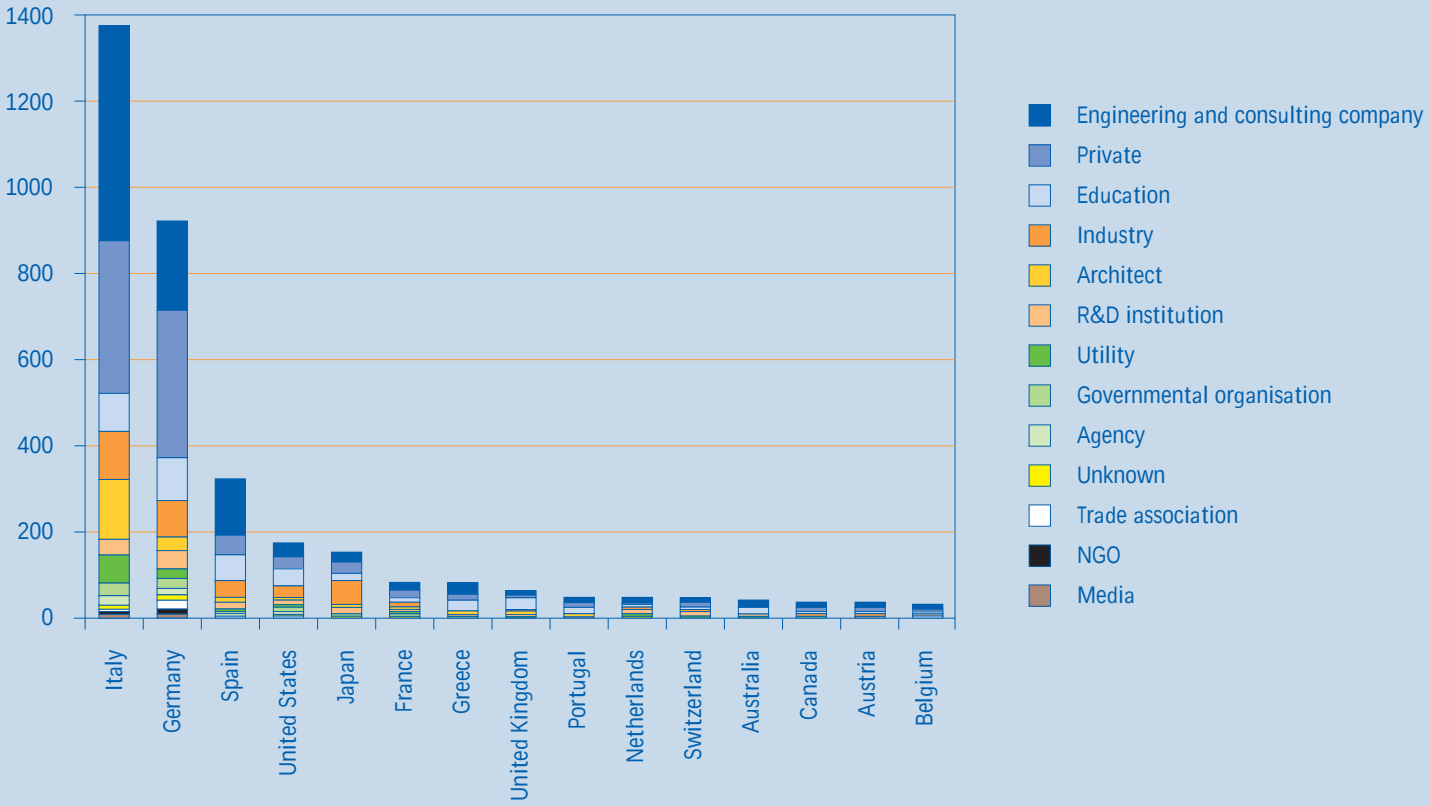



*Fig. 1 - IEA-PVPS Task 2 Performance Database programme dissemination between 2001 and 2006: 4 179 registrations of different users in 90 countries. The top 15 countries are shown.*

## OVERALL OBJECTIVE

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

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

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

### SUBTASK 1: International Database

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

### SUBTASK 5: Technical Assessments and Technology Trends of PV Systems

Participants analyse and validate expertise and performance results from grid-connected (GCS), stand-alone (SAS) and PV-based hybrid systems. The aims of this subtask are to demonstrate up-to-date performance validation criteria for a qualitative ranking of PV grid-connected, stand-alone and PV-based hybrid systems.
It will also identify high performance products, technologies and design methodology in order to foster the development of maximum conversion efficiency and optimum integration of PV.

### SUBTASK 6: PV System Cost over Time

Task 2 will identify and evaluate the important elements, which are responsible for the life cycle economic performance of PV systems by investigating economic data for all key components of PV systems and by gathering information about real life costs of maintenance of PV systems.

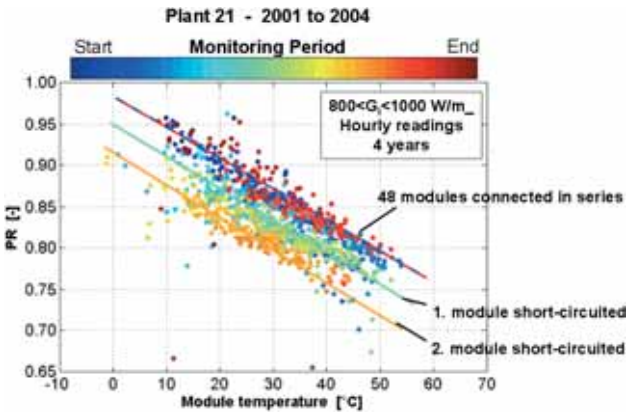



*Fig. 2 - Long-term performance measurements help to identify system failures: Performance Ratio (PR) shown at the y-axis as a function of module temperature (x-axis) and time (colour). Conclusion: Due to low scattering of PR at high irradiance levels, the failure of one or two PV modules out of 48 becomes clearly visible.*

## SUMMARY OF TASK 2 ACCOMPLISHMENTS FOR 2006

During 2006, Task 2 focused on performance analysis, characterization and prediction of PV systems for exchanging Task 2 results with other groups and networks (e.g. EU projects: IP Performance, PV Catapult, PV Enlargement, PVSAT-2). Task 2 enhanced efforts to disseminate Task 2 results and deliverables to target audiences on national and international level by conference and seminar presentations, training courses and a European master course. For the dissemination of Task 2 deliverables, the public Task website enables downloads and technical information to be provided quickly and cost-effectively to the users. The information retrieval of PVPS Task 2 products is being tracked to measure the extent to which the website is visited and the products are used.

### SUBTASK 1: International Database

The PV Performance Database was updated and the programme was released in September 2006 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 from 461 PV systems with different system technologies, located in 21 countries. The Performance Database programme (48 MB) is available from the Task website http://www.iea-pvps-task2.org and needs to be installed locally on the user's personal computer.

For faster access to the database information, a visualization tool for the web-based database was developed and optimized. The Internet database was released in October 2006. The online database version contains the essential information of the original database and was particularly designed to meet the requirements of a broader target audience.

Task 2 focused on the dissemination and promotion of the Task 2 database. As a result, 4 179 database users from 90 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 2006, highest demand for the Performance Database came from users in Italy and Germany in the engineering sector and the private sector, followed by the education and industry sector (Figure 1).

### SUBTASK 5: Technical Assessments and Technology Trends of PV Systems

#### Long-term Reliability of PV Systems

Based on the extended Performance Database, long-term "performance continuity" of the PV systems was investigated using monitoring data from 21 PV systems operating over 106 years. Both, monitoring data including hourly values of in-plane irradiance, module temperature and energy output of the inverter from 21 individual PV systems, as well as several years of maintenance and failure information were evaluated. PV system performance was analysed and compared at identical climatic conditions such as in-plane irradiance and module temperature. Different filter algorithms, visualizing even very small shifts in Performance Ratio (PR) were applied (Figure 2). First results revealed that many PV installations show a constant performance level over many years, while a decrease of performance ratio over time was observed for a few PV systems. Most relevant results were orally presented at the 21st EUPVSEC in Dresden, Germany, in September 2006.

#### User's Awareness of PV System Performance

Activity leader Japan (AIST and JET) conducted a survey on technical problems of PV systems and on the users' awareness for grid-connected and for stand-alone PV systems. In the first step, the survey addressed grid-connected PV systems and users of the residential programme in Japan in November 2004. Differences between expected and actual energy yields seem to be one reason for a pessimistic view on the PV systems in general. In the second step, the questionnaire survey was extended to stand-alone systems (SAS) investigating the troubles of SAS and the users' perception of PV systems in Mongolia in July 2005. Final results and the outcome of the investigations and analysis will be summarized in an internal Task document.

#### Performance Prediction

Activities concentrated on the possibility of using solar irradiation calculated from satellite images for PV systems performance prediction. Comparisons have been conducted first at the horizontal surface with ground based metrological stations and secondly on an inclined surface by comparison with measurements coming from the Task 2 Performance Database. The second part of this activity focused on the PV array performance prediction where output data from the Performance Database was compared to performance predictions made using satellite data and PV performance models.

### SUBTASK 6: PV System Cost over Time

The global Economic Survey aims at gathering information on plants, technical performance, maintenance and cost of as many PV systems as possible. The multilingual internet-based Economic Survey was started in June 2005 by placing the data acquisition tool on the public website www.iea-pvps-task2.org. The Economic Database includes the capability to search, sort and export information a free excel

environment and allows Task 2 members to analyse all collected economic data. The survey was terminated at the end of 2006. In total, useful data from 200 systems and 15 countries were collected including data from 544 operational years and economic data from 197 PV systems. No information on maintenance and maintenance cost over time was available for these 200 PV systems.

## SUMMARY OF TASK 2 ACTIVITIES PLANNED FOR 2007

Task 2 activities for 2007 will focus on the technical assessments and technology trends of PV systems (Subtask 5) and on the analysis of performance and cost data of PV systems (Subtask 6).

### SUBTASK 1: International Database

For 2007 the Task 2 aim is to enrich the PV Performance Database content in order to make it consistent with national PV market characteristics of the Task 2 countries, national PV plant typologies and state of the art system technologies.

### SUBTASK 5: Technical Assessments and Technology Trends of PV Systems

#### PV in the Built Environment

Task 2 will review PV system cases from the Performance Database with respect to shading effects. Case studies on shading losses on the PV array will be selected from the extended Performance Database and the literature. Methods and tools to determine shading losses will be analysed and validated. First recommendations how to minimise yield losses due to shading will be developed making use of existing simulation programmes. The usefulness of recommendations will be tested against typical cases of shading from the extended database, and better guidelines will be delivered where appropriate.

#### Long-term Reliability of PV Systems

Further long-term monitoring data will be collected to gain quantified information and results on the systems' reliability and learning curves. The results of other failure detection algorithm (e.g. Failure Detection Routine of PVSAT) will be compared to the analysed performance and failure curves for different examples. The influence of the incidence angle of irradiance on the Performance Ratio (PR) will be investigated. For more detailed system analysis the future work will also focus on array efficiency. A draft report including case studies as well as general information on the operational performance and reliability of PV systems will be presented.

#### Performance Prediction

The efforts on performance prediction will focus on finalizing the studies on the possibility to use solar irradiation calculated from satellite images for PV systems performance prediction. A final report will summarize the findings made from the comparison of the horizontal and inclined irradiations obtained from satellite data to measurements coming from the Performance Database, as well as PV array performance predictions using these satellite data.

In addition, the description of the potential transfer criteria of PV monitoring system insolation data into existing insolation mapping databases will be developed further in collaboration with IEA Solar Heating and Cooling programme's Task 36 in order to:

- Define measures of the quality of models deriving irradiances from satellite observation and procedures for comparison,
- Develop methodology for benchmarking and testing models.

### SUBTASK 6: PV System Cost over Time

During 2007 Task 2 will analyse the available information in the *PV System Cost over Time* database. The number of 200 reported systems is not as high as expected. Therefore, the Task 2 members agreed to compile case studies of selected systems with a common denominator for each country (for example: PV plants from a specific national programme). These case studies will be compiled in a report together with the findings from the internet-based survey on cost analysis.

## INDUSTRY INVOLVEMENT

Task 2 activities rely on a fruitful co-operation with PV industries, installers and system owners. PV industry organizations, particularly, the European PV industry (EPIA) and the German Solar Industry Association (BSW), clearly support Task 2 work and gain first-hand technical and non-technical information on performance and reliability issues. The quality aspect of PV systems and components is considered to be a major issue for the PV industry. It is important that the PV industry is effectively engaged in the Task 2 work for collecting, analysing and exchanging information on quality aspects of PV systems and components.

## KEY DELIVERABLES (2006 AND PLANNED 2007)

The following were published and also made available on the public website during 2006:

- *Long-term Performance Analysis and Reliability of Photovoltaic Systems.* In: 21st European Photovoltaic Solar Energy Conference, Dresden, Germany, September 2006, pp 2676.
- PVPS Task 2 Performance Database programme update with collected data from 461 PV systems, released in September 2006.

The following publications will be prepared during 2007:

- The activity leader from the European Commission will produce a report on guidelines on shading effects and recommendations on temperature effects as well as lessons learned on BIPV.
- The activity leaders from France and Canada will prepare a report on PV system performance prediction (in progress).
- The activity leaders from Switzerland, in co-operation with the Task 2 members, will produce a report on the findings of the Economic Survey. Case studies from Task 2 member countries will be included in the report. This report will be part of a second edition of the Country Report on PV system performance and will include all the latest data available from the PVPS Performance Database.

*Fig. 3 - PVPS Task 2 Meeting at arsenal research, Vienna, Austria, September 2006.*

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

## MEETING SCHEDULE (2006 AND PLANNED 2007)

The 4th Task 2 Participants' Meeting was held in Vancouver, Canada, March 2006 as a Joint PVPS Task meeting.
The 5th Task 2 Participants' Meeting was held in Vienna, Austria, September 2006.
The 6th Task 2 Participants' Meeting will be held in Tokyo, Japan, March 2007.
The 7th Task 2 Participants' Meeting will be held in Lucerne, Switzerland, September 2007.

## TABLE 1 - LIST OF PARTICIPATING COUNTRIES, TASK 2 PARTICIPANTS IN 2006 AND THEIR ORGANISATIONS

| COUNTRY | PARTICIPANT | ORGANISATION |
|---|---|---|
| Austria | Stefan Mau | Arsenal Research, Vienna |
| Canada | Yves Poissant | CANMET Energy Technology Centre, Varennes |
| European Photovoltaic Industry Association | Eleni Despotou | European Photovoltaic Industry Association (EPIA), Brussels |
| European Commission | Harald Scholz | DG Joint Research Centre (JRC), Ispra |
| France | Didier Mayer | Centre d'Energétique, Ecole Des Mines de Paris |
| Germany | Ulrike Jahn (Operating Agent)<br>Ugo Caminoli<br>Willie Chieukam | Bavarian Center for Applied Energy Research (ZAE Bayern), Erlangen |
| Italy | Salvatore Castello | ENEA C.R. Casaccia |
| Japan | Kenji Otani | National Institute of Advanced Industrial Science and Technology (AIST) |
| | Takeshi Igarashi | Japan Electrical Safety & Environment Technology Laboratories (JET) |
| Poland (Observer) | Tadeusz Zdanowicz | Wroclaw University of Technology |
| Sweden | Jonas Hedström<br>Carina Martinsson | Energibanken AB, Stockholm<br>Ångpanneföreningen ÅF-Process AB |
| Switzerland | Thomas Nordmann<br>Luzi Clavadetscher | TNC Consulting AG |
| United Kingdom | Nick Davies | Building Research Establishment Limited |
| United States of America | Andrew L. Rosenthal<br><br>Kevin Lynn | Southwest Technology Development Institute (STDI), New Mexico<br>Florida Solar Energy Center (FSEC), Cocoa |

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

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

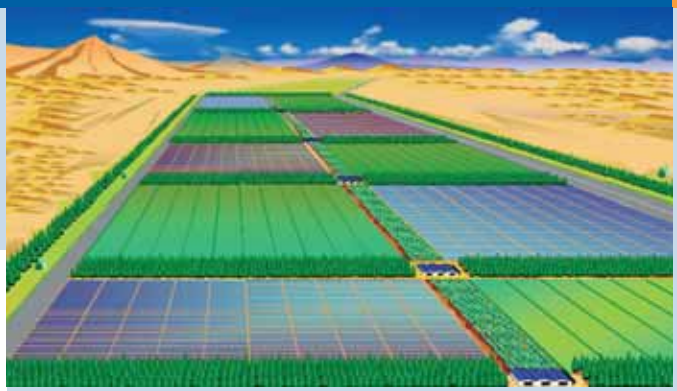


*Fig. 1 - Image of a VLS-PV System in a Desert Area.*

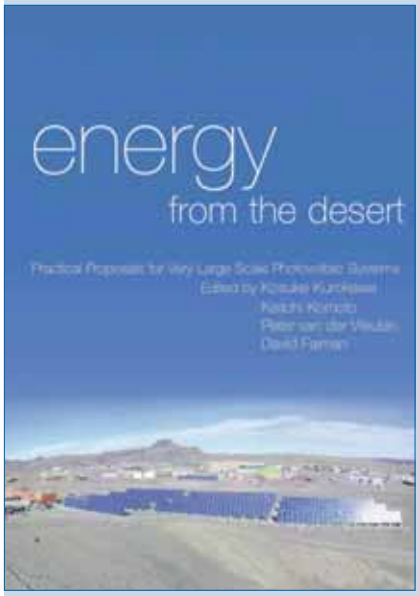



*Fig. 2 - Energy from the Desert: Practical Proposals for very Large Scale Photovoltaic Systems (cover page).*

## 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 1 (1999-2002), key factors that enable VLS-PV systems feasibility were identified and the benefits of this system's applications for neighbouring regions, as well as the potential contribution of system application to global environment protection and renewable energy utilization in the long term, were clarified. Mid- and long term scenario options for making VLS-PV systems feasible in some given areas were also proposed.

Based on the mid- and long-term scenario options of Phase 1, in Phase 2 (2003-2005) case studies on VLS-PV systems were carried out in depth and practical proposals for demonstrative research projects on pilot PV systems suitable for selected regions, which enable sustainable growth into VLS-PV Systems in the future, and general instruction to propose practical projects for large-scale PV system were discussed.

In Phase 3 (2006-2008), toward a realization of VLS-PV Systems, specific case studies from viewpoints of local, regional and global aspects are carried out, and financial and institutional scenarios and a general instruction for practical project proposals are developed. Also, considerable future technical options implementing VLS-PV system are analysed.

## MEANS

To complete the overall objectives, participants carry out three subtasks in the third phase.
Subtask 2: Case Studies for Selected Regions for Installation of VLS-PV System on Deserts
Subtask 5: General Instruction for Practical Project Proposals to Realize VLS-PV Systems in the Future
Subtask 6: Future Technical Options for Realizing VLS-PV Systems

### SUBTASK 2: Case Studies for Selected Regions for Installation of VLS-PV System on Deserts

#### Objective

Employing the concepts of VLS-PV and the criteria and other results obtained in the previous phases, 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. Feasibility and potential of VLS-PV on deserts will be evaluated from viewpoints of local, regional and global aspects.

#### Major Activities

The following are working items proposed, and some case studies will be carried out in parallel:

*Case studies of selected large-scale PV systems*

- System configuration
- Operation and maintenance
- Transmission and grid-connection issues

*Case studies/feasibility studies for implementing VLS-PV project*

- Existing CDM and emission trading project
- Feasibility for CDM or emission trading project
- Technology transfer and industry development

*Potential evaluation from environmental viewpoints*

- Life-cycle analysis, including LCC
- Micro climate analysis
- Desert and agriculture development scheme: impact on regional environment

*Survey and analysis of global solar resource*

- Solar resource analysis


*Fig. 3 - International Symposium held in Makuhari, Japan, in October 2006, in conjunction with the Renewable Energy 2006.*

### SUBTASK 5: General Instructions for Project Proposals to Realize Systems in the Future

#### Objectives

Detailed practical instructions and training kit for the development of other practical project proposals, to enable others to sustainable implement VLS-PV systems in the future, will be discussed. Employing the results developed under Subtask 4, financial and institutional scenarios will be further discussed, and the guidelines for practical project proposals will be developed.

#### Major Activities

The following are working items to be discussed in Subtask 5:

*Survey of existing large-scale PV systems in the world, as useful information*

- Centralised or integrated PV systems which have a capacity of Multi-MW (several hundreds kW, in case of desert)

*Technical aspect of VLS-PV*

- Successful and unsuccessful factors
- Variety and adoption of PV and/or solar technologies
- System and array design (including CPV)
- Transmission availability and interconnection condition

*Survey of existing institutional, organisational and financial scheme, as useful information*

- Support scheme for PV installation and operation
- Existing financial schemes and relative organisations

*Socio-economic aspect of VLS-PV*

- Successful and un-successful factors
- How to develop a financial plan
- How to commercialise (mainly, in developed countries)
- Effective assistance for sustainability (mainly, in developing countries)
- Risk assessment

### SUBTASK 6: Future Technical Options for Realizing VLS-PV Systems

#### Objective

Various technical options for implementing VLS-PV systems, including scenarios for storage and for reliable integration of VLS-PV systems into the existing electrical grid networks, will be proposed and analysed. From the viewpoint of future electrical grid stability, a global renewable energy system utilizing globally dispersed VLS-PV systems as the primary electrical energy source will be also analysed.

#### Major Activities

Following working items have been proposed and discussed.

*Electric Grid Network Scenario*

- Grid connection (similar issues as for PV and wind)
- Transmission (HVDC, HTSC, others)
- Negative load technique

*Energy storage*

- Cloud mitigation
- Load matching (storage batteries, capacitors, flywheels, others)

*Solar hydrogen scenario*

*Concentrator*

- Low concentrator
- High concentrator

## OTHER ACTIVITIES

### Technical Report Publication

A technical report based on the Phase 2 activity, entitled “Energy from the Desert: Practical Proposals for Very Large Scale Photovoltaic Systems” has been completed. The report, which will have more than 200 pages, will be published by James and James, in January 2007.

### International Symposium: "Energy from the Desert: Practical Proposals for Very Large Scale Photovoltaic Systems", in Makuhari, Japan.

In conjunction with the Renewable Energy 2006, an international symposium, "Energy from the Desert: Practical Proposals for Very Large Scale Photovoltaic Systems", was taken place in 9 October 2006 in Makuhari, Chiba, Japan. Task members introduced the results of the Phase 2 activity and Summary booklet of "Energy from the Desert: Practical Proposals for Very Large Scale Photovoltaic Systems" was distributed to the participants.

### Contribution to International Conferences

As dissemination activities, we contributed to following International Conferences.

- 4th WCPEC in Hawaii Island, USA (May 2006)
- 21st EU-PVSEC in Dresden, Germany (September 2006)
- Renewable Energy 2006 in Makuhari, Japan (October 2006)

At Renewable Energy 2006, our paper, entitled "Implementing VLS-PV on a World-Wide Scale, in a Cost-Effective Manner" presented by Prof. D. Faiman, won a best paper award.

## DELIVERABLES (2006 AND PLANNED 2007)

### External Publications

Executive Summary Booklet:
"Energy from the Desert: Practical Proposals for Very Large Scale Photovoltaic Systems," 2006.
James and James, 2007 (ISBN 1 844073 637)

## MEETING SCHEDULE (2006 AND PLANNED 2007)

15th Task 8 Meeting, 5-6 May 2006, Hawaii Island (USA)
16th Task 8 Meeting, 6-8 October 2006, Tokyo (Japan)
17th Task 8 Meeting, April 2007, Athens, Greece
18th Task 8 Meeting, September 2007, Europe

## LIST OF TASK 8 PARTICIPANTS

| COUNTRY | PARTICIPANT | ORGANISATION |
|---|---|---|
| Canada | Mr. John S MacDonald | Day4Energy Inc. |
| Germany | Mr. Claus Beneking<br>Mr. Matthias Ermer | ErSol Solar Energy AG<br>SunTechnics Solartechnik GmbH |
| Israel | Mr. David Faiman | Ben-Gurion University of the Negev |
| Italy | Mr. Fabrizio Paletta<br>Mr. Angelo Sarno | CESI Centro Electtrotecnico Sperimentale Italiano<br>ENEA |
| Japan | Mr. Kosuke Kurokawa (OA)<br>Mr. Keiichi Komoto (OA-alternate)<br>Mr. Masanori Ishimura (secretary) | Tokyo University of Agriculture and Technology (TUAT)<br>Mizuho Information & Research Institute (MHIR)<br>Photovoltaic Power Generation Technology Research Association (PVTEC) |
| Korea | Mr. Jinsoo Song | Korea Institute of Energy Research (KIER) |
| The Netherlands | Mr. Peter van der Vleuten | Free Energy International bv |
| USA | Mr. Thomas N. Hansen<br>Mr. Herb Hayden | Tucson Electric Power Company<br>Arizona Public Service |
| Mongolia (observer) | Mr. Namjil Enebish | National Renewable Energy Center |

# TASK 9 - PHOTOVOLTAIC SERVICES FOR DEVELOPING COUNTRIES

## RATIONALE AND OBJECTIVE

Photovoltaics, and other renewable energy technologies, can contribute to the economic and social development of the 2 billion people in the world who do not have access to electric lighting, adequate clean water supplies, primary health care, education and other basic services. At the Millennium Assembly of the United Nations in 2000, the international community adopted the eight Millennium Development Goals (MDGs), and set clear and ambitious targets for improving the conditions of these disadvantaged people. The focus of the programmes of the world's development assistance agencies (bilateral and multilateral donors, development banks, NGOs) are now clearly aimed at poverty alleviation in general, and at achieving the MDG targets in particular. It is generally accepted that the potential for renewable energy to transform people's lives is enormous. Figure 1 shows a typical and increasingly common sight; children whose lives are transformed thanks to electricity, from PV. This example is in Morocco, which has achieved considerable market deployment since the PVSDC meeting and workshop there in 2000.

The MDGs were reaffirmed at the UN Summit in 2005. Since then, the G8 Summit at Gleneagles in 2005 agreed on a Plan of Action, including clean energy for the developing world. The IEA is supporting this, as is the World Bank, which has committed to a target of a 20 % annual average increase in its financing of renewable energy and energy efficiency.

PV is uniquely attractive as an energy source to provide basic services, such as lighting, drinking water and power for income-generating work, for the people without access to electricity. After its first five year phase of work, PVPS Task 9 (PVSDC) adopted the primary mission of *increasing the sustainable use of PV in developing countries in support of meeting the targets of the Millennium Development Goals*. Other Renewable Energy Technologies (RETs) can also be used for electrification and basic services, and are increasingly becoming a part of the work of PVSDC. In many locations, small wind generators can be used in the same way as PV and at lower level cost. China is well known for its rapid increase in PV manufacture, almost all for export. Locally manufactured wind generators are used in large numbers domestically, such as Inner Mongolia, as illustrated in Figure 2. China is also the world's largest producer of pico-hydro systems. Figure 3 shows a 1 kW turbine on test at the manufacturer's premises in Yunnan.

In 2005, the Renewable Energy and Energy Efficiency Partnership (REEEP) began providing additional support to include other RETs, and in 2006 close cooperation was agreed with the Global Village Energy Partnership (GVEP). Both REEEP and GVEP were launched at the World Summit on Sustainable Development (WSSD), held in South Africa in 2002.

The objective of PVSDC is to increase the rate of successful deployment of PV systems (and other RETs, when appropriate) in developing countries. This is being achieved through enhanced co-operation and flow of information between the IEA PVPS Programme and the other international development stakeholders. PVSDC has drawn upon the experience of the participating countries aid and technical assistance programmes, as well as the work of agencies such as the Global Environment Facility (GEF), World Bank and United National Development Programme (UNDP). By this means, objective and impartial information is published and disseminated through workshops and seminars.

*Fig. 1 - Village electrified by PV, Morocco (photo Isophoton).*

*Fig. 2 - 500 W wind generators, Inner Mongolia (photo ITPower/BMcNelis).*

## ACHIEVEMENTS IN 2006

Task 9 has been operational since 1999. The Phase 1 Workplan was completed, in 2004.

*Fig. 3 - 1 kW pico-hydro turbine on test at DLLD, Dali (photo ITPower/BMcNelis).*

### SUBTASK 10: Deployment Infrastructure

This work contributes to overcoming the critical barriers to widespread PV deployment and implementation through the development, dissemination and application of a series of guideline documents to promote the necessary infrastructure requirements in developing countries. The aim has been to develop and disseminate a coherent series of reports to promote the necessary infrastructure requirements in developing countries to help overcome the critical barriers to widespread PV deployment and implementation. Six Recommended Practice Guides (RPGs) have been published by Task 9. Subtask 10 was essentially completed in Phase 1.
The overview document on issues for photovoltaics in developing countries 'Photovoltaics for Development': the Key to Success' has been expanded to 'Renewable Energy Services for Developing Countries', and includes micro-hydro and wind energy technologies.

The document presents an overview of PV deployment in developing countries and the key points and messages of Task 9, and has also been realigned to emphasise the linkages to the Millennium Development Goals and the International Action Programme that emerged from Renewables 2004 in Bonn and the G8 summit in the UK in 2005. This document has been expanded to cover applications such as water supply and community services, and will be published in 2007. Clean water can transform lives; the excitement of the villagers at a new PV borehole installation in Ghana is illustrated in Figure 4. The big demand for clean water from a PV pump in Senegal is shown in figure 5.

Task 9 supports Task 1 in the collection of PV market data for non-PVPS (developing) countries.

### SUBTASK 20: Support and Co-operation

PVSDC stimulates awareness and interest amongst the multi- and bilateral agencies, NGOs and other target sectors on the technical and economic potential and opportunities arising for RETs. This enables decision-makers to obtain the expertise and knowledge that is required for the appropriate RET system deployment.

There is a particular interest of the G8, IEA, REEEP and other institutions in co-operation with the five major energy consuming and greenhouse gas emitting developing countries, known as the "G8+5"; Brazil, China, India, Mexico and South Africa. PVSDC has been active in China and developed close links, as reported previously. In February 2006, PVSDC contributed to the organisation of workshops in India and South Africa, where the work was presented to large audiences. India and South Africa have quite different experiences with PV deployment. India has a thriving market and industry, while South Africa has yet to achieve such successful market deployment. The sixth Delhi Sustainable Development Summit (DSDS) was held in New Delhi, organised by the Tata Energy Research Institute (TERI). The theme of the meeting was "Linking across the Millennium Development Goals". PVSDC organised a side-event with TERI to present its work and results. The UK-DTI organised a Renewable Energy Evaluation Mission to South Africa. Workshops were held in Cape Town and Johannesburg.

PVSDC was presented and supplemented by REEEP.

In 2005, PVSDC held an Experts' Meeting at the World Bank in Washington DC, in conjunction with Energy Week. Energy Week is an important annual gathering of stakeholders concerned with energy in the developing world and includes other side-events. In 2006, PVSDC again contributed a booth to the Energy Week Exhibition, in the atrium of the World Bank, and participated in the week's programme. The exhibition posters were redesigned so as to be more graphic, and also include other renewable energy technologies, as well as PV.

The 14th Experts' Meeting was held in Vancouver in March, hosted by CANMET, and conducted in conjunction with meetings of Tasks, 1, 2 and 10. A joint Tasks workshop was also held. Canada's contribution to PVSDC is through the Canadian International Development Agency (CIDA), which is a major

bilateral donor. CIDA is not presently supporting an energy programme but provides expert experience in the delivery of aid. The work of Task 9 was presented at the 21st European Photovoltaic Solar Energy Conference in Dresden in September.

The 15th Experts' meeting was held in Makuhari, near Tokyo in October. This was a significant meeting, as the first to be held in Japan, hosted by the New Energy Development Organisation (NEDO), and with the direct participation of the Ministry of Economy and Trade (METI), the Japan International Co-operation Agency, (JICA) and the Japan PhotoVoltaic Energy Association (JPEA). A significant contribution to the Case Studies used by PVSDC for its published RPGs is from JICA projects. JICA provides technical assistance and undertakes projects in developing countries as part of Japan's Official Development Assistance (ODA). In the field of energy, JICA's view is that stable securing of energy is essential for sustainable, economic development, and improvement of quality of life. Co-operation with developing countries is on energy policy, energy planning, rural electrification using renewable energy, and energy saving. Most co-operation in the field of PV has been Masterplan Studies, which in some cases has also included installation of pilot equipment, as part of the transfer of technology, know-how, and knowledge. A good example is the Masterplan prepared in Laos, which led to a follow-on World Bank/GEF investment/loan project. PVSDC held a workshop in Laos in 2005 which benefited from this (see 2005 Annual Report). JICA has developed a comprehensive methodology for Masterplans for rural electrification. This includes business models, capacity development, with manuals for technology and financing mechanisms. JICA will support a Rural Electrification Masterplan in Peru starting in 2007. Other JICA PV projects have been undertaken in Bolivia, Botswana, Cambodia, Ghana, Indonesia, Kiribati, Mongolia, Morocco, Nigeria, Philippines, Senegal, Syria and Zimbabwe. The meeting was also timed to link with the Renewable Energy 2006 Conference, including a PVPS Task 8 International Symposium, to which PVSDC contributed. Tasks 8 and 9 share some contries of interest, particularly Mongolia.

### SUBTASK 40: PV Energy Services for Rural Electrification and Proverty Alleviation

This work reviews and investigates the techno-economic aspects and potential of PV systems for provision of rural services and poverty alleviation. This focuses on the role of PV in the provision of water, health, education and Information & Communication Technologies (ICT) services, PV battery charging stations, hybrids and village mini-grids. The approach is to collate information from topical PV case studies and use the information to develop review documents and guides. The impact on mobile phones across the world is enormous. This is especially the case in Africa where communications have been traditionally very poor, but this is changing rapidly. Better contact with family and friends is transforming lives. Figure 6 is an example of mobile phone charging in Tanzania. This development also addresses gender issues which have been a barrier to economic and social development.

*Fig. 4 - First output of water from newly installed PV pump in Ghana (photo Isophoton).*

*Fig. 5 - Large demand for clean water from PV pump in Senegal (photo ITPower/KSyngellakis).*

There are five main activities:

- Economic Assessment of PV Energy Services
- PV Based Energy for Water Services
- PV in Health, Education and ICT
- Battery Charging Stations and PV Hybrids and Mini-grids
- Role of PV in the Alleviation of Poverty

Progress with this subtask has continued to be very slow during 2006 because of reduced levels of input by several of the experts. No new publications have yet been prepared.
The European Photovoltaic Industry Association (EPIA) is a sponsor member of PVPS. EPIA is active in PVSDC and has agreed to work closely together to develop a new joint work plan. The sad loss of Michel Viaud in December 2006 has been a major set back to this endeavour.

### SUBTASK 50: Market Penetration Activities

Training and capacity building are essential for sustainable market development. The RPGs prepared by PVSDC are used for these

*Fig. 6 - Large demand for clean water from PV pump in Senegal (photo ITPower/KSyngellakis).*

*Fig. 7 - PV installers training course conducted by DENG in Ghana (photo ITPower/BMcNelis).*

purposes. PVSDC also co-operates and assists with training courses. Figure 7 illustrates an internationally – accredited PV installer training programme underway in Ghana.

This Subtask also investigates technical and economic aspects of PV power packs and larger scale grid-connected PV plants. There are many locations in the developing world where electricity demand is growing rapidly and lack of capacity frequently results in power cuts or 'brown-outs' caused by indiscriminate load shedding. This Subtask will collate relevant case studies and review situations in developing countries where network capacity and/or generation capacity needs to be increased and where it is cost-effective to install PV (or PV hybrids) as an alternative. The work will also examine emerging grid-connected or grid-support applications for PV in developing countries. The objective is to evaluate the techno-economic aspects of small PV power packs (which provide back-up power supply to customers when grid supplies are cut) and grid support applications in developing countries. The work is being co-ordinated with Task 11. The main outputs will be review documents and a number of relevant case studies.

Australia is leading the work for Subtask 50, commencing with a review of grid-connected systems for developing countries.

### SUBTASK 60: PV and the Kyoto Mechanisms

Many developing countries are looking to the CDM to help leverage funding to achieve sustainable economic development, through investment in renewable energy and end-use efficiency projects which fit with their developmental needs. It has become clear that PV cannot significantly compete with other options for CDM projects, and an internal Task 9 paper recommended that work on this Subtask should be put in abeyance.
The Executive Committee agreed at its 28th meeting to cancel the Subtask.

### Plan for 2007

The focus of work from 2007 onwards will shift more towards policy. There is a considerable expansion in interest in and support for renewables for rural electrification and the MDGs. Global expenditure is set to increase significantly. The PVSDC Team is established as a well experienced, balanced and impartial group, and has the capacity to advise on policy and resulting programme design. This will involve issuing short bulletins (for example, "10 Key Recommendations for Deployment Strategies for RETs for Rural Electrification"). Contributions to policy groups will be increased.
The 16th Experts Meeting will be hosted by the German Agency for Technical Assistance (GTZ) in Eschborn. The GTZ is the world's largest agency of it's type and conducts a major multi-country Energy for Sustainable Development Programme. The meeting will also have an internal planning workshop including water services.

An International workshop on Water Services will be held in 2007. This may be held in Africa.

PVSDC has been invited to hold a meeting and/or Workshop in Uganda and Zambia. There is an interest in the team to do this. This could be a Workshop organised jointly with UNDP and GVEP. There is also a proposal to contribute to the EC ENABLE project in Kenya, Senegal, Tanzania and Uganda. This is providing capacity building for ministries of health, water, and education relating to the use of renewable energy Technologies to meet national targets for poverty reduction/MDG's.

## MEETING SCHEDULE (2006 AND PLANNED 2007)

2006:

14th Experts' Meeting, 27-28 March 2006, Vancouver, Canada.

15th Experts' meeting 7-8 October 2006, Chiba, Japan (coinciding with Renewable Energy 2006 Conference).

2007:

16th Experts' Meeting 29-30 March 2007, Eschborn, Germany.

17th Experts' Meeting – Not yet fixed.

## TASK 9 PARTICIPANTS

| COUNTRY | NAME | AFFILIATION |
|---|---|---|
| Australia | Geoff Stapleton | GSES |
| Canada | Fayez Malek | CIDA |
| Denmark | Peter Ahm | PA Energy |
| France | Anjali Shanker<br>Lara Bertarelli<br>Taric de Villers | IED<br>IED<br>IED |
| Germany | Dieter Uh | GTZ |
| Italy | Francesco Groppi | CESI |
| Japan | Takayuki Nakajima<br>Tetsuzou Kobayashi<br>Takahito Ilma | JPEA<br>Showa-Shell<br>Shikoku Electric Power Co. Inc |
| Switzerland | Alex Arter | ENTEC |
| Sweden | Anders Arvidson | Stockholm Environment Institute |
| United Kingdom | Bernard McNelis<br>Paul Cowley<br>Rebecca Gunning | IT Power<br>IT Power<br>IT Power |
| USA | Mark Fitzgerald* | ISP |
| EPIA | Ernesto Maccias | Isophoton |

**Mark Fitzgerald passed away in June 2005 and he has not yet been replaced by another US representative on the Task 9 Team.*

## PVPS AND THE MILLENNIUM DEVELOPMENT GOALS

Delivering a real contribution towards achieving the Millennium Development Goals (MDGs) is one of the strong driving principles behind PVSDC.
Neither access to modern energy services in general, nor provision of electricity is recognised as specific goals in themselves. Nevertheless, they can play a central role in poverty alleviation, through impacts on education, health and local enterprise, as well as access to modern telecommunications and information technology resources.

The MDGs and some of the roles for PV are:

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

# TASK 10 – URBAN SCALE PV APPLICATIONS

## INTRODUCTION

As Task 10 completes its third year, the market oriented nature of the task is evident as deliverables are completed. The [CH1] workplan for this Task is designed for flexibility towards the fast growing and emerging market. The grid connected PV market requires new financial relationships beyond the network industry and their customers, as well as integration into traditional operations and planning of the broader stakeholder group involved in the market. Task 10 work was initiated in January 2004, with a 5 year planned period of work. There were delays of resource commitment to the Task, but during the third year, all subtasks have committed leadership and the relationship between the European Commission project titled *PV in Urban Policies: a Strategic and Comprehensive Approach for Long-term Expansion*, PV-UP-SCALE, was clearly defined as shown in Figure 1. PV-UP-Scale was basically intended to expand Task 10 country contributions to include more European countries not formally participating in Task 10 (Netherlands, Spain, Germany and UK), enhance some current contribution (Austria and France), while utilizing the Task 10 participants to broaden the market perspectives most important to the European Commission.

## OVERALL OBJECTIVE

The objective of Task 10 is to enhance the opportunities for wide-scale, solution-oriented applications 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. In the stakeholder list below, goals as related to stakeholders has been included.

PV-UP-SCALE

| Leaders | | E. ter Horst Horisun (NLD) | D. Munro Halrow (UK) | H. Laukamp (Fraun) E. Caamano (UPM) | A. Lopez D. Suna (AUT) | B. Gaiddon (HESPUL) | not adressed in UPSCALE |
|---|---|---|---|---|---|---|---|
| Task 10 | Topics | WP2 SoA PV-projects | WP3 Urban planning | WP4 Grid Issues | WP5 Economical drivers | WP6 Targeted Dissemination | |
| A. Lopez (AUT) | 1.1 Value Analysis | | | | | | |
| A. Lopez (AUT) | 1.2 Barriers Resolution | | | | | | |
| A. Lopez (AUT) | 1.3 Market Drivers/Roadmap | | | | | | |
| | 1.4 Merged with 1.3 | | | | | | |
| Pierre & Pierre | 2.1 Integrating PV into Development and Design Pratice | | | | | | |
| C. Herig | 2.2 Urban Planning | | | | | | |
| D. Elzinger | 3.1 Building Industry and BIPV Products and Projects & Database | | | | | | |
| K. Fredricksen | 3.2 Codes and Standards | | | | | --> | |
| T. Ehara (JPN) | 3.3 PV and Electricity Networks | | | | | | |
| may be deleted | 3.4 Market Driven Approach | | | | | --> | |
| C. Herig | 3.5 Certification Practices | | | | | --> | |
| M. Anderson (SWE) | 4.1 Educational Tools | | | | | | |
| M. Rodriques | 4.2 Marketing Competition | | | | | --> | |
| | 4.3 Merged with 4.1 | | | | | | |
| B. Gaiddon (Fra) | 4.4 Stakeholder Perceptions | | | | | --> | |
| B. Gaiddon (Fra) | 4.5 Continuous Communication and Dissemination | | | | | | |

*Fig. 1 - Coordination of Task 10 and PV-UP-Scale.*


*Fig. 2 - Joint Task 2 and Task 10 Educational Tool.*

## APPROACH

There will be four subtasks in Task 10, with 17 activities. The total range of deliverables has been designed comprehensively to include and meet the various needs of the stakeholders who have been identified as having value systems which contribute to urban-scale PV. The deliverables are designed to optimise usefulness to the stakeholders and have multiple communication and promotion scenarios. Although each of the deliverables is a separate product which can be developed independently from all the other deliverables, the relationship between deliverables will be cross-referenced or data based as appropriate. Through developing and producing these deliverables, Task 10 will contribute to achieving the vision of mainstreaming urban-scale PV. The comprehensive list of targeted stakeholders is:

- Building Sector: builders and developers, urban planners, architects, engineers, permit and code authorities;
  Goal – Solar technologies and energy efficiency – whole building energy design – is an option in all design, development and construction and a market differentiation as a standard feature.
- End-Users: residential and commercial building owners;
  Goal – Full awareness of the financial, operational, and comfort features resulting in whole building energy design.
- Government: supporting, regulatory and housing agencies;
  Goal – The benefits to government revenue, infrastructure and services, such as jobs, gross regional product, import/export, environmental and security are metrics to the development and revisions to energy market transformation policies.
- Finance and Insurance Sector: Banks, insurance companies, loan for houses;
  Goal – The benefits and risks from both a credit and disaster perspective are included in the development of rates. As insurance companies base rates on the height above sea level of structures in a region, so could the resilience of the energy infrastructure influence rates.
- PV Industry: system manufacturers, PV system supply chain, retail sector;
  Goal – PV industry has clear market knowledge, ensuring fair profitability throughout the supply chain, particularly to the influence of other stakeholders. An additional goal is internationally consistent standards and certification (to the extent possible, with differences clearly defined), as well as access to retail energy consumers.
- Electricity Sector: network and retail utilities; and
  Goal – A full understanding of the business and operational opportunities related to energy efficiency and solar technologies. The comparative economics of generation planning will include the full life cycle economics of both traditional network design and whole building design as well as the energy coordination benefits such as disaster resilience and demand side management.
- Education Sector.
  Goals – Basic education will include alternative energy and the life cycle impacts and benefits of energy choices. Specialised education in the building, sciences, and engineering sectors will include alternative energy options.

## SUBTASKS AND ACTIVITIES

### SUBTASK 1: Economics and Institutional Factors

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

#### Activity 1.1 Value Analysis

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

Progress includes a release of the initial PV-UP-Scale report "Demand Side Value of PV". Some Task 10 participants contributed to this report and were acknowledged. The extension of this report for Task 10, "Value Analysis of PV" will expand to include more Task 10 countries and more values, specifically the benefit and impact of investments and incentives to different stakeholders. This Task 10 report final draft will be completed in June 2007.

#### Activity 1.2 Barriers Resolution

Recommendations to stakeholders will be developed for removing barriers to mass market uptake of PV. Austria leads this activity. Progress includes the development of a barriers survey. Surveys were sent to fours countries with very different markets. Japan, Sweden, Spain and Austria were specifically questioned on both lead times and transaction costs. This along with Barriers resolution will be the focus of this report.

#### Activity 1.3 Market Drivers and Roadmaps

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


*Fig. 3 - PowerFold First Lisbon Ideas Challenge Winner.*

Progress includes the collection of individual country's analysis. The results in activities 1.1 and 1.2 will be used to determine priorities for the global analysis. The results in the value analysis activity have identified the relationships of benefits/impacts between stakeholders. The best practices will identify where the benefits are optimised and the impacts are minimised in existing markets.

### 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. Switzerland leads this subtask.

### Activity 2.1 Integrating PV Development and Design Practices

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

Progress on integrating into whole building design is minimal. However, the urban planning design integration has developed as noted below. Related to this activity is the products, projects, and community database under Activity 3.1.

### Activity 2.2 Urban Planning

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

Progress in the development of the model from Norway includes the Task 10 and PV-UP-Scale participants review and input on the criteria and indicators which are used in the model to lead planners to solar energy choices. Additionally, a questionnaire was developed by Switzerland to acquire information on urban policies, along with a more detailed workplan for this activity. Initially, this looked like an overlap to the Subtask 1, however, Subtask 1 has a national perspective, whereas this work is focused on cities. The UK, through PV-UP-SCALE will make specific contributions to this activity.

### SUBTASK 3: Technical Factors

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

### Activity 3.1 Building Industry/BIPV Products and Projects

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

Progress includes an updated, on-line version of the Task 7 database. This database includes BIPV projects and products as Task 7 did, and also includes a database of urban scale PV which includes both housing developments and urban or public building developments. Projects which are fully detailed in the educational tool (Activity 4.1) are also linked to the database which contains essential information. This is the first combined Task 10-PV-UP-Scale deliverable, with 125 new entries. In addition to this a report on housing developments will be developed for Task 10 by Japan. Canada also has a report under draft review titled "Urban BIPV in the Residential Building Industry". Malaysia's MBIPV development program plan, may

potentially serve as a guide for other countries as well as communities program development.

### Activity 3.2 Codes and Standards

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

Progress on this activity is includes an information matrix for investors or installers of PV systems which points to legal demands, guidelines and good advice for PV system components, issues and systems as part of buildings. Task 10 participants have not provided input to this matrix as of yet, but will be encouraged to do so in 2007 so that it can be included in the educational tool (Activity 4.1).

### Activity 3.3 Electricity Networks

This activity will analyse electricity network effects, benefits, impacts, and issues. Interconnection, operational effects, and market issues will be included. Japan leads this Activity
Progress on this important urban scale activity includes full coordination with the PV-UP-Scale work. The proposed scope of work from Japan includes:

1 Impacts & Effects of PV Interconnection
2 Guidelines & Network Operation Policies
3 Countermeasures & Technologies
4 Case Study Approach
5 Project Checklist

In developing this proposal Japan has started the development of graphics to explain network issues. Germany is the PV-UP-Scale lead for the corresponding work package.

### Activity 3.5 Certification Practices

Certification practices will be reviewed and standard test procedures harmonized and transferred to the relevant stakeholders and standard committees. The US leads this activity:

Progress includes a set of documents developed by the US installer certification program in accordance with ISO/IEC 17024 Working Draft, “General Requirements for Bodies Operating Certification Systems of Persons”. These documents will be reviewed by Task 10 participants to be made into templates for countries to use.

### 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

## TABLE 1 - LIST OF PARTICIPANTS AND THEIR ORGANISATIONS

| COUNTRY | PARTICIPANT | ORGANISATION |
|---|---|---|
| Australia | Mr. Mark Snow | University of New South Wales |
| Austria | Mr. Reinhard Haas<br>Mrs. Assun Lopez-Polo<br>Mrs. Demet Suna | Institute of Power Systems and Energy Economics<br>Energy Economics Group<br>Vienna University of Technology |
| Canada | Mr. David Elzinga | NRCan/Climate Change Technology Early Action Measures/Ontario |
| Denmark | Mr. Kenn Frederiksen | Energimidt Erhverv A/S |
| France | Mr. Marc Jedliczka<br>Mr. Bruno Gaiddon | HESPUL |
| Italy | Arch. Niccolo’ Aste<br>Mr. Michele Pellegrino<br>Mr. Carlo Zuccaro | Politecnico di Milano<br>CER ENEA<br>CEPI SpA |
| Japan | Mr. Keiichi Komoto<br>Mr. Tomoki Ehara | Environment, Natural Ressources and Energy<br>Mizuho Information & Research Institute Inc. |
| Korea | Mr. Kyung Shick Yoom | Korea Photovoltaics Development Organization<br>Korea University |
| Malaysia | Mr. Ahmad Hadri Harris | Malaysia Energy Center, PTM |
| European Union | Mr. Henk Kaan | Energy research Centre of the Netherlands Through EU, PV-UP-SCALE |
| Norway | Mrs Inger Andresen<br>Mrs. Käthe Hermstad<br>Mrs. Anne Grete Hestnes | SINTEF Civil and Environmental Engineering |
| Portugal | Mrs. Maria Joâo Rodrigues<br>Mrs. Joana Fernandes | Center for Innovation Technology and Policy Research<br>Instituto Superior Têcnico (Technical University of Lisbon) |
| Sweden | Mr. Mats Andersson | Energibanken AB |
| Switzerland | Mr. Pierre Renaud | Planair SA |
| USA | Ms. Christy Herig | Segue Energy Consulting/Subcontractor to National Renewable Energy Laboratory |

*Fig. 4 - 7th Task 10 Technical Experts and PV-UP-Scale, Malmö, Sweden.*

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

France is the Subtask leader, and is also the Work Package leader for the corresponding Work Package in the PV- Upscale project, thus guaranteeing a broad dissemination.

### Activity 4.1 Educational Tools

This activity includes a best practices web site which will include templates for tender documents, sales contracts, consumer guides, as well as best practices, detailed real project development information. Sweden leads this activity.
Progress includes an on-line educational tool which details projects from the idea phase to the commissioning phase (see Figure 2, www.bipvtool.com). The tool has defaults of general information if the information was not available in the case study. This design allows it to be a way to put Task 10 graphics and information on line in a user friendly format (instead of only long reports). PV-UP-Scale has made contributions to the tool. This website will serve as the one of the main dissemination tools for all Task 10 deliverables and is also used to provide specific performance indicators for detailed projects for Task 2.

### Activity 4.2 Competition

Progress – The first Lisbon Ideas Challenge was awarded in November of 2007. The winner, LIC Winner: Power Fold, from the Portuguese team of architects from Atelier Data, for the Best Business Idea! See Figure 3. The PowerFold is a modular, folded devise that can take many shapes and therefore serve multiple purposes in the urban environment.

Industry was pleased with the results of the contest and has funded a second Lisbon Ideas Challenge - www.lisbonideaschallenge.com.pt. Three monetary prizes of 5.000,00 each shall be awarded to the entries that present the Best Technological Integration Projects in each of the described categories, in straight coordination with the Technological Integration Plan.

1 Commercial Building
2 Public space, with the inclusion of urban art
3 Social Housing

### Activity 4.4 Stakeholder Perceptions

This activity will analyse and assess the community, utility and customer perception and preferences regarding i) the security of energy, (including revenue protection) ii) certain and homogenous Quality and Safety levels. Additionally this activity will develop products in response to misconceptions such as energy required in manufacturing (Life Cycle Analysis). Denmark leads this activity

Progress includes the report IEA-PVPS T10-01-2006 “Compared assessment of selected environmental indicators of photovoltaic electricity in OECD cities”, developed by France. The executive summary of this report as well as the country results were published by EPIA and are available on the European Photovoltaic Technology Platform website. This report was developed in response to the misconception of the energy required for PV manufacturing being more than ever produced in the operation of the system. The report did not perform lifecycle analysis, but rather took the most recent results, combined with solar energy availability to determine energy and environmental factors. Additionally, Denmark has developed a draft report on revenue protection which identifies ways to maximise the revenue from a PV plant regardless of size.

### Activity 4.5 Continuous Communication

France leads this activity

With France leading this activity under this subtask, as well as the similar work in PV-UP-Scale, the Task will continue to progress.
A stakeholder meeting was held in Malmo Sweden. Whereas most

publications will be electronic, EPIA agreed to print the executive summary of the environmental indicators report. And the website and resources for Task 10 remain up to date.

## INDUSTRY INVOLVEMENT

As Task 10 moves into its fourth year, industry participation appears minimal relative to the technical experts participating in the Task (except utilities). However, in individual countries and throughout Europe, it is evident that industry is giving feedback to Task 10. The Activity under Subtask 1 titled Market Roadmap was merged with the activity Market drivers because industry (EPIA and SEIA) felt that presenting the information as market drivers rather than a roadmap was more appropriate for Task 10. Industry has already provided input to the products database. And a second Lisbon Ideas Challenge will be supported by industry.

## KEY DELVERABLES (2006 AND PLANNED 2007)

The following key deliverables were prepared and presented in 2006:

- Swedish stakeholder meeting, September 13, Malmo, Sweden Report "Compared assessment of selected environmental indicators of photovoltaic electricity in OECD cities;" as well as the executive summary in print.
- A completed Lisbon Ideas Challenge Award Ceremony, Lisbon, November 2006 with a second challenge initiated.
- On line educational tool, www.BIPVtool.com
- On line products, projects, and solar communities database www.pvdatabase.com

The following key deliverables are planned for 2007:

- Report "Urban BIPV in the Residential Building Industry"
- Report "Solar Cities Around the World"
- Report "Value Analysis of PV"

## TABLE 2 – MEETING SCHEDULE (2006 AND 2007 PLANNED)

| MEETING | DATE | PLACE |
|---|---|---|
| 6th Task 10, combined with Tasks 1, 2 & 9 | March 27-28, 2006 | Vancouver, BC, Canada |
| 7th Task 10 Technical Experts | Sept 11-13, 2006 | Malmö, Sweden |
| 8th Task 10 Technical Experts and PV-UP-Scale | March 12-13, 2007 | Freiburg, Germany |
| 9th Task 10 Technical Experts with _ day Joint Meeting with Task 11 | November 30 - December 1 2007 | Fukuoka, Japan |

# TASK 11 - HYBRID SYSTEMS WITHIN MINI-GRIDS

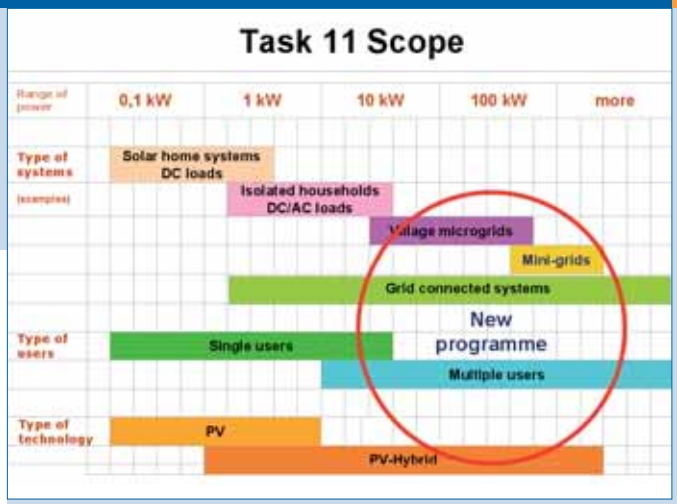



*Fig. 1 - Scope of the Task 11 Program.*

## INTRODUCTION

Task 11, which began work in 2006, is concerned with PV based hybrid electricity generation and distribution systems that combine PV with other electricity generators and also energy storage systems. A particular focus is on mini-grid systems in which energy generators, storage systems and loads are interconnected by a "stand-alone" AC distribution network with relatively small rated power and limited geographical area. The mini-grid concept has potential applications that range from village electrification in less developed areas to "power parks" that offer ultra-reliable, high quality electrical power to high tech industrial customers. These systems can be complex, combining multiple energy sources, multiple electricity consumers, and operation in both island (stand-alone) and utility grid connected modes.

## OVERALL OBJECTIVES

The main *goal* of Task 11 is to promote PV technology as a technically relevant and competitive energy source in mini-grids. It aims to enhance the knowledge-base of PV hybrid mini-grids and reduce barriers to market penetration of these systems.
The *objectives* of this new Task are to:

- define concepts for sustainable PV hybrid mini-grids taking into account local factors (specificity of the application, financing regimes, location, others);
- provide recommendations on individual designs (mix of technologies, architecture, size, performances, other) in order to achieve high penetration of PV as a means to improve the quality, reliability and economics of electrification systems such as mini-grids;
- assess the potential of technologies to be mixed with PV for hybridisation; and,
- compile and disseminate best-practices on PV hybrid power systems.

## APPROACH

The approach to meet the Task 11 objectives is to subdivide the Task into four relevant subtasks and a number of detailed work activities on key aspects of PV hybrid and mini-grid technology and implementation.

## SUBTASKS AND ACTIVITIES

The current subtasks and activities are as follows:

### SUBTASK 10: Design Issues

This Subtask addresses the complex nature of PV hybrid system design. Tradeoffs have to be made between first cost, energy efficiency, and reliability. Oversizing a system may increase reliability but also increase first cost. Undersizing a system will decrease reliability and frustrate users. The correct choice of components and system architecture is critical. The task has the following three activities:

*11)* Review, analysis and documentation of current hybrid mini-grid system architectures.
*12)* Evaluation and comparison of system design methodologies and tools and development of guidelines for design tools.
*13)* Development of best practices for design, operation, and maintenance of PV hybrid projects.

### SUBTASK 20: Control Issues

This Subtask addresses the need for new coordinating control mechanisms in hybrid mini-grids to maintain grid stability and to optimize the contribution of all generation sources. It has the following five activities:

*21)* Investigate existing methods for stabilizing voltage and frequency in mini-grids and develop new, improved methods if required
*22)* Investigate data communication architectures and protocols for mini-grids.
*23)* Develop supervisory control parameters and strategies for mini-grids.
*24)* Evaluate the role of energy storage technologies to stabilize mini-grid operation.
*25)* Investigate technical issues associated with autonomous and interconnected operation of mini-grids and a main utility grid.

### SUBTASK 30: PV Penetration in Mini-Grids

Subtask 30 addresses the goal of increasing the use of the PV resource in PV hybrid systems and displacing fossil fuel resources. It has the following two activities:

*31)* Develop performance assessment criteria for PV hybrid systems that allows for objective comparison of different systems
*32)* Develop recommendations to maximize the solar fraction in hybrid systems through demand side management, dispatch strategies and optimization of the battery energy storage system.

### SUBTASK 40: Sustainability Conditions

Subtask 40 addresses the social, political, economic, and environmental factors necessary for successful implementation of PV hybrid power systems within mini-grids. It has the following three activities:

*41)* Develop case studies that demonstrate the social and political framework for successful operation of PV hybrid systems within mini-grids.
*42)* Evaluate the financial aspects of PV hybrid power systems, considering both first costs and operating costs, and determine the conditions for economic sustainability.
*43)* Evaluate the environmental impacts and benefits of PV hybrid systems with focus on greenhouse gas emission mitigation and potential for recycling of system components.

*Fig. 2 - First Task 11 Experts Meeting, Aix en Provence.*

## PROGRESS IN 2006

This new Task got underway with a kick-off meeting in Aix en Provence in May, 2006 which was attended by 28 experts from eleven countries. Accomplishments at this meeting were primarily in the areas of Task organization and planning

- Draft Work Plan was reviewed and updated
- Subtask and Activity leaders were confirmed or selected
- Initial work plans for Activities were prepared.

During the remainder of 2006, work continued on planning, organization and the initial data gathering portions of the Activities. Progress within each Subtask is described below:

### SUBTASK 10: Design Issues

Surveys have been started of currently available guides, handbooks and software tools used for design of PV hybrid systems and mini-grids. This will provide raw material for the review of system architectures and the evaluation and comparison of design methodologies and design tools.

### SUBTASK 20: Control Issues

Progress has primarily been on developing work plans and identifying participants for the Activities in this Subtask. Participants are reviewing the existing technical literature to establish the baseline state of technology and identify areas for further work.

### SUBTASK 30: PV Penetration in Mini-Grids

Progress has primarily been on developing work plans and identifying participants for the Activities in this Subtask. Work on Activity 31 has been deferred until results are available from Activity 30.

### SUBTASK 40: Sustainability Conditions

A "light" template for case studies of PV hybrid systems has been developed and circulated to Task participants. The case studies will be reviewed and a portion will be selected for deeper study and analysis. The results will be used in Subtask 40 Activities and also in Subtasks 10 and 30.

## PLANS FOR 2007

In 2007, Task 11 expects to move from planning mode to implementation of its work plan. Specific activities will depend on the detailed work plans for the Subtasks but, in general, the Task will follow a strategy, similar to previous PVPS Tasks, in which the current state of technology and design practice in the participating countries are first assessed and summarized. Further work will then focus on those areas where technology improvements or better design practices are needed. This may require new research or data, or simply an expert consensus on best practices.

## PUBLICATIONS AND DELIVERABLES

There are as yet no formal reports or publications from the Task 11 Activities. However some papers have been presented to publicize the new Task and outline its mission and Work Plan.

A paper, "PV Hybrid Systems within Mini Grids – IEA PVPS Task 11", was presented by the Operating Agent at the 3rd European Conference on PV-Hybrids and Mini-Grids in Aix en Provence on 11-12 May, 2006. The paper summarized the objectives and work plan for Task 11. A second paper, "Integration Experience of Photovoltaic Power Systems in Sub-Urban and Remote Mini-grids", was presented by the Operating Agent at the 2nd International Conference on Integration of Renewable and Distributed Energy Resources, in Napa, California on 4 – 8 December, 2006. The paper discussed the results of previous IEA Tasks on integration of PV into electricity distribution networks and the work underway in Task 11 to extend these results to mini-grids.

## TABLE 1 - INDUSTRIAL PARTICIPANTS IN TASK 11

| COMPANY | COUNTRY | BUSINESS ACTIVITY |
|---|---|---|
| Conergy AG | DEU | PV system integrator and equipment manufacturer |
| Fronius International Gmbh | AUT | PV inverter manufacturer |
| Nissin Electric Co. | JPN | PV system integrator and equipment manufacturer |
| Novolta Pty. | AUS | Engineering Consultant |
| PHK Consultants | FRA | Consultant |
| SMA Technologie | DEU | PV inverter manufacturer |
| Sputnik Engineering AG | CHE | PV inverter manufacturer |
| Steca Gmbh | DEU | PV inverter and charge controller manufacturer |
| SunTechno | JPN | Consultant |
| Sustainable Energy Technologies | CAN | PV inverter manufacturer |
| Sweco Groener AS | NOR | Engineering Consultant |
| Trama TecnoAmbiental | ESP | PV system integrator and equipment manufacturer |
| Transenergie | FRA | PV system integrator |
| Xantrex Technology Inc. | CAN | PV inverter and charge controller manufacturer |

*Fig. 3 - Residential 1 kWp PV/6 kVA genset hybrid in New Liskard, ON, Canada (photo courtesy of Xantrex Technology).*

*Fig. 4 - Ponelo hybrid system in Indonesia 24 kWp 950 Ah, 240V DC, 125 kVA (photo courtesy of BPPT (Indonesia) / Transénergie (France)).*

## INDUSTRY INVOLVEMENT

Task 11 is fortunate to have significant industrial participation from manufacturers and system integrators. Table 1 summarizes the current industrial (private sector) participation.

## TASK PARTICIPANTS

Currently, the following IEA PVPS countries are participating in Task 1l – PV hybrids in mini-grids: Australia, Austria, Canada, France, Germany, Japan, Korea, Norway, Spain, and Switzerland. The management of the Task - the Operating Agent - is being executed by Canada.

## MEETING SCHEDULE

### 2006

First Experts Meeting, Aix en Provence, France, 9-10 May, 2006
Second Experts Meeting, Vancouver, Canada, 28-29 September, 2006

### 2007

Third Experts Meeting, Freiburg, Germany, 28-30 March, 2007
Fourth Experts Meeting, Fukuoka, Japan, 30 November – 2 December, 2007

*Fig. 5 - Second Task 11 Experts Meeting, Vancouver. Experts embarking on a trip up the BC coast to visit a PV hybrid installation on one of the offshore islands.*

## TABLE 2 - LIST OF TASK 11 PARTICIPANTS

| COUNTRY | NAME | ORGANISATION |
|---|---|---|
| Australia | Wolfgang Meike | Novolta Pty. |
| Austria | Hannes Heigl | Fronius International GmbH |
| Canada | Konrad Mauch (Operating Agent) | KM Technical Services |
| France | Jean-Christian Marcel | Transenergie SA |
| Germany | Michael Müller | Steca GmbH |
| Japan | Kunio Asai | SunTechno Ltd. |
| Korea | Gyu-Ha Choe | Konkuk University |
| Norway | Astri Gillund | SWECO Grøner AS |
| Spain | Xavier Vallvé | Trama TecnoAmbiental |
| Switzerland | Harald Barth | Sputnik Engineering AG |

# AUSTRALIA

DR MURIEL WATT
SCHOOL OF PHOTOVOLTAIC AND RENEWABLE ENERGY ENGINEERING, UNIVERSITY OF NSW

*Fig. 1 - Solar Mallee Trees, Adelaide Festival Centre. Based on a design by the University of South Australia, individual solar cells were pieced together to form oval shaped solar panels. The panels are placed atop curved poles with the whole structure designed in the form of the indigenous mallee tree. There are 9 lights in total, 3 per mallee tree. The panels were formed by local company, Street Park and Furniture. The trees have an audio interpretative feature informing the public about Adelaide as a Green City. The original voices for this audio feature come from one of the City's first Solar Schools - Sturt Street Community School (photo Capital City Committee, a partnership between the South Australian Government and Adelaide City Counci).*

## GENERAL FRAMEWORK

2006 has been a year of rapid change in the political rhetoric on climate change in Australia. Although there have been a variety of greenhouse gas reduction strategies in place for the past decade, there has been no overwhelming consensus on either the reality or the causes of climate change. For the first time, governments at Federal, State and Local levels have now acknowledged the need for Australia to address its fossil fuel use. For PV, this has raised the profile of current programmes, thus eliciting early commitments to their extension, while also encouraging new strategies. Two State governments have announced PV feed-in-tariffs, although they are likely to be on net exports, not total PV generation. Several States have introduced renewable energy targets to operate on top of the current Federal government Mandatory Renewable Energy Target, which is essentially fully subscribed, and all States are currently exploring the possibility of introducing an emissions trading scheme at State level.

Although Australia has not ratified the Kyoto Protocol, it has joined with the USA, Japan, South Korea, India and China in an Asia-Pacific Partnership on Clean Development and Climate (AP6) which is to develop and demonstrate a range of strategies to improve energy security, reduce local air pollution and reduce greenhouse gas emissions in the region. The 6 countries are responsible for approximately half the world's GDP and greenhouse emissions and have just under half the world's population. The Partnership will focus on expanding investment and trade in cleaner energy technologies, goods and services in key market sectors. The Partners have approved eight public-private sector task forces including one on renewable energy and distributed generation. Opportunities for demonstration of PV and other renewables are expected through the Partnerships.

Australia also has a bilateral climate change partnership with China which includes improving Australian renewable energy business opportunities in China and developing renewable energy training programmes, including PV trade certification and engineering.

*Fig. 2 - Rooftop PV array on South Australian Museum. This is a 19.8 kW PV system, installed by Origin Energy. The panels were manufactured by BP Solar. It is the first installation of the North Terrace Solar Precinct. Solar panels have also been installed on the roofs of Adelaide's Art Gallery, Parliament House and State Library (photo Capital City Committee, a partnership between the South Australian Government and Adelaide City Council).*

## NATIONAL PROGRAMMES

### Existing Programmes

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

*Mandatory Renewable Energy Target (MRET)* – which seeks to increase the contribution of renewable energy sources in Australia's electricity mix by 9 500 GWh per year by 2010, and maintaining it until 2020. Electricity retailers and large energy users must purchase increasing amounts of electricity from renewable sources in proportion to their sales. A trade in Renewable Energy Certificates (RECs) which are created for each 1 MWh of approved generation, and financial penalties for non-compliance are features of this scheme. Thirty one PV systems have so far registered for REC creation. Small generating sources, such as rooftop PV systems, are allocated RECs on the basis of deemed generation over their lifetimes, rather than claiming RECs annually. For PV systems up to 100 kW, RECs are available on installation for up to 15 years of operation.

*Renewable Remote Power Generation Programme (RRPGP)* – commenced in 2000 and is expected to make available over 300 MAUD over nine years 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 used fossil fuels. The RRPGP provides up to 50 % of the capital value of renewable generation for indigenous and other small communities, commercial operations, including pastoral properties, tourist facilities and mining operations, water pumping and isolated households that operate within diesel grids, use direct diesel generation or are at the end of long grid lines. In 2006, only Western Australia and the Northern Territory had significant funding remaining but new allocations are expected to be made to other States from 2007 following a 123 MAUD increase in the Programme budget. Important sub-programmes also funded include RESLab, a renewable energy systems test centre, and Bushlight (an Indigenous renewable energy services project) which installs PV power systems in small remote aboriginal communities, as well as increasing industry capacity to service these communities and building greater understanding of renewable energy issues within communities. 5,35 MWp of PV has been installed under RRPGP, of which 0,81 MWp is installed in large utility run diesel grid systems. The latter includes 0,72 MWp of solar concentrating dishes. Although it is not PV specific, over 95 % of small systems installed under the RRPGP include some PV.

*PV Rebate Programme (PVRP)* – commenced in 2000 and currently runs until 2007, although the Government has promised an extension. Rebates on PV capital costs are provided to householders or community building owners who install photovoltaic power systems. Householders are eligible for a rebate of 4 AUD/W capped at 4 000 AUD per system. Smaller rebates are also paid for extensions to an existing system. As part of the Programme, the Australian Government has made available one million Australian dollars to fund projects by residential housing developers and display home builders. A rebate of AUD 3,50/Wp is available in 50 000 AUD blocks. Since the start of the programme in 2000, more than 7 300 systems, using 9 MWp of PV, have been installed and rebates of 37 MAUD have been provided. More than half the installed capacity has been grid connected.

*Renewable Energy Development Initiative (REDI)* – launched in October 2005, this programme will provide 100 MAUD over seven years in the form of competitive grants to Australian industry to support early-stage commercialisation; research and development; technology diffusion and proof-of-concept activities in renewable energy technology. Projects are required to demonstrate strong commercial and emissions-reduction potential. Origin Energy received 5 MAUD in the first grant round to assist with commercialisation of its Sliver™ Cell PV technology.

### New Programmes

*Solar Cities* - 75 MAUD have been allocated over 5 years to demonstrate high penetration uptake of solar technologies, energy efficiency, smart metering and other options aimed at improving the market for distributed generation and demand side energy solutions. Consortia were formed to bid for the Solar City funding and comprise a mix of PV companies, banks, local governments, utilities and research groups. 3 of an expected 5 Solar Cities were announced in 2006 – Adelaide, South Australia, Townsville, Queensland and Blacktown, New South Wales. It is hoped that the interest generated and the knowledge of PV which has been developed within the Consortia will remain even with the unsuccessful bids, thus facilitating new PV deployment strategies in the long term.

### R , D & D

In the priorities for Australian Government R&D funding, PV and Remote Area Power Systems are identified as technologies of strategic importance. Australian Government annual funding for PV R, D & D (including market incentives) was about 25,5 MAUD in 2005. Funding from the State governments for the same period was around 0,7 MAUD.

*Fig. 3 - Roof integrated PV Solar Tiles at Newington Solar Village. The PV Tiles can be installed with a PV Airflow system which facilitates module cooling and offers space heating in winter (photo PV Solar Energy).*

University based PV research is undertaken in a number of facilities. Research undertaken at the Centre of Excellence in Advanced Silicon Photovoltaics and Photonics, University of NSW, includes cost reduction and efficiency improvements for wafer based silicon cells, improved silicon thin film processes and all-silicon tandem cells. Research into GaAs and DSC solar cells and nanoscale networks is also undertaken by other groups at the University of NSW.

The Centre for Sustainable Energy Systems at the Australian National University undertakes research into solar thermal and photovoltaic technologies including cell performance, thin films, efficiency and processing, parabolic trough and paraboloidal dish PV concentrator systems, and associated concentrator cells, trackers, controllers and mirrors, as well as a Combined Heat and Power Solar System. The Centre continues in depth research and development of Sliver cells, concentrating on efficient and cost effective manufacturing processes and designs. Sliver modules with record efficiencies of 20 % have been constructed.

Other university PV programs include:

- Monash University - power systems design, supramolecular assemblies, DSC solar cells
- University of South Australia - PV applications, commuter cars
- Murdoch University - low cost silicon production
- Flinders University - improved dye sensitised solar cells
- University of Queensland - semiconductor biopolymers, anti-reflection coatings
- Newcastle University – nanoscale polymer devices
- Sydney University – TiO2 nanostructures, flexible photovoltaics
- University of Western Australia – Tantalum-Silicon cells
- Adelaide University – Sustainable development strategies
- Melbourne University – organic optoelectronic materals
- University of Wollongong – TiO2 coatings, PV water purification
- Queensland University of Technology – DSC solar cells, carbon nanotubes
- Curtin University – hybrid mini-grids
- University of Technology, Sydney – PV water pumps.

Industry based R&D is undertaken in several organisations: BP Solar is the only commercial flat plate PV manufacturer in Australia and continues its development of automated production equipment, improved cell and module manufacture and systems development.

Solar Systems Ltd. continues development and commercialisation of its PV tracking concentrator dishes for off-grid community power supplies and end of grid applications. Current systems achieve 500 times concentration and use air or water cooling. System efficiencies of 20 per cent have been achieved. The systems are currently based on silicon cells, but trials have been undertaken on higher efficiency non-silicon devices. The company has recently received State and Federal Government funding towards a large solar thermal heliostat PV concentrating power station using its dish technology.

Origin Energy is commercialising the “Sliver Cell” PV technology developed by the Australian National University. The technology promises crystalline Si cell performance with significantly lower wafer requirements.

CSG Solar undertakes R&D on Crystalline Silicon on Glass, a thin film PV technology based on initial research at the UNSW. CSG cell and module manufacture commenced in Germany in 2006.

Dyesol is the industrial research hub for the world’s network of researchers into Dye Solar Cell (DSC) technology. Dyesol researches, develops and manufactures DSC materials and components as well as providing research and manufacturing equipment.

## IMPLEMENTATION

The main applications for PV in Australia are for off-grid industrial and agricultural power supplies for telecommunications, signalling, cathodic protection, water pumping and lighting. Significant markets also exist for off-grid residential and commercial power supplies and increasingly for fuel saving and peak load reduction on community diesel grid systems. Some of this market is supported by government grants aimed at reducing diesel fuel use.

PV installations connected to central grids continue to increase steadily, with the majority of installations taking advantage of government grant programs which currently contribute 20-25 % of

up front capital costs. The main applications are rooftop systems for private residences, schools and community buildings.

The rapid growth in electricity demand, and particularly in peak load demand, is dominating utility planning in Australia at present. Increased air conditioner use is the major contributor to both these trends. These developments have an indirect bearing on utility attitudes to PV. At substations where PV can be shown to generate during times of peak demand, there is likely to be utility interest. Nevertheless, PV remains a high cost option and there has been no discussion so far on possible utility incentives for PV installation.

## INDUSTRY STATUS

BP Solar is the major PV manufacturer in Australia and expects to maintain its current production capacity of 50 MW for the immediate future.

In 2006, a crystalline thin film technology developed in Australia entered commercial production by CSG Solar in Germany and the Sliver cell technology entered pilot production by Origin Energy in Adelaide. Patents for a number of new and improved technologies and production processes continue to be developed and licensed to Australian and international companies.

Chinese based PV manufacturer, Suntech Power, which is a joint Chinese - Australian company, continues to improve its production processes in cooperation with Australian researchers. The company has been awarded the contract to supply 130 kW of PV for the Beijing Olympic Stadium.

Balance of system component manufacture and supply is a critical part of the PV system value chain. There are a number of Australian manufacturers of inverters, battery charge controllers and inverter/chargers, particularly catering for the off-grid system market. Some of these manufacturers also supply inverters suitable for grid interconnection, and the industry is constantly looking for new ideas, improved products and reduced prices. Although some battery components are made in Australia, only a few manufacture complete solar batteries.

There is an increased interest in the use of trackers for off-grid pumping and power supply systems. Passive gas and electronic controlled trackers are used and expect to increase power output by up to 40 % compared with non-tracked systems.

As the PV component market becomes more global, expertise is increasingly being built up at the systems design level. There a several hundred companies around Australia which distribute and install solar systems. A number of these have now become significantly sized systems houses, providing products and systems for a range of applications in Australia and worldwide.

## MARKET DEVELOPMENT

Total PV installed in Australia reached 60,6 MW in 2005. Installations grew at a steady rate of 15 % over the past year and totalled 8,3 MWp in 2005. The largest PV market, accounting for 3,4 MWp in 2005, is in off-grid systems for industrial, agricultural and telecommunications applications. Off-grid residential systems comprise the next largest market at 2,9 MWp, followed by grid connected (main grid and diesel grid) residential systems with 1,4 MWp.

PV module prices remained steady in 2005 at around 8 AUD per Wp. Prices are largely set on the international market, but are influenced by exchange rates and local delivery costs. System prices vary by location and application but also remained reasonably steady in 2005. Residential rooftop systems averaged 12-14 AUD per Wp and stand-alone systems for off grid applications 19-22 AUD per Wp, although system types and inclusions vary widely.

Australia produced 35,5 MWp of crystalline silicon cells in 2005 using imported wafers. Most of these were for the export market. 6,7 MWp of modules were made locally, of which nearly 50 % were exported. Imported modules made up an increasing share of local sales. 0,4 MWp of concentrating PV systems were also manufactured and installed in 2005. This technology is increasingly cost effective, particularly in diesel grids.

## FUTURE OUTLOOK

As Australia enters an election year, with a growing acknowledgement of climate change, the prospects for PV are improving. In addition, a number of newly announced State Government PV tariff initiatives, as well as the start of the Solar Cities trials, will keep the spotlight on PV technologies, implementation options and prices.

The two most important capital grant programmes, the PV Rebate Programme and the RRPGP are both expected to be extended in 2007 thus at least maintaining current deployment rates. Increased community awareness of climate change issues is likely to see any increase in budgets for these programmes quickly translated into extra sales for both grid and off-grid applications. Continued expansion of voluntary utility GreenPower programmes, as well as increased deeming periods for PV under the Mandatory Renewable Energy Target may also result in new PV installations.

Relative price remains the critical issue, given that Australia has some of the lowest electricity tariffs in the OECD. Hence greater emphasis will need to be placed on the ease of installation, peak load contributions, unobtrusive and quiet operation, as well as climate change benefits.

# AUSTRIA

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

HUBERT FECHNER AND ROLAND BRÜNDLINGER, ARSENAL RESEARCH

*Fig. 1 – PV Architecture at the Community Centre in Ludesch/Voralberg (photo ertex Solar GmbH, Amstetten, Austria).*

## GENERAL FRAMEWORK AND NATIONAL PROGRAMME

After a period of about 3 years with no federal support for PV, Austria's parliament has passed a revision of the Green Electricity Act in May 2006, including a once again renewed slight photovoltaic incentive. The overall aim of the Green Electricity Act (GEA) is to increase the share of electricity from Renewables to more than 78,1 % in 2010, based on the obligations from the EU directive on Renewable Electricity. The GEA governs not only the support for green electricity but also for electricity from combined heat and power generation. A new paragraph now includes support for larger hydro power plants (50-100 GWh/a).

The GEA has set a target to meet 10 % of the public national electricity demand with electricity generated from 'new' renewable energy sources by 2010 (RES (not including hydropower) as well as an additional 9 % by small hydropower until 2008, respectively. These RES are supported mainly via long-term guaranteed feed-in tariffs to achieve the above mentioned political target quotas. The feed-in tariffs are stated by the Federal Ministry for Economics and financed by a supplementary charge on the net-price and a fixed price purchase obligation for electricity dealers.

Starting from 2006 up to 2010, another 17 MEUR will be dedicated each year to cover feed- in tariffs for newly installed energy systems. While the main part is dedicated to biomass and a much smaller part for wind, 10 % is reserved for all other sources; such as PV, liquid biomass, co-firing power plants and/or others. Concluding from that, for PV an annual maximum of 1,5 MEUR from the federal budget can be expected; specifically for PV support, regional parliaments are encouraged to double this federal subsidy, which makes the support system even more complex.

Photovoltaic feed-in tariffs for 2007 are 46 EURCent (< 5kW), 40 EURCent (< 10 kW) as well as 30 EURCent (>10kW); Compared to the former regulation, the time frame for the feed-in tariff is reduced, as well as the tariffs being reduced in total (100 % of the source/size specific tariff in year 1 to 10, 75 % in year 11, 50 % in year 12). Also, a decrement factor shall be implemented (to reduce the source/size specific maximum tariffs each year by about a few percentage points). It can be expected that this new regulation will lead to about 4-6 MW annually installed systems in Austria. Furthermore, no definitions for supporting special PV application (as e.g. Building Integrated PV) niche markets, where Austrian companies could maybe reach a leading position, has been made. Currently the regions are developing individual strategies to complement the federal support systems.

National PV stakeholders question the effectiveness of the support system, mainly because of the support system's complexity and the

modest financial limits, which might not be able to significantly foster the Austrian PV market. A significant market stimulation aiming at establishing competitive Austrian PV industry will not be achievable.

## RESEARCH AND DEVELOPMENT

Initiated by the Ministry of Innovation and Technology, a national PV roadmap is just under development; mainly focussing on technology aspects in order to find out the needs for establishing PV as significant source of electricity in Austria, as well as the possible future role of Austria's industry in the worldwide PV market. This roadmap, which was worked out in a broad discussion process amongst the main national PV stakeholders under the leadership of the mainly governmental research centre arsenal research will be published in spring 2007 aiming at an adaptation of the general frame conditions for PV in Austria.

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

The national programme, "Energysystems of tomorrow", (http://www.energiesystemederzukunft.at/) successfully initiated by the Ministry of Transport, Innovation and Technology is quite a broad research programme on energy technologies. Although research is not directly related to PV, PV systems as well as distributed generation with many aspects relevant to PV is of high priority within this programme.
On a European level, the ongoing initiatives to increase the coherence of European PV RTD programming (PV-ERA-NET) are actively supported by the Austrian ministry of transport, innovation and technology. The new and extended governmental energy research programme, energy 2050, will also cover PV as one of the essential research topics.

Research highlight of photovoltaics in Austria are:

- Organic Solar Cells based on thin plastic films have been intensively investigated during the last 10 years, at the Kepler University of Linz, lead to the foundation of a local branch of an U.S. PV company in Linz.
- Grid-interconnection, not exclusively related to PV but more to Distributed Generation from RES in general ("smart electricity networks"), is the main focus of several national and EU financed projects, which are jointly carried out by research institutions, industry and network operators.
- Research on PV inverter specification (MPP, islanding, etc.) is done at arsenal research; attracting world wide inverter manufacturers for collaborations.
- Cost reduction and optimization of new solutions for building integrated PV are addressed within several EU projects.
- At the University of Salzburg, a new initiative was started in 2006 to develop thin film solar cells, based on sulfosalt solarcells.
- Socio-economic research concerning the integration of PV is internationally well positioned at the Technical University of Vienna.
- A large Austrian glass industry has started activities in PV, mainly for addressing architectural building design.
- In the area of system technology, activities for quality assurance, certification and testing of PV modules were extended; arsenal research an Austrian research and testing institution is officially accredited to qualify crystalline silicon PV modules.

## IMPLEMENTATION & MARKET DEVELOPMENT

Approximately 24 MW of PV power was installed in Austria by the end of 2005. Figures for 2006 are not yet available, but it is expected that currently about 27 MW are installed in Austria.

The annual growth rates are very changeable and must be seen in relation to the unsteady support system in Austria. This situation is responsible for the weak home market with some internationally well positioned manufacturers nearly exclusively involved in foreign trade; mainly focussing on the neighbouring large German market.

The main applications for PV in Austria are grid connected distributed systems, representing more than 90 % of the total capacity. Grid-connected centralised systems in the form of PV-power plants play a minor role with about 1,2 MW installed.

Building integration is an important issue and several remarkable installations were realised.
Besides on-grid applications off-grid systems are widely used to provide electricity to technical systems or for domestic use in Alpine households or mountain huts lying far away from the grid. However, this is not exclusively in remote areas, but also on urban sites, PV is an increasingly selected option for supplying infrastructure systems. PV is also becoming more and more visible on Austrian highways; supplying the increasing numbers of screens which are informing the drivers on actual information about the traffic situation.

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

## INDUSTRY STATUS

Despite the unclear and unsatisfactory situation with an insignificant national market for PV, the Austrian PV industry could still expand their activities during 2006; focussing on the export of their products to the booming German market and other international markets.

SOLON-Hilber Technology: A subsidiary of the German SOLON manufacturer produces solar trackers and solar modules in Tyrol, close to Innsbruck; starting in 2003, currently more than 180 employees are working with this company.

*Fig. 2 – Tracked PV Systems in Arnstein, Germany (photo Solon Hilber).*

Ertex Solar: A new subsidiary company of the traditional company Ertl Glass (known for e.g. safety glass, insulation glass production, etc.), specialised on production and distributing building integrated PV modules. The company uses a new and innovative laminated glass production technology.

RKG Photovoltaik, since 2004 produces PV modules. The company is closely linked to GREENoneTEC, European's market leader in solar thermal collectors.

SED manufactures modules specially designed for integration into PV-roof tiles. The custom laminates produced are directly stuck into standard format tiles made of recycled plastic and can easily replace conventional roofing materials.

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

Blue Chip Energy GmbH will start production of silicon solar cells in the energy autarkic municipality of Güssing in late 2007, and is expecting to finally employ 140.

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

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

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

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

Altogether, the Austrian PV industry is expected to employ more than 1 000 people in 2007.

## MARKET DEVELOPMENT

In 2004, The Ministry of Environment, engaged in climate protection has started a large programme of initiatives to reduce $CO_2$ emissions ("klima:active"), by addressing and fostering various technology sectors like biomass-heating, solar thermal systems, heat-pumps, low energy buildings, environmental benign transport, etc., and is currently developing a programme for photovoltaics; concentrating on heightening awareness, education and information about the potential and possible future contribution of PV to the general energy supply.

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

By the end of 2006, about 75 companies and people involved into the PV business were members of the Association, which is about three times as much as of end 2005.

The annual National Photovoltaic Conference 2006 (for the first time a two days event) was jointly organised by arsenal research and the national PV association with support from the Ministry of Transport, Innovation and Technology and was a big success; with about 150 participants. Beside technical presentations, an "industry forum" was part of the Conference where all relevant national market players (module producing companies, BOS producing companies, research experts etc.) informed the audience on the latest developments.

In 2006, the Austrian research centre "arsenal research" initiated "Certified PV Training" for installers and planners in order to improve the quality of the installed systems. The first two training courses (theoretical and practical training, for a total of 6 days) have been given as pilot courses aiming at preparing regular training courses, which are scheduled to start in Spring 2007.

## FUTURE OUTLOOK

- While waiting for the effects on the new support scheme, the PV situation is unsatisfactory, mainly because of the complex and insignificant subsidies. If no significant and stable support mechanisms, (which can provide long and promising perspective for a national PV industry development) are introduced, the market will remain limited; relying on regional incentives which will only partly support the market.
- Potential PV niche markets, in which Austrians could take a leading position, have to be developed, in order not to fully lose the link to the booming international market. Some new initiatives and considerations at regional governments seem to be promising.
- 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 worldwide PV development progress. Specifically, the direct links to the new members of the European Union in Central and Eastern Europe in energy related items are to be mentioned (e.g. EU-Interreg Initiatives), where PV plays more and more an important role.
- The level of the public know-how about the potential and perspectives of PV is still insignificant but continuously growing. Several renewable energy education courses are already implemented; some new courses are currently being developed. All of them include PV as essential part of the future energy strategy. For example, at the Technical University in Vienna, a post graduate education on renewable energy was introduced with PV as important energy option and is included in the curriculum. The importance of proper education for installers and planners of PV systems will increase depending on the market situation; the training is already available and can be extended easily.
- It can be expected that the National PV Association and other important PV stakeholders will further significantly promote the topic in Austria. The small PV industry, currently taking advantage of the strong German market, is very much interested in creating a home market for PV, and is still waiting for an improvement of the economic frame conditions.

# CANADA

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

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

*Fig. 1 - The Solar Buildings Research Network headquarters, Concordia, University, Montreal, Quebec, Canada.*

## GENERAL FRAMEWORK

The Canadian Solar Buildings Research Network (SBRN)[1] – a consortium of federal and academic research centres, and industry headquartered at Concordia University in Montreal - was officially launched in May 2006 by the Government of Canada to begin its five-year mandate to innovate solar energy production and efficiency of its use in commercial, institutional and residential buildings in Canada. Also in 2006, the SBRN held its first Conference in conjunction with the Annual Conference of the Solar Energy Society of Canada bringing together leading experts from Canada and around the world to discuss all aspects of solar housing, from solar electricity to design issues to finding ways to encourage Canadians to go solar. The SBRN is expected to pool the R&D resources of 10 universities and federal departments to develop the future generation of experts knowledgeable in solar buildings research. The R&D efforts of the SBRN will provide in-depth analyses to Canadian stakeholders on the optimization of low and net-zero energy homes for Canadian climatic conditions. It will help to support innovation in the construction industry in order to accelerate the adoption of low and net-zero energy solar homes.

The Government of Canada is continuing to fund the Net Zero Energy Healthy Housing (NZEHH) Pilot Demonstration Initiative, implemented by the Canada Mortgage and Housing Corporation[2]. In 2006 a Request for Expressions of Interest (REOI) was issued to the public and the response was overwhelmingly positive. Since the launch of the REOI phase on May 15, 2006, six hundred and thirty-six information packages were sent out across the country to prospective proponents. By the REOI submission deadline of July 10, 2006, seventy-two Expression of Interest responses were received, proposing NZEHH projects Canada-wide. This level of response exceeded expectations for the project and also indicates a very positive reception and interest expressed by the Canadian housing industry in the concept and scope of the NZEHH initiative, and their enthusiasm to create exciting new models of sustainable housing in Canada. These applications recognized the significance of PV power generating systems in their final designs to enable them to reach their energy targets. Of these 72 applications, a maximum of 12 projects will be recommended in January 2007 for government funding.

Also in 2006 the Government of Canada released the report of the National Advisory Panel on Sustainable Energy Science and Technology (S&T)[3] that highlights a number of areas that should be strengthened if Canada is to remain a key energy player in the world. The final report, *Powerful Connections: Priorities and Directions in Energy Science and Technology in Canada*, identifies a number of key energy S&T priorities. It also outlines a number of operational recommendations to ensure that Canada maintains a commitment to excellence and innovation in the energy sector, while also positioning itself as a leading international player in energy S&T. The findings of this report reflect the strategic direction that Canada will be adopting in energy S&T in the foreseeable future.

Growth in the Canadian sector has been strong over the past 14 years, with capacity growing by more than 20 % percent annually between 1993 and 2006. Whereas, the worldwide trend has been moving towards grid-integrated application supported by market stimulation measures mainly in Germany, Japan and the U.S.A.; in Canada, the market is mainly for off-grid applications and represents 93 percent of total installed PV power capacity. There has been a growing number of grid-connected PV applications in Canada in 2006 because the barriers to interconnection of “micropower” systems have been addressed through the adoption of harmonized standards and codes. In addition provincial policies supporting “net-metering” of PV power have encouraged a number of building integrated PV applications throughout Canada during this period. More recently, the Ontario Power Authority has announced a program for standard offer contracts at 0,42 CAD per kilowatt-hour for PV electricity and several local electricity distributors in Ontario have identified PV applications as part of their conservation and demand management programs. The PV market and industry in Canada is continuing to grow, despite the low price for conventional energy. A sustainable market for remote and off-grid applications has developed over the last 14 years in Canada and continues to accounts for about 93 % of total PV installed. This is an unsubsidized market that is growing because PV technology is meeting the remote power needs of Canadian customers particularly for transport route signalling, navigational aids, remote homes, telecommunication, and remote sensing and monitoring. The total installed PV power capacity in Canada has reached approximately 20,5 MW in 2006 compared to 16,75 MW in 2005 (see table 1).

## NATIONAL PROGRAMME RESEARCH AND DEVELOPMENT

The Canadian Photovoltaic Programme, managed by CETC–Varennes (Department of Natural Resources Canada), focuses on the scientific aspects of work on photovoltaic energy. It is funded by the Programme of Energy Research and Development and the Technology

TABLE 1: CUMULATIVE PV POWER CAPACITY INSTALLED IN CANADA

| Year | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PV power (MW) | 1,24 | 1,51 | 1,86 | 2,56 | 3,338 | 4,47 | 5,83 | 7,15 | 8,83 | 10 | 11,83 | 13,88 | 16,77 | 20,50 |

**NRCan estimate is based on expected 20 % growth in 2006.*

and Innovation Research and Development initiative which support the energy-related R&D activities of federal departments. The Programme's primary mandate is to help develop and deploy photovoltaic energy technologies in Canada. It does so by accelerating the deployment of this technology domestically, while supporting R&D activities that exploit the technology's potential, both nationally and internationally. CETC–Varennes promotes and facilitates the use of photovoltaic systems in buildings, by carrying out research and demonstration projects, serving on international standards committees and developing information and training tools. On-going activities undertaken by the PV Programme in 2006 include:

- R&D for the integration of PV-thermal systems in buildings;
- Solar optimisation on Net-Zero Energy Homes;
- Participating in the Canadian Solar Buildings Research Network (Figure 1);
- Developing photovoltaic resource maps for Canada[4];
- Facilitating R&D activities between universities and the private sector involved in fundamental solar cell research;
- Establishing standards and codes for the certification and installation of PV systems and their components;
- Establishing national guidelines for the connection of small, distributed power sources to the public power system[5];
- Collaboration with Measurement Canada on net-metering to address the regulatory issues[6];
- Simulation studies on the impact of utility interconnected PV systems and micro-grids;
- Representing Canada in the International Energy Agency Photovoltaic Power Systems Programme;
- Disseminating information to the Canadian PV industry, the Royal Architectural Institute of Canada and other PV stakeholders; and
- Partnering with the solar power industry through the development of federally-funded demonstration projects.

The PV Programme also actively contributes its expertise to innovative partnerships with key players in the field. Most research projects are carried out on a cost-sharing basis with industry, universities, research groups, quasi-public agencies and other departments or governments.

## DEMONSTRATION

### Largest Solar Photovoltaic Pilot Project in Canada Installed at Exhibition Place in Toronto

In August 2006, the City of Toronto installed a 100 kilowatt PV rooftop system - the largest solar power system in Canada on the roof of the Horse Palace at Exhibition Place[7] (Figure 2). The system is comprised of four subsystem, each using a different combination of solar, inverter and mounting technologies, and are expected to generate a combined 120 megawatt-hours of electricity per year. The electrical performance of each of the subsystems is separately monitored and compared, allowing Exhibition Place to determine the best overall combination of technologies for use in future projects. This performance is available on a public website[8]. Exhibition Place is mixed-use property on the Toronto shore of Lake Ontario located a few kilometers just west of central business district. The 197–acre area features expo, trade, and banquet centers, theater and music buildings, parkland, sports facilities, and a number of civic, provincial, and national historic sites. It holds world-class events, including the Canadian National Exhibition, the Royal Agricultural Winter Fair, and World Youth Day. Each year about 5,2 million people visit the site. The solar system on the Horse Palace roof will join other renewable energy systems operating at Exhibition Place, which is the location of the first city-sited wind turbine in Canada. A fuel cell demonstration project was introduced in 2003. Exhibition Place's goal is to become energy self-sufficient by 2010, and ultimately to become a net exporter of clean electricity. Exhibition Place plans to expand the installation to 1,5 – 2 megawatts in the near future to enable it to reach its goal becoming energy self-sufficient by 2010. This project was funded by the federal government through the Federation of Canadian municipalities, the municipal government through the Toronto Atmospheric Fund and the private sector through the Better Buildings Partnership. This is an innovative public-private sector partnership that promotes and implements building renewal and energy- efficient retrofits of industrial, commercial, institutional and multi-residential buildings.

## IMPLEMENTATION

### Overview of the Government of Ontario's Renewable Energy Standard Offer Program

In the fall of 2006, the Province of Ontario, through the Ontario Power Authority (OPA) and the Ontario Energy Board (OEB), has developed a Renewable Energy Standard Offer Program (RESOP)[9] for the Province, designed to encourage and promote the greater use of renewable energy sources including solar photovoltaic, wind, waterpower and biomass from small (10 MW or less) generating projects that would be connected to the electricity distribution system of Ontario. The RESOP, when implemented, will help Ontario meets its renewable energy supply target of having 2,700 megawatt of electrical power generated by new renewable energy sources by 2010, by providing a standard pricing regime and simplified eligibility, contracting and other rules[10] for small renewable energy electricity generating projects.

The intent of the Program is to "make it easier for the operators of small renewable energy generating facilities to contribute to Ontario's electricity supply by providing power to their Local Distribution Company and receiving payment for the power they provide. To qualify under the RESOP, applicants must be willing to make necessary investments in their facilities and in the costs of connection to the distribution system and metering, bear certain ongoing costs of operation and maintenance, and enter into a contract with the OPA pursuant to which the OPA will pay the Generator for electricity delivered for a 20 year payment period".

The RESOP rules establish a "market-based pricing system for all technologies except solar photovoltaic that provides a Base Rate to be paid to Generators for each kilowatt-hour (kWh) of electricity delivered, plus a performance incentive for Generators who can

control their output to meet peak demand requirements reliably over time. It also provides for price escalation to the Base Rate paid to some Generators, linked to the Consumer Price Index in Ontario. The rules also establish a cost-based price for solar PV production in order to conduct price discovery. A cost-based price recognizes that PV Projects cannot be successful at this time under a pricing regime suitable for other renewable generation sources. PV Projects will be paid 42,0 cents per kWh but will not be eligible for inflation indexation or the peak-hour premium." (Check the RESOP website for additional information).

### Federal S&T Funding in support of Technology Demonstration to Market Commercialization

Federal investment in technology transfer is through continued support to two key delivery programmes:

- *Technology Early Action Measures (TEAM)*[11], is continuing to provide financing for promising environmental technologies that have the greatest potential to reduce greenhouse gases. TEAM plays a key strategic role in the technology innovation process. By supporting late-stage development and first demonstrations of GHG-reducing technologies, it enables the federal government to support a wide range of technology options and pathways towards the reduction of GHGs. Many companies that have been involved in TEAM partnerships have subsequently received further private and public financing or have commercially replicated their technology in the marketplace. Since 1998, TEAM has invested 120 million CAD in 111 projects, leveraging more than 850 million CAD in technology development investments. Of this, 10,35 million CAD were invested in six photovoltaic technology early market-entry demonstration projects.
- *Sustainable Development Technology Canada (SDTC)*[12] is a not-for-profit foundation established by the Government of Canada in 2001 with an investment fund of 550 MCAD. SDTC finances and supports the development and demonstration of clean technologies which provide solutions to issues of climate change, clean air, water quality and soil, and which deliver economic, environmental and health benefits to Canadians. SDTC works closely with an ever-growing network of stakeholders and partners to build the capacity of Canadian clean-technology entrepreneurs, helping them form strategic relationships, formalize their business plans, and build a critical mass of sustainable development capability in Canada.

### Net Metering Initiative

A working group composed of stakeholders from the electricity industry (manufacturers and utility) and federal regulatory branches in collaboration with the federal government is continuing work on the Net-Metering Project to identify and eliminate barriers to the introduction of net metering in the electricity sector. Since electricity power in Canada is a provincial jurisdiction and the connection are usually done according to the local distribution company's requirements. Net metering regulations have been put in place in several provinces that establish rules for the flow of electricity between utilities and distributed PV systems. The implementation of these regulations is challenging, requiring the installation of new equipment (for example, proper meters) and new billing systems. Some utilities have developed and implemented programs that streamline the application process, specify net metering requirements and set out approved tariffs (BC Hydro, Toronto Hydro, HQ Distribution). Where local distribution companies do not have streamlined application processes, the approval process can be complex for individual consumers responsible for their installation. Canadians in those regions must deal with different types of approval or verification to install a rooftop system that are handled on a case-by-case basis. 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.

*Fig. 2 - 100 kW PV roof-mounted installation at exhibition Place, Toronto, Ontario, Canada.*

## INDUSTRY STATUS

There are over 150 solar energy organizations (sales companies, wholesalers, product manufacturers, private consultants, systems installers and industry associations) driving the PV market in Canada. A majority of them are active in the Canadian Industry Association and Energie Solaire Quebec. The Canadian PV manufacturing sector has grown significantly in the last four years to serve both the domestic and export market. There was a small increase in manufacturing employment in Canada from 627 in 2005 to 645 in 2006. The largest manufacturers are Xantrex, Carmanah, Automation Tooling Systems and ICP Global. Other Canadian companies that have recently expanded their operations include:

- Day4Energy Inc.[13] formed in 2001 in Burnaby, British Columbia, "is a manufacturer of PV modules and receivers for a variety of applications ranging from "one-sun" flat panel modules to specialized Photovoltaic receivers designed to operate under sun concentration ratios of up to 7-times above normal levels. All of the company's products are based on a proprietary technology for contacting and interconnecting crystalline silicon PV cells. In 2006, the Company has received certification from the Underwriters

Laboratory of its first product, the DAY4 48MC solar module – a product line is based on the company's patented Day4™ electrode technology and offers a number of valuable features including high power density, attractive aesthetic appearance, overall product reliability and market driven design. The company is also continuing to push forward with its sun concentrator program that holds the promise of dramatic cost reduction of PV power generation in the near future."

- Solera Sustainable Energies Company™[14] is a "leading provider of utility-grid connected solar power in Canada. Solera is the new operating division of Phantom Electron which was founded in Toronto, Ontario in 1985. Solera has been providing clean, reliable, maintenance-free electricity for residential, commercial and institutional applications for more than a decade. Partnered with Compower Systems Inc., a Canadian manufacture of telecom power products, Solera offers the marketplace proven capabilities in renewable energy and backup power system design, engineering, manufacturing, service and installation, and product supply."
- Based in Calgary, Alberta, Sustainable Energy Technologies Ltd.[15] is a "developer and marketer of advanced power electronics products for the emerging alternative and renewable energy markets. Sustainable Energy's main product line is the SUNERGY series of inverters for solar PV applications. The first product is a 5 kW inverter for European grid-connected markets. In 2006, it announced agreements with Barcelona based companies Gabriel Benmayor SA and Free Power SL to jointly manufacture and distribute SUNERGY 5 inverters in Spain. The Company's corporate vision is to play a key role in the advancement of all clean energy technologies by developing and marketing of the most technologically advanced power electronics in the industry, by strategically partnering with the largest and most established players in the market."

## MARKET

The Canadian total PV installed capacity in 2006 was 20,5 MW with a sustained domestic market growth that has averaged 22 % annually since 1992. In 2006, the PV module market in Canada was 3,75 MW compared to 3,68 MW in 2005. Module prices have gradually declined from CAD 11,09 in 1999 to CAD 5,36 in 2006. This represents an average annual price reduction of 9 % over the eight year period (Table 2). Twelve manufacturers in Canada reported revenues from manufacturing operations related to modules and BOS sales of 137 million CAD and the addition of 55 new jobs in 2006. It is estimated that the PV business in Canada is valued at 205 MCAD and employs 1 030 people.

## FUTURE OUTLOOK

Private sector investments in the development and marketing of solar PV power systems in Canada will continue to drive the domestic PV market for the foreseeable future. This is reflected by steady growth in the installed base, as well as the significant private-sector investment in manufacturing. The Canadian Solar Industries Association and Energie Solaire Québec have continued their promotional and marketing activities. CanSIA in particular has been very active in 2006 in developing the foundation for significant changes in polices and programs that will support the solar industry in the coming years.

The Solar Buildings Research Network will generate opportunities for demonstrations of innovative PV projects and will expand the knowledge base of Canadians to the benefits and add value of PV technology in the buildings of the future. Technology demonstration funding opportunities in support for climate change mitigation will continue to generate private sector interest in demonstration projects and collaborative joint ventures.

### TABLE 2: MODULE PRICES (CAD/W) IN CANADA FOR 1999-2006

| Year | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|---|---|---|
| Average price (CAD) | 11,09 | 10,70 | 9,41 | 7,14 | 6,18 | 5,53 | 4,31 | 5,31 |

Footnotes with relevant web sites:

1 *Solar Buildings Research network website: http://www.solarbuildings.ca/main.php?l=e*
2 *Zero Energy Healthy Housing website: http://www.cmhc-schl.gc.ca/en/inpr/su/neze/*
3 *In May 2005, a panel of experts representing a broad segment of the Canadian energy economy was brought together to reflect on and provide its views on two key questions in the area of energy science and technology (S&T): What should Canada's energy S&T priorities be, given economic, social and environmental considerations that are important to Canadians?, and What are the best mechanisms for delivering on these priorities?*
4 *Photovoltaic (PV) potential and insolation web-based maps: https://glfc.cfsnet.nfis.org/mapserver/pv/index_e.php*
5 *Micropower Connect Website: http://www.powerconnect.ca/mpc/index.htm*
6 *Net Metering update in Canada website: http://www.powerconnect.ca/net/index.htm*
7 *Exhibition Place, Toronto: http://www.explace.on.ca/*
8 *Monitored Performance of 100 kW PV system at Horseshoe Palace: http://view2.fatspaniel.net/FST/Portal/TorontoHorsePalace/*
9 *Renewable Energy Standard Offer Program website: http://www.powerauthority.on.ca/sop/*
10 *The Program Rules for the Renewable Energy Standard Offer Program, as prepared by the OPA, are available for download at http://www.powerauthority.on.ca/sop/Page.asp?PageID=122&ContentID=4107&SiteNodeID=162&BL_ExpandID=161*
11 *Technology Early Action Measure website: http://www.climatechange.gc.ca/english/team_2004/*
12 *Sustainable Technology development Canada website: http://www.sdtc.ca/en/index.htm*
13 *Day4 Energy Technology Inc. website: http://www.day4energy.com/*
14 *Solera Sustainable Energies Company website: http://www.soleraenergies.com/about.aspx*
15 *Sustainable Energy Technologies Ltd. website: http://www.sustainableenergy.com/SET-home/index.html*

# DENMARK

PV TECHNOLOGY AND PROSPECTS

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

*Fig. 1 – Visualisation of the PV panels from the new head office of the Danish National Television, DR-byen, made by the architect company Dissing + Weitling arkitektfirma a/s. When the building is completed, it will have the biggest PV system in Denmark, with a capacity of 125 kWp.*

## GENERAL FRAMEWORK

The Danish government launched an energy plan in March 2005. The energy plan focuses on 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 energy plan further focuses on the ongoing development of efficient energy technologies both nationally and in the EU, and the government wish to strengthen the research community and the development of new and promising energy solutions. With regard to renewable energy (RE) the plan sets quantifiable targets for the overall contribution from RE, but no technology specific targets. The market forces are supposed to promote the most suitable and competitive RE technologies. The energy plan is reported to be up-dated or replaced by early 2007.

The Kyoto protocol and the consequent EU agreement on GHG reduction targets has lead to a Danish commitment to reduce GHG emissions by 21 % in the period 2008-2012 compared the base year 1990. The market for $CO_2$ 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 2006 more than 25 % of the national electricity consumption was generated by renewable energy sources. Ongoing research, development and demonstration of new energy solutions including renewable energy sources have high priority in the present energy plan; 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, both at favourable cost to the consumers.

Photovoltaic technology (PV) is not specifically mentioned in the government's energy plan, but in early 2004 the Danish Energy Authority (EA) in collaboration with the electricity sector, the industry and other key stakeholders finalized a national strategy on PV after a public hearing. This PV strategy includes the fields of research, development and demonstration. Deployment activities in support of the PV strategy are expected to be developed in the coming years and an overall framework for the coordination of PV development and deployment in Denmark is thus expected to be in place inside a few years. The PV strategy was updated mid 2006 by the way of an annex outlining the need of long term operational targets and support mechanisms. A full update is expected during 2007.

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 PROGRAM

Denmark has no unified national PV programme, but a number of projects supported mainly by the Danish Energy Authority and via the Public Service Obligation (PSO) of Danish network operator, Energinet.dk. In late 2006, a new support mechanism, Energy Development and Demonstration (EUD), to be administered by the Energy Authority was announced. It is supposed to go active in 2007, but the extent to which PV can benefit from this new instrument is not yet known.

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 2006 about 2,9 MW has been installed in the context of various projects and demonstrations plants supported by various instruments. A 300 roof-top's project including 750 kWp was launched early 1998 and was completed by end of 2001. A 1 000 roof-top programme was launched late 2001 as a follow up; this programme targets a mix of general cost reductions, increase in end-user payment and promotion of small roof-tops. Only a few weeks after the announcement of the programme, the SOL 1000, more than 3 000 house owners had registered their interest. However, uncertainty about the programme due to change of government and increased demand for end-user payment have introduced a delay of almost a year in the programme implementation. By the end of 2002, the programme reported a portfolio of some 1 300 house owners expressing firm interest in the programme and by end 2006, about 700 kW had been implemented stimulated by an investment subsidy of 40 % of the turnkey system

*Fig. 2 – PV system from the Danish Sol 1000 with a capacity of 3,15 kWp.*

cost, average turnkey system cost being 4,40 EUR/W. The SOL 1000 programme was extended until end of 2006. The average system size in the project for private households is 1,8 kWp. By the end of 2006, there were no longer any instruments in Denmark to bring down the investment cost of PV systems in general.

A special support programme for PV applications in the commercial sector, funded by the $CO_2$ tax on electricity, was set up early 1998. The support includes a subsidy of up to 40 % for the 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 5-6 years no projects have been implemented using this support mechanism.

Net-metering for privately owned PV systems was established mid 1998 for a pilot-period of four years. In late 2002, the net-metering scheme was extended another four years up to 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. During the political negotiations in the fall of 2005 the net-metering for privately owned PV systems was made permanent.

## RESEARCH & 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

*Fig. 3 – HCPV 1 kWp prototype plant.*

more than 150 MDKK were allocated to renewables; however it is still to early to say to which extent PVs can benefit from the programme. In 2004 the government increased the PSO allocation for R&D into environmentally benign generating technologies from 100 MDKK per year to 130 MDKK per year. However, due to an ongoing merging of the two network operators into one new state-owned venture, Energinet.dk, this extra funding was only effective for the call for proposals with the deadline date of 01.10.05. A few R&D PV projects did indeed benefit from support during 2006.

In 2004, the EA became part of the new EU supported PV RTD network PV-ERA-NET focussing on EU level and national level coordination and optimization of PV RTD programmes. Denmark has, in 2006, decided to investigate the viability of entering the first Joint Call in the framework of the PV-ERA-NET.

R&D activities into PEC cells (Grätzel type cells) are ongoing at the Danish Institute of Technology. This activity has been supported in 2002-04 by the PSO of the Danish network operators. This R&D activity has now attracted commercial finance and a new company has been formed. Ongoing support has been granted from 2007 and onwards for continued R&D activities in this field. At the Risoe National Laboratory basic research into polymer based PV cells is ongoing with progress reported in both efficiency and, in particular, stability and life time.

In mid-1995, the Photovoltaic System Laboratory (PVSyslab) was established in collaboration between the 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.

The first Danish book on PV and architecture focussing exclusively on Danish buildings, design, architecture and products was published in the fall of 2005, by the publishing branch of the Danish Architects Federation.

Municipal-based PV interest groups have been formed in two municipalities: Solar City Copenhagen and Solar City Horsen. These groups are quite active and more similar groups are expected.

## IMPLEMENTATION

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

The SOL 1000 programme run by the utility EnergiMidt, which, as mentioned above, intends to demonstrate low cost and architectural acceptable integration of PV technology primarily on existing single family houses, has by end of 2006 implemented about 700 kW in total. There is a focus on the gradual increase of end-user payment, this way 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. Small “do-it-yourself” PV plants were also introduced with a size of 250 Wp, and in 2005, 120 of these systems were sold and installed.

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 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.

Also in Copenhagen, the so called Valby Initiative has progressed. Valby is a region of Copenhagen undergoing extension changes and refurbishment, and a PV initiative targeting about 300 MW has long been in preparation. The initiative has been integrated into actions in the EU Concerto Programme.

## INDUSTRY STATUS

R&D efforts are beginning to exhibit commercial results in terms of export. The Topsil Company, which uses a float-zone technique to produce 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. In 2004, the first commercial results of its R&D into low-cost float-zone processing were realised and it is expected to continue to supply SunPower in the US with float-zone Si for high efficiency PV cells.

Inverter technologies have been R&D'd for some years for both fuel cell and PV applications. For the latter, a commercial breakthrough was also announced in 2003 by the Danfoss related company Powerlynx, which reports in 2006 to have underpinned and significantly strengthened the commercial breakthrough announced in 2003. Powerlynx now employs more than 200 people.

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 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.

A project on the integration of PVs in industrialized residential buildings was completed in 2005 with good results. In particular the collaboration with the Aarhus School of Architecture proved to be successful with PVs entering the curricula. The objective of integrating PV's in industrialized building processes has been continued in 2006 via a new project.

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 National Program.

Total PV business volume in 2006 is very difficult to estimate with any degree of accuracy, primo 2007; due to the commercial secrecy surrounding the above mentioned new business developments in the fields of Si feed stock and inverters. However, an increase from 35 MEUR in 2005 to 40 MEUR in 2006 is a “best guess”.

The cumulative installed PV capacity in Denmark (including Greenland) was, by end of 2006, estimated to be about 2,9 MWp; an increase of about 7 % compared to 2005.

## 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. However, funding for large scale demonstrations has proven to be difficult to find in the existing support structure of the Danish Energy Authority and the PSO system.

It is regarded as obvious that without funding and a clear public support to large scale demonstration of PVs for yet some years to come, the sector risks quickly to diminish because of an insufficient home market.

However, the trend towards commercial sustainability for PVs is seen as ongoing and with the objective realistically within reach. Projections and scenarios completed during 2006 indicate, that with the continued global technical and economic development of the PV technology, with a now permanent net-metering scheme in Denmark and with unchanged development of the Danish end-users increasing willingness to invest in PVs, a market for PV roof-tops in Denmark without any investment subsidy will emerge around 2011-12; given that the necessary demonstration activities can be continued in the period up to 2011-2012.

# EUROPEAN COMMISSION

RESEARCH, DEVELOPMENT AND DEMONSTRATION ACTIVITIES ON PHOTOVOLTAICS SUPPORTED BY THE EUROPEAN COMMISSION
PIETRO MENNA, RESPONSIBLE FOR THE SOLAR ELECTRICITY SECTOR, EUROPEAN COMMISSION, DG ENERGY AND TRASNPORT
DAVID ANDERSON, SCIENTIFIC OFFICER, EUROPEAN COMMISSION, DG RESEARCH

## GENERAL FRAMEWORK

Climate change, increasing oil and fossil fuel dependence and rising energy prices: all these factors are rendering Europe increasingly vulnerable. The key to a sustainable future must involve renewable energies. As part of its Energy Policy for Europe[1], the European Commission has put forward a proposal for a long-term Renewable Energy Roadmap[2]. The proposal includes an overall binding 20 % renewable energy target and a binding minimum target of 10 % for transport biofuels for the EU by 2020, and a pathway to bring renewable energies in the fields of electricity, heating and cooling and transport to the economic and political mainstream. Like many of the renewable energy sources, solar photovoltaics is still relatively new to the market. This is why there is a need for a targeted legislative and commercial infrastructure to encourage rapid market growth. At the same time, there is still a need for high profile research development and demonstration and promotional activities to raise the confidence of investors. The European Commission is therefore active in both these areas, with the clear purpose of increasing the share of renewable energy sources in the energy portfolios of the EU Member States.

## PHOTOVOLTAICS RTD AND DEMONSTRATION PROGRAMME

Through a series of RTD framework programmes (FP), the Commission has maintained long term support for research development and demonstration in the PV sector providing a framework within which researchers and industrialists could work together to develop new applications for PV technologies. In terms of research objectives, a combination of actions needed to address the PV sector, are primarily related to cost reduction: (1) fundamental research aimed at achieving progress either through reducing manufacturing costs or through increasing the efficiency of PV cells, and (2) integrated research and demonstration, including the development of system design options and concepts, with a view to expanding the market and providing a basis for economies of scale in PV module production.

## RTD AND DEMONSTRATION WITHIN FP5 (1998-2002)

The 5th Framework Programme, coordinated by the European Commission, was organized into short to medium term and medium to long term activities for demonstration and research respectively in the photovoltaic sector. In total almost 100 PV projects were launched between 1999 and 2003. For more information, the reader is referred to the Project Synopses, collecting a two-page description of each project [3].

## 6TH FRAMEWORK PROGRAMME (2003-2006) (FP6)

The transition from FP5 to FP6 was marked by an increased awareness of the need to reduce the fragmentation in European research and improve the exploitation of the results. This is why the research actions supported under FP6 have been focused at the development and demonstration of integrated approaches to new system design options and concepts, with a strong emphasis on cost reduction.

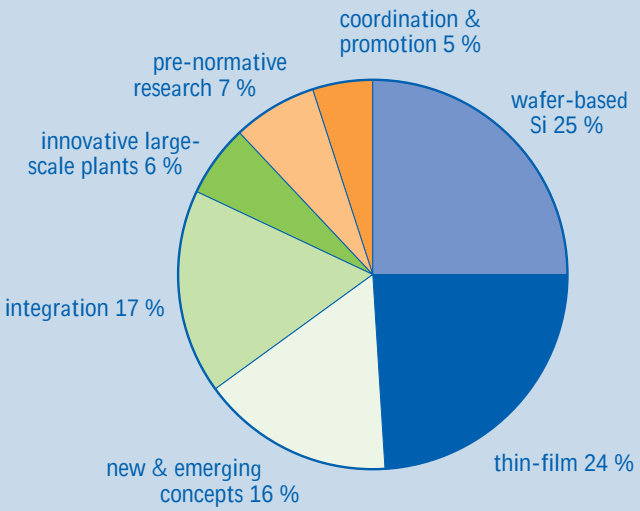



*Fig. 1 - Distribution of EC contribution (104,8 MEUR) in FP6 across research areas.*

The short to medium term activities emphasize mostly demonstration aimed at accelerating the market penetration of more cost-effective PV technologies. More specifically, the priority has been given to innovative production concepts for high efficiency cells/modules to be integrated into larger scale photovoltaic production facilities to lower the cost; and including low cost integrated components or devices for PV generators; large area, low cost photovoltaic modules for building integrated PV and autonomous solar electricity generation systems.

The medium to long term part of the programme has focused on cost reduction of crystalline silicon; innovative concepts and fundamental materials research for the next generation of PV technologies; thin film PV technology; PV processing and automated manufacturing technologies; PV components and systems; and research for innovative applications of PV in buildings and the built environment.

At the end of 2006, FP6 came to an end. At the time of this writing, the European Commission has provided a contribution of 104,8 MEUR for supporting PV R&D in FP6 (Figure 1: Distribution of contribution under FP6), thus continuing a 30-year tradition of co-financing the development of solar electricity in Europe (Figure 2: Contribution of the EU Research Programme to the activities in the photovoltaic field during the years 1975-2006). Some of the projects supported under the CONCERTO initiative (launched with the FP6 TREN 2nd Call) include the demonstration of innovative PV systems, for a total of 2,9 MW of power.

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

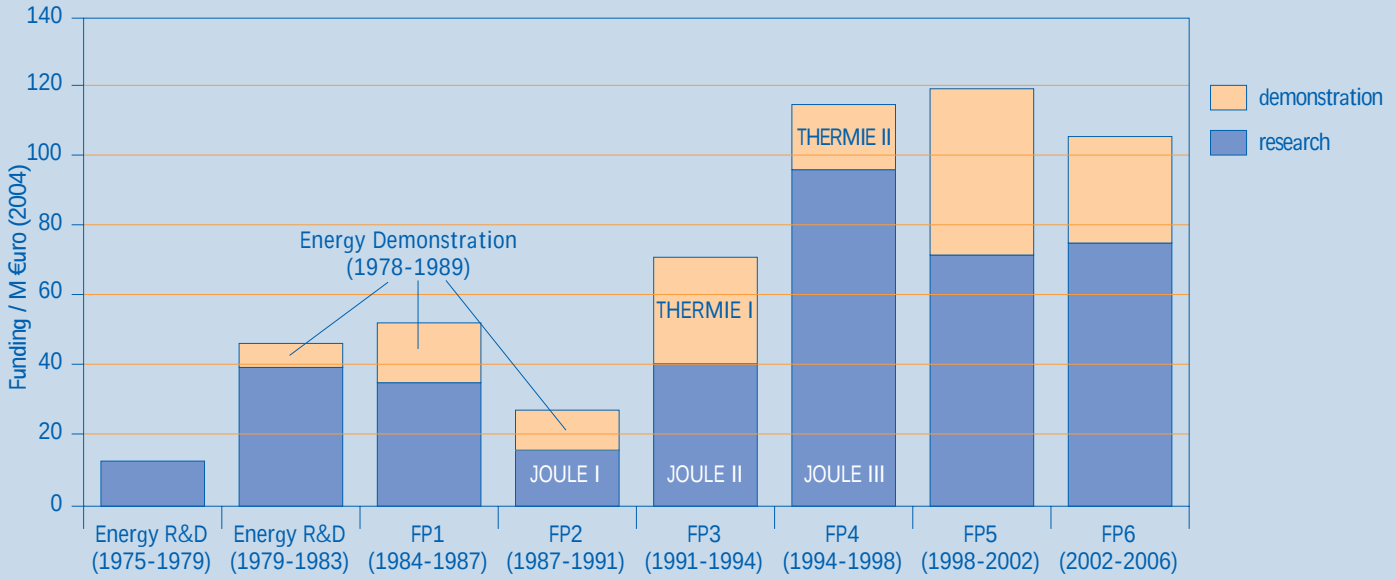



*Fig. 2 - Contribution of the EU Research Programme to the activities in the photovoltaic fieldduring the Years 1975-2006 (M€ 2004).*

To provide some examples of the projects launched under FP6, it is worth to start with the activities on feedstock material which represents an appreciable share of the production cost, and has traditionally been sourced from the electronics industry. The SISI and FOXY projects are exploring alternative routes for solar-grade silicon, through carbothermic reduction of quartz and refining of metallurgical-grade silicon, respectively.

In spite of the feedstock shortage, crystalline silicon has actually increased its market share in recent years, and is expected to remain the dominant technology for many years to come. The largest PV project under FP6 is *CrystalClear*. The project has the goal of defining a manufacturing process for crystalline silicon capable of realising a production cost of 1 €/W (see also website http://www.ipcrystalclear.info/default.aspx). The BITHINK project aims to develop and demonstrate new thin bifacial modules, manufactured by an integral screen-printing technique and using a BSF structure. The project aims to obtain low-cost crystalline technology in a multi-megawatt facility. The Lab2Line project aims at taking solar cell processes and materials successfully developed within previous research projects to manufacturing level. In particular, the project will address low-cost options for the laser-grooved solar cell and manufacturing issues related to the use of n-type multi-crystalline silicon.

For thin-film technologies, the focus has been on thin-film silicon and copper-indium-diselenide (CIS) technologies. Notably, 2006 saw the launch of the ATHLET project, with a total budget of 20,8 MEUR and an EC contribution of 11 MEUR. The project will target high-efficiency laboratory cells, module issues, analysis and modelling and environmental aspects. There are also two vertical approaches orientated along the value chain: large-area chalcopyrite modules and the industrial up scaling of silicon tandem cells. The consortium comprises well-known research institutes and solar cell producers and includes also several equipment manufacturers. The main objectives of the project are to improve existing thin-film PV technologies towards module costs of 0,5 €/W (see also http://www.hmi.de/projects/athlet/). HIGHSPEEDCIGS is an innovative project which aims to demonstrate the economical production of CIGS solar cells by batch processing of many small circular substrates through a small vacuum chamber. The approach will incorporate high-speed automation techniques and experience from the optical disc industry. Furthermore, for its considerable potential for economic mass production, the European Commission is co-financing several projects in the area of flexible thin-film silicon, prepared in a roll-to-roll environment.

In addition to crystalline silicon and thin-film technologies, the European Commission is also supporting new and emerging concepts – comprising both high-efficiency and low-cost approaches. The FULLSPECTRUM project brings together several of these concepts which have the common aim of making fuller use of the solar spectrum (see http://www.fullspectrum-eu.org/). The multi-junction activity aims to progress as much as possible towards 40 % efficiency, and last year the partners achieved a new European record of 35,2 % at 600-suns concentration. Other activities include thermo-photovoltaics, intermediate band gap cells, diffuse-light concentrators and up/down converters. Also working on multi-junction technology, the HICONPV project aims to develop, set up and test a new cost-effective, high-concentration (1000-suns) system. The cost goal for the proposed type of system is 1€/W by 2015. Exploring the low-cost route, the MOLYCELL project aims to improve the lifetime and efficiency of organic solar cells (see also http://www-molycell.cea.fr).

As the photovoltaic market continues to mature, the importance of standardisation is coming to the fore. The European Commission is co-financing a large pre-normative project called PERFORMANCE, which aims to improve the understanding of measurement issues, and to harmonise procedures for testing, PV-system Monitoring and labelling. The project, which started in January 2006, receives a

contribution of 7 million Euro (see also http://www.pv-performance.org/). At the systems level, the PV-MIPS project aims to significantly reduce the cost of grid-connected PV through the development and demonstration of PV modules with integrated inverters. The cost targets for production are 0,3 €/W for the inverter and 3 €/W for the complete PV system. (See also http://www.pvmips.org/over.html).

The photovoltaic activities also extend to coordination and support actions. The PV-ERA-NET project is a four year initiative which aims to improve networking and integration of national and regional RTD programmes (see http://www.pv-era.net). The PV-CATAPULT project consists of ten diverse work packages, centred on a common goal of accelerating the development of the photovoltaic technology towards market deployment. The PV-Employment project addresses the strategic objectives of analysing the net amount of jobs created by the European PV industry up to 2020, together with the required qualification profiles of employees to produce recommendations to the policy makers and to the educational sector. Finally, the European Commission is financing the secretarial support for the Photovoltaic Technology Platform (described below).

## PHOTOVOLTAIC TECHNOLOGY PLATFORM

The Photovoltaic Technology Platform, which was designed in 2004 to implement the "PV Vision" of the Photovoltaic Technology Research Advisory Council (PV-TRAC), is now fully operational, following the constitution of the Mirror Group at the end of 2005. Main aim of the Mirror Group, composed of representatives of the EU Member States and Associated States, is to improve the coordination among the PV research programmes at National and European level.

The Platform is steered by a Committee of 20 members, representing the different European PV sectors. It is composed of four working groups (policy, market, research and developing Countries) and is supported by a secretariat, funded by the Commission. The working groups formed at the beginning of 2005, have prepared documents and action plans on policies, socio-economic and research and technological issues.
In particular a Strategic Research Agenda has been drafted to provide advice to PV research policy-making, at European level, including the seventh Framework Programme and the Competitiveness and Innovation Programme, as well as national and regional level, via the PV-ERA-NET and the Mirror Group.
For further information, see http://www.eupvplatform.org/.

## 7TH FRAMEWORK PROGRAMME 2007-2013 (FP7)

The first call for proposals under the FP7 has been launched on 22 December 2006[4]. Work includes development and demonstration of new processes, standardized and tested building components, demonstration of additional benefits of PV electricity and longer term strategies for both high-efficiency and low-cost photovoltaic routes. The eleven topics open for proposals have the ambition to cover the whole value chain of the technology, in both the short-medium term and the medium-long term research domain.

## REFERENCES


1 *The relevant documents are available at the following internet address: http://ec.europa.eu/energy/energy_policy/index_en.htm*

2 *Communication from the Commission: - A Renewable Energy Roadmap: paving the way towards a 20 % share of renewables in the EU's energy mix by 2020. COM(2006) 848 Final*

[3] *European Photovoltaics Projects 1999-2002, European Commission (2003), http://ec.europa.eu/research/energy/pdf/european_photovoltaics_en.pdf*

[4] *All the information is available at the following website: http://cordis.europa.eu/fp7/home_en.html*

# EPIA

THE EUROPEAN PHOTOVOLTAIC INDUSTRY ASSOCIATION (EPIA) MISSION AND ACTIVITIES

ELENI DESPOTOU, POLICY OFFICER
MARIE LATOUR, COMMUNICATION OFFICER

With over 110 Members drawn from across the entire solar electricity sector, the EPIA represents over 95 % of the European photovoltaic cells production and 80 % on the global scale. EPIA membership is spread along the whole value-chain of the photovoltaic industry from silicon producers, cells and module manufacturers to system providers.

## EPIA 2006-2010 STRATEGY

The successful result of the 2003-2006 strategy lead to propose a new and more ambitious market oriented action plan for the years 2006-2010.

### EPIA's Mission Statement

EPIA exists to deliver a distinct and valuable service driven by the strength of a single European photovoltaic voice.

### Objective

EPIA's objective is that 7 million European families may produce clean and sustainable solar electricity by 2010. This represents a global objective of 5,6 GWp global annual market and a European market of 3,1 GWp in 2010.

### EPIA's CIPQ® Strategy

Four main pillars are driving EPIA activities to reach this objective:

- Competitiveness – The challenge for the industry is to reach competitiveness. Cost reduction can be only obtained with mass production and technological research.
- Innovation – Promoting research activities and stimulating technological transfer from laboratories to the industry with particular focus of financing the industry priorities through the European Framework programs for research and development (FP7).
- Quality – Standards, certification and performance of devices are of extreme importance for PV products. The PV industry can demonstrate that it can deliver quality products and have social responsibility, too.
- Promotion – Improving EPIA's visibility to all relevant stakeholders by maintaining and reinforcing its credibility.

### As part of its activities at the European and global level, EPIA is member of the following organizations:

- EREC – European Renewable Energy Council
- CEFIC – European Chemical Industry Council
- EUFORES – European Forum for Renewable Energy Sources
- IEA-PVPS – International Energy Agency Photovoltaic Power System
- ARE – Alliance for Rural Electrification

### EPIA Implication in the activities of the IEA-PVPS

In the year 2006 EPIA has participated to two ex-co meetings:

- London (March 2006), represented by Eleni Despotou
- Korea (October 2006), represented by Michel Viaud

*Fig. 1 - EPIA is involved in the organization of major events such as the 3rd PV Industry Forum, which took place within the framework of the 21st EU PV Conference and Exhibition.*

EPIA's main task as member of the IEA-PVPS is to disseminate and promote the results of the different tasks, stimulate and initiate subjects of particular interest for the industry and in general terms bring the voice of the industry amongst the countries members.

### Task 2: Performance, Reliability and Analysis of Photovoltaic Systems

In the meeting in Vancouver on March 2006, EPIA represented by Eleni Despotou committed to contribute to this task. The integrated project "Performance" has been presented there as it may have complementary added value for the task. As a scientific officer Dr. Wouter Leroy has been recently integrated the secretariat, he will partially dedicated to that task.

### Task 8: Very Large Scale Photovoltaic Power Generation Systems

It is planned that EPIA will organize a workshop or dedicate a session on PV in deserts within the program of the Second PV Med conference due to take place on 19 and 21 April 2007 in Athens. More information on the 2nd PV MED can be found here: www.pvmed.org.

### Task 10: Urban Scale Photovoltaic Applications

In 2006, EPIA supported this Task by:

- Supporting *the 1st Lisbon Ideas Challenge* through dissemination and participation to the evaluation process. In addition it supported the final presentation event which took place in Lisbon in December 2006. Eleni Despotou presented the market development and perspectives globally with particular focus on Europe and feed in tariffs.

*Fig. 2 – The European Parliament, Brussels: EPIA represents the European Photovoltaic Industry towards European and International Institutions.*

- Financing the edition and printing of the report "Compared Assessment of selected environmental indicators of photovoltaic electricity in OECD cities" prepared within this task and in collaboration with EPIA and the European Photovoltaic Technology Platform. This report published in April 2006 provides clear and well-documented answers to politicians, decision-makers and the general public about what PV can and cannot achieve in terms of renewable, clean energy production and environmental protection.

In 2007 EPIA supported Task 10 by:

- Offering the opportunity to launch *the 2nd Lisbon Ideas Challenge* on an event organized by EPIA for the European PV Technology Platform on 2nd February 2007 in Brussels. This event, entitled "New rising era for photovoltaic integration in buildings" took place in the frame of the Sustainable Energy Week. It is jointly organized with the European Construction Technology Platform. It will gather over 120 participants from all over Europe, targeting at architects, developers, installers and PV and construction industry.

### New Task 12: Environment, Health and Safety

Considering the growth of the PV sector globally, the issues such as Environment, health and safety took of a great importance. EPIA and USA have shown an increased interest and it has been decided that both will take the leadership of the task. EPIA will be represented by Eleni Despotou assisted by industrial partners active already in the field and Brookhaven laboratories represented by Vassilis Fthenakis. This new task is planned to be launched in March 2007 in Brussels. The action plan has already been presented in Korea by Michel Viaud but it will be revised before the launch of the task.

## GENERAL SUPPORT TO THE IEA PVPS

### Organization of the 2007 IEA PVPS Ex-Co Meeting in Athens from 16 to 18 April

As part of its general support to the activities of the IEA-PVPS, EPIA will host the 29th IEA PVPS Executive Committee Meeting in Athens from 16 to 18 April 2007 prior to the 2nd PV MED conference. This meeting will give the opportunity to bring IEA PVPS closer to the Greek authorities and it is hoped that Greece will become an official member for (the organization. Eleni Despotou and Christos Protogeropoulos from CRES will organize the stay in Athens and make all the arrangements for a potential meeting with the ministry for development.
The Second PV MED will gather stakeholders of the PV sector from the Mediterranean and will enable to discuss on latest market trends. To learn more on the 2nd PV MED: www.pvmed.org.

*Fig. 3 - Michel Viaud, was General Secretary of EPIA for three years. He left us in December 2006 after substantially boosting the activities of the industry organization.*

# FRANCE

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS IN FRANCE

ANDRÉ CLAVERIE AND FABRICE JUQUOIS
FRENCH AGENCY FOR ENVIRONMENT AND ENERGY MANAGEMENT (ADEME)

*Fig. 1 – Tenesol Technologies photovoltaic modules factory in Haute-Garonne department, 20kW (photo courtesy of Tenesol).*

## GENERAL FRAMEWORK

The years 2005 and 2006 were marked by a certain number of events which were conducive to the exploitation of renewable energy sources. French Parliament has passed the Energy Planning Act that sets the guidelines for the energy policy while the government was implementing fresh fiscal and financial measures:

- The law text (Energy Planning Act) passed on 13 July 2005 focuses on energy management together with the development of renewable energies; while priority was given to the utilisation of bio-resources and the recourse to solar thermal energy (Face *Sud* Plan). Solar photovoltaic energy (PV) has also been included in the same research package of the law on par with hydrogen and carbon dioxide sequestration;
- The new fiscal measures are aiming at promoting the use by private individuals of materials for heat and electricity generation that are based on renewable energy sources. The tax credit has been set at 50 % for the year 2006;
- The feed-in tariff for PV-generated electricity were set at 0,55 EUR the kWh for the photovoltaic installations integrated into the building and at 0,30 EUR the kWh for the traditional photovoltaic installations. The decree for the enforcement of the said measures came into force on 10 July 2006.

In parallel with these measures, the government has overhauled its policy for research funding and created two new means agencies. The ministry in charge of research has created the National Research Agency (ANR, www.agence-nationale-recherche.fr) while the Ministry for Industry was setting up the Industrial Innovation Agency (AII, www.aii.fr). Both agencies have put photovoltaics high on their agendas as priority action themes. As a result, in 2005 and in 2006 the ANR has contributed significant funds to research projects covering photovoltaics, which has given a great boost to new projects that ADEME, the original sponsor could not support anymore.

No photovoltaic projects have yet been selected by the Industrial Innovation Agency (IIA): these will have an industrial aspect associated with significant financial backing. The ANR and ADEME have joined forces since 2006 for launching annual calls for research projects. The ANR is providing financial backing to fundamental and industrial research projects while ADEME is sponsoring projects covering industrial technology development and pre-competitive development. In France, the main industrial players in the photovoltaics industry are developing and manufacturing the different components of the photovoltaic systems. These manufacturers act in conjunction with public research teams for research and technological development projects (RTD) funded either by ADEME or by the ANR, or by OSEO Anvar in the case of the innovative SMEs. The regional and departmental councils, already well involved in funding the photovoltaic generators on the field, have been reinforcing their financial commitment since two to three years to PV research projects. There is also a fresh initiative from the regions to reactivate R&D notably in the SMEs through the *Competitiveness Poles* that provides scope for the renewable energies and photovoltaics.

The activities deployed by the main industrial players are described in the Industry Status section and those of the public laboratories are discussed in the R&D, D section below.
Public research establishments such as CNRS (National Research Organisation) and the CEA (Atomic Energy Agency) are involved in the research and study works, usually, in co-operation with the industry. CNRS and CEA receive funding from ADEME and ANR through calls for proposals. CEA and CNRS have decided to join forces for the implementation of the new National Institute for Solar Energy (INES). There are ongoing prefiguration initiatives (research, development, innovation, RID of INES). This institute will have personnel from CEA, CNRS and the CSTB (Scientific and Technical Centre for Building). The power utility (EDF) also has one programme aimed at R&D and

the promotion of the photovoltaic systems and receives subsidies from ADEME and the ANR for research on the materials and the development of international standards. The R&D division of EDF has created a joint research institute, the IRDEP; in association with the CNRS and the École de chimie of Paris. IRDEP is involved in projects covering the development of thin film electrodeposited copper indium di-selenide and the concepts of 3rd generation PV cells.

In order to implement the policy of market development, ADEME is sharing with the regional councils the incentives meant for investment and is acting in some operations in conjunction with the European Commission structural funds. ADEME and the regional councils have revised their modalities for funding in order to adjust to the Finance Act that came into force in 2005, regarding the tax credit and new feed-in tariffs. Some regional Councils are very active and have implemented a policy that involves calls for projects in the tertiary and collective sector with a focus on architectural integration, energy performance of the buildings as well as the demonstrative aspect (Languedoc-Roussillon, Provence – Alpes – Côte d'Azur, Poitou-Charentes, etc.).

## PHOTOVOLTAIC PROGRAMME

The Environment and Energy Management Agency (www.ademe.fr) is the public establishment that the French government has put in charge of the implementation of the national policy for sustainable development in the following four fields of intervention: energy management, waste management, soils conservation and air quality. The energy management aspects include energy efficiency and the use of renewable energy sources of which, solar photovoltaics. ADEME's *Photovoltaic Electricity Programme* has five types of actions structured around different axis and departments:

- R&D covering components and the PV systems. It should be said that funding is supplementary to funds provided by the National Research Agency (ANR);
- Installation operations of the systems on the field (undertaken by the ADEME's regional delegations, often in cooperation with the regional councils);
- Training through research (PhD grants), training of electricians and professionals;
- Information dissemination (colloquia, status reports, technical guides, leaflets for the general public, etc.);
- International collaborations with similar agencies for specific study projects.

These actions are guided by the policy for the markets regulation implemented with the Ministry of Industry (the R pole of the tetrahedron of the Innovation Strategy for Sustainable Development R-S-T-M). ADEME is funding projects for research and technological development undertaken by the industrialists from the photovoltaic sector in conjunction with the public laboratories. The aim is to cut the costs for manufacturing the photovoltaic materials, cells and PV modules, and optimise the systems performance and their impact on the environment and ensure the quality of products and services.

The ANR is responsible for funding the fundamental and industrial research projects. Similarly to ADEME, it is promoting partnership between the public and the private sector and is contributing to the transfer of the results of public research to the industrial sector.

ADEME's two first poles of activities, R&D and market incentives, are described in the following sections. The three other poles cover several activities. For instance, ADEME is running, at its Sophia Antipolis headquarters, in Lyon and in the overseas department (DOM) from 7 to 11 annual training sessions aimed at training the installers and promoters of PV projects. ADEME is also contributing to young engineers' training through PhD grants. During their three-year thesis, the future researchers will participate in the industrial research projects funded by either ADEME or the ANR in the public or private research laboratories.
In parallel, ADEME is involved in several types of cooperation projects with European and international partners. ADEME is a partner in two projects funded by the European Commission: PV-ERA-NET (www.pv-era.net) and PV Policy Group (www.pvpolicy.org). ADEME participates also in the works of the European Photovoltaic Technology Platform (www.eupvplatform.org). ADEME is also active within the Photovoltaic Power System programme of the International Energy Agency (IEA/AIE, www.iea-pvps.org) with direct or subcontracted participation in the working groups Task 1, 2, 9, 10 and 11 (the new working group whose kick-off meeting was held in Aix-en-Provence in May 2006). Concerning international standards, ADEME contributes together with its partners to the works of the International Electrotechnical Commission (IEC/CEI, Technical committee 82, www.iec.ch). ADEME is equally involved in multiple international projects where photovoltaics is just one of their components (projects such as CRESMED, RESTMAC, SYNERGY+, etc.).
As part of bilateral partnerships, ADEME intervenes to provide support to some French-speaking African countries for off-grid electrification projects.
ADEME is also sponsoring events with national or international impact; for example, the *Pollutec* trade show which was held in Lyon in November 2006. Renewable energies and more particularly, photovoltaic energy have attracted many information requests. ADEME is funding one network of energy information centres that allows dissemination of its messages to private individuals. At the national level, ADEME is campaigning for raising awareness of energy savings and renewable energies associated with the campaign slogan, "Let's act fast, it's heating up".

## TECHNOLOGICAL RESEARCH AND DEVELOPMENT (RTD)

In 2005, the creation of the National Research Agency (ANR) and the launch of one PV R&D programme went down well with the French photovoltaic teams. The latter, having observed that for the past few years ADEME's budgets could no longer meet their ambitions, namely for fundamental and applied research.
In 2005 and 2006, the ANR has selected some twenty projects following the launch of annual calls for proposals. The projects last from two to three years and cover the crystalline silicon sector, thin

TABLE 1 – FEED-IN TARIFF FOR PHOTOVOLTAIC ELECTRICITY IN FRANCE FROM 10 JULY 2006

| | MAINLAND FRANCE | OVERSEAS DEPARTMENTS AND CORSICA |
|---|---|---|
| Basic Tariff | 0,30 EUR/kWh | 0,40 EUR/kWh |
| Building Integration Premium | 0,25 EUR/kWh | 0,15 EUR/kWh |
| Feed-in BIPV | 0,55 EUR/kWh | 0,55 EUR/kWh |

films, the organic materials and the new concepts. Additional projects focus on studies on the photovoltaic systems and components.
ADEME itself has, among others, sponsored two industrial technology development projects: the PHOTOSIL project that focuses on the construction of one pilot for the manufacturing of silicon with solar photovoltaic quality through the metallurgic path (three-year project) and, the REDUCOP project which is aimed at cutting the manufacturing costs of the photovoltaic cells and modules (four-year project). Both projects are launched by manufacturers in co-operation with the public laboratories. A third important project called CISEL/GENECIS (2005-2008) on the electrodeposited thin film CIS is co-funded by ANR and ADEME. Under the EUREKA cooperation programme, one pilot project for manufacturing of silicon ribbons was funded by OSÉO Anvar, the agency for funding innovation in the SMEs.
Development of PV construction materials comes under one fresh programme called PREBAT and managed jointly by ANR and ADEME. In 2006, no PV project has been selected under this framework.
Regarding the *"Competitiveness Poles"* that have been created and some sections of the TDR, photovoltaics will benefit from the regional councils and ANR funds.
The photovoltaic research and development budget has thus increased from 4 MEUR per year in 2004 (ADEME's intervention budget) to over 12 MEUR per year in 2005 and in 2006 (ADEME and ANR budgets). ANR and ADEME are launching mid-January 2007 a new call for proposals associated to an identical annual budget (www.agence-nationale-recherche.fr and www.ademe.fr).
The photovoltaic scientific community has met once a year on the occasion of the national colloquium. The annual colloquium previously planned for late 2006 has been postponed to 20-22 March 2007. Such postponement of dates is consequential to the necessary adjustment to be made in the ADEME and ANR agendas, as they both now share the organisation of this national photovoltaic event. The minutes of the previous photovoltaic seminar (in CD-ROM form) are available upon request to be made to ADEME. In May 2006, in Aix-en-Provence, ADEME was the co-host or the European conference on the hybrid photovoltaic systems and the mini-networks (chair M. D. Mayer from the CENERG laboratory of the École des mines of Paris). Several other conferences on the thin layers (E-MRS) and on the organic materials (ECOS) were held in France during this period.

## IMPLEMENTATION

The Finance Act which came into force early 2006 has implemented the new financial subsidy system designed for private individuals installing a photovoltaic array on the roof of their homes. As a result, for the private individuals subject to taxation, the fiscal measure consists of reimbursement covering up to 50 % of the costs of the materials (installation costs are excluded). The fiscal measure replaces the subsidies granted by ADEME to the private individuals through its regional delegations. A few regional Councils continue to allocate subsidies to the private individuals in the form of electricity buy back rate or direct grant).
For the private or public operators the subsidy amount is granted on a case-by-case basis as part of calls for projects. In this case, ADEME is insisting on the quality of the architectural integration of the PV modules in the buildings when it is a new building and requires that a strong energy management policy be implemented. In 2006, the overall power of the systems installed in France is estimated at over 14 MW the majority of which is connected to the grid, which means a significant increase against the previous year (7 MW).
The most important project being the photovoltaic power system of 1 MW capacity installed on the Réunion Island. This project was dedicated in December 2006 and should supply the Réunion island with 1,3 GWh in electricity per year. The issue of energy independence in the French overseas departments has become a priority for the local political authorities and photovoltaics is, associated with a reduction in the energy demand, the preferred solution to remedy this problem. About 60 % of the park of photovoltaic installations is connected to the French grid and is currently concentrated in the three overseas departments (Réunion, Martinique and Guadeloupe).
The increase in the French PV feed-in tariff that came into force in the decree published 10 July 2006 (see Table above) constitutes the major event for the French players of the photovoltaic industry this year. In 2005, the tariff stood at 0,14 EUR the kWh in mainland France, a level clearly insufficient for ensuring financial profitability of this type of investment. Tariff was increased fourfold in 2006 for the building integrated PV (BIPV) up to 0,55 EUR/kW generators ADEME has actively participated in this tariff determination with the Ministry of Industry.

This feed-in tariff gives a strong boost to the building integration and could allow robust and sustainable growth of the French market on the market segment of BIPV. Up to now, this segment of applications has been poorly developed in Europe and it is a strong added-value creator. The strategy developed by the French authorities through this tariff is to give a strong impetus to innovation in architectural integration, in order that in the long run photovoltaics could become one construction material that generates electricity and that is becoming commonplace among the companies from the construction industry. The additional costs generated to date by the integration of the photovoltaic components should in the short-term result in savings made in the implementation of the PV systems.

## INDUSTRIAL STATUS

The French photovoltaic industry relies on a few motivated players acting since the early 80s: Photowatt International (materials, multicrystalline silicon cells/modules and systems); Apex BPSolar (PV components and systems); Tenesol (formerly Total Énergie, PV modules, components and systems); Free Energy Europe (amorphous silicon modules and systems). Some new companies got recently involved in this industry: Emix (multicrystalline silicon ingots); Invensil/Ferroatlantica (feedstock silicon); Apollon Solar (crystalline silicon processes); Solar Force (silicon ribbon). Other companies

manufacturing equipment gained visibility in the field ECM, Vésuvius, Semco, Saint Gobain, etc., as well as construction components manufacturers: Imerys Toiture, Lafarge Couverture, Sunland21, Kawneer Europe, ARCELOR, etc.
The firm Photowatt International –specialised in manufacturing multicrystalline silicon ingots, wafers and photovoltaic cells and modules– has increased its production capacity in 2006 that now stands at 60 MW against 40 MW for the previous year. The company has 600 employees. In order to meet the high demand for photovoltaic modules, the firm is also manufacturing cells based on monocrystalline silicon by purchasing monocrystalline silicon ingots outside. The firm is also running one ambitious RTD project called REDUCOP (ADEME funding 2004-2008). The project is aimed at reducing the production costs and increasing the conversion efficiency in cooperation with research teams from the CEA and the CNRS. Photowatt is installing photovoltaic systems with balance-of-system components approved by the firm. In 2006, Photowatt set up a 1 MW photovoltaic power system on the Réunion Island. In the field of the PV modules integrated into the building, Photowatt is working on new concepts together with Imerys, Clipsol and other construction companies.
The Emix firm has launched the production of multicrystalline silicon ingots through one method of continuous casting in electromagnetic cold crucible. The firm's customers have validated the products coming from this new production tool. Emix is running a new RTD project called TWIN (ANR funds).
The Tenesol firm (formerly Total Energie) held jointly by Total and EDF, has launched on 2 December 2006 a plant for the assembly of photovoltaic modules at Saint-Martin-du-Touch near Toulouse. One PV generator of 20 kW has been installed on the building. Tenesol is purchasing the photovoltaic cells from foreign suppliers. The production capacity stands at 17 MW per year. Tenesol, with its headquarters in the region of Lyon, is the first French company designing and installing photovoltaic systems and employs 500.
The Invensil/Ferroatlantica and Apollon Solar firms have launched the construction of one pilot for manufacturing solar photovoltaic grade silicon through the metallurgical route (200 tonnes capacity per year). This project called PHOTOSIL, in which the CEA/LITEN is collaborating, has received grants from ADEME and the local communities. The pilot should be operational in 2007. It is installed at Bourget-du-Lac and is included in one of the buildings of the future solar research Institute INES.
The consortium *Silicium de Provence* (SILPRO) has decided to build in Saint-Auban in the Alpes-de-Haute-Provence, one plant for the production of solar photovoltaic grade feedstock silicon (chemical route). The site was chosen because of the proximity of a chlorine production unit from Arkema, one chemical company that is undergoing restructuring. The plant should be operational in 2008 and have initial annual capacity of 2 000 to 3 000 tonnes.

Concerning the thin film technology sector based on hydrogenated amorphous silicon the industrial players Free Energy Europe and Solems (low power) are continuing their PV modules production but they have not announced new specific developments in 2006.

*Fig. 2 – Office of Energy Syndicate of Drôme department, 14 kW; Architect: M. Solnais (photo courtesy of Tenesol).*

## MARKET DEVELOPMENT

Operational photovoltaic capacity existing in France[1] at the end of 2006 was estimated at 47 MW which accounts for the annual production of 47 GWh of electrical energy. In the year 2006, over 10 MW have been installed. The installed power of the stand-alone systems remains stable, at about 1 MW. And this includes an activity of replacement of the installations at end of life and the reinforcement of the existing installations as well as the installation of new equipment. The most powerful installation ever installed in France, 1 MW is found in the Réunion Island. There are now several installations in the range of 100 kW. The regional councils have launched calls for projects in 2005 and 2006 representing several megawatts. PV installations or the large majority of them are in urban environment and on the buildings.

## FUTURE OUTLOOK

The year 2006 was marked by important initiatives that have strengthened photovoltaics within one favourable legal and regulatory framework. It is worthwhile noting the Energy Planning Act that has re-launched energy management and the applications of renewable energy sources, the new solar photovoltaic research programme of the National Research Agency (ANR) and lastly, the publication of new feed-in tariffs for PV electricity and an increase in the tax credit for the private individuals.
Research teams were the prime beneficiaries of the new measures. The public intervention budget for PV R&D grew three-fold over the years 2005 and 2006. ADEME and ANR that are now the two national agencies funding research, will continue to back targeted PV R&D projects undertaken by consortia of industrial and public partners. The call for PV R&D projects 2007 of ANR and ADEME is confirming the efforts made over the last two years. Launched mid-January 2007, the tender will be closed on 16 March 2007.
Regarding the market for PV applications, the investments originated mostly from the local communities and the manufacturers. The new feed-in tariffs and the environmental concerns are driving the investors. The installation volume of photovoltaic roofs at private individuals has increased in relation to last year. However, in the beginning of 2007, it is difficult to assess the number of installations that have benefited from the tax credit. The total power of the PV systems installed in 2006 is greater than 14 MW. A mention should be made about the noticeable realizations from operators some of which have been well integrated into buildings.The photovoltaic industry is taking advantage of this new outlook for growth.

[1] *France means here, mainland France and Corsica Island and the four French overseas departments: Guadeloupe, Martinique, Guyane and Réunion that are important users of photovoltaic energy systems.*

*A French version of this memorandum is also available.*

# GERMANY

PHOTOVOLTAIC BUSINESS IN GERMANY – STATUS AND PROSPECTS

CHRISTOPH HÜNNEKES, PROJEKTTRÄGER JÜLICH (PTJ), FORSCHUNGSZENTRUM JÜLICH

## GENERAL FRAMEWORK

The reduction of greenhouse gas emissions is an ongoing task in Germany. An enhanced utilisation of renewable energies is the key to a sustainable energy system. Moreover, increased independency of energy supply goes hand in hand with growing usage of renewable energies. For the electricity sector, the Federal Government set a national target for renewable energies of 12,5 % by 2010 and 20 % by 2020. While in 2000 a share of 6,3 % for renewable energies was assessed, in 2006 already 11,6 % were reached.

Photovoltaic (PV) adds to this development. From the currently installed PV capacity one can estimate a share for PV of roughly 2,8 % of the renewable power generated in Germany. Driven by the Renewable Energy Sources Act (EEG), PV still shows an impressive development. Additionally, PV has become a real business with noticeable employment and turnover.

## NATIONAL PROGRAMMES

Today, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) takes the responsibility for the renewable energies within the German Federal Government. In 2006, Research and Development (R&D) was conducted under the 5th Programme on Energy Research and Energy Technology called “Innovation and New Energy Technologies” [1]. Main parts of this programme are administrated by the Project Management Organisation PtJ in Jülich. In addition to this programme, there are other sources for the support of PV R&D: The Federal Ministry of Education and Research (BMBF) conducts a programme aiming for the support of renewable energies related networks. Moreover, the funding of renewable energies at national institutes is partly covered by their institutional funding provided by the Federal Government and the Federal States. Finally, some of the Federal States carry out their own R&D programmes.

From January 1999 until end of 2003, the “100 000 Rooftops Solar Electricity Programme” provided soft loans for approximately 65 700 grid connected PV systems. This support scheme is now continued by a soft loan programme called “Solarstrom Erzeugen - Solar Power Generation” [2].

In addition to the soft loan programmes, the Renewable Energy Sources Act (EEG) is guaranteeing favourable feed in tariffs for renewable energies. The EEG is the main driving force for the PV market in Germany.

## RESEARCH AND DEVELOPMENT

### Overview

The new 5th Energy Research Programme is designed to be valid for the period from 2006 to 2008. Under this programme, a call for tender was released in September 2006. Concerning PV, the call addresses five focal points:

- Silicon feedstock and wafer technology, especially the production of solar silicon, reduced material consumption and the development of new cell and module concepts.
- Thin film technologies, especially transfer of concepts and processes into an industrial environment, optimisation of processes considering reduction of costs and investigation of degradation processes aiming for long term stable structures.
- System technology, especially for decentralised grid structures, adaptation to future module generations and standardisation of island systems for global applications.
- Alternative concepts which are both suitable for power applications and feasible for industrial production.
- Cross-cutting issues like enhancement of the lifetime of all system components, avoidance of materials which are harmful to the environment, reduction of energy usage in the production and recycling.

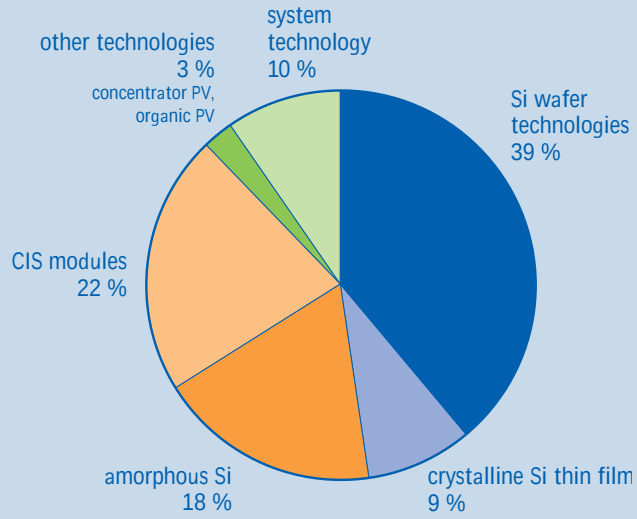



*Fig. 1 - BMU funding of R&D in 2006.*

In order to provide these targets with concrete goals, in November 2005 a R&D roadmap was developed during the 9th BMU R&D strategy meeting [3]. This roadmap developed by representatives from industry and research institutes puts emphasis on a stable decrease of the costs of electricity from PV. It demands the need for an efficient consumption of raw materials, especially of silicon, as well as higher efficiencies in general, long-term stability of all system components and innovative production technologies.

In general, the federal PV R&D strategy is designed to support the German PV industry to reach, maintain and extend their leadership in all relevant disciplines. Therefore, key-projects in the areas of silicon wafer technology, thin-film concepts and system technologies are funded. In 2006, the BMU support for R&D projects on PV amounted to about 38 MEUR shared by 121 projects in total. The distribution of the budget shows that one focal point still is on wafer based silicon technologies (40 % of the budget). But thin-film technologies receive an increasing share of the budget (48 %). The development of system technology (10 %) and alternative technologies like organic PV and concentrating PV (3 %) are funded as well. (see Fig. 1)

*Fig. 2 - Erection of a 5 kW FLATCON®-System (Source: Concentrix Solar GmbH).*

In addition to the BMU grants, the BMBF provides funds for the development of PV technologies as well; in 2005 approximately 22 MEUR were spent.

### Research and Development

In accordance with the PV R&D strategy outlined above, 45 new grants were contracted by the BMU in 2006. The funding for these projects amounts to 43,4 MEUR in total (after 32,3 MEUR in 2005 and 29,5 MEUR in 2004).

In 2006 the highlights of R&D were as follows:

- Systems with high efficiencies are crucial for a further reduction of costs of solar power. Significant progress was achieved in two projects:
  - Rear contact solar cells with efficiencies of 21 % were developed in the project QUEBEC which is carried out by the company Q-Cells AG together with the Fraunhofer-Institut für Solare Energiesysteme (FhG-ISE) and the Institut für Solarenergieforschung Hameln (ISFH). In 2007 this development will be transferred into pilot production [4].
  - A record efficiency of 18,8 % for large area screen printed solar cells was reported by the company SolarWorld Industries Deutschland GmbH, Munich. The company is now optimistic to realise 20 % cells using this technology [5].

- Today, PV systems show a typical lifetime of more than 20 years. For a live after the live recycling concepts are developed by the project SOMOCELL. Under the leadership of the company Deutsche Solar in Freiberg this project deals not only with the re-usage of silicon wafers but also recycling concepts for thin film technologies will be developed.

- Currently, a significant extension of thin film production capacities founded on sustainable funding of R&D is been undertaken. The main technologies of interest are based on amorphous / micro-crystalline silicon (aSi/µSi) and on the compound semiconductor CIS. In the coming months the realisation of a aSi/µSi pilot production line at Brilliant234, an extension of aSi module production at Schott Solar as well as the implementation of full CIS production capacity at Würth Solar are on the agenda. All initiatives are supported by accompanying R&D projects.

- PV has also the ability to contribute to enhanced power quality and secured power supply. This kind of added value can be achieved by adding a UPS function (Uninterruptible Power Supply) to the PV inverter. In 2006 two projects were launched which address this issue.

- In November 2006 Concentrix Solar GmbH a spin-off of the Fraunhofer-Institut für Solare Energiesysteme (FhG-ISE) received a contract from ISFOC Spain for the erection of a 500 kW concentrating solar power plant at the Spanish province of Castilla-La Mancha. This proves the high confidence in Concentrix's FLATCON® technology (see Fig. 2) which is based on a development started at the FhG-ISE in the late 1980s. In 2006, a new grant was contract by the BMU mainly for the development of efficient production processes for FLATCON® modules.

## IMPLEMENTATION

Since 2004, Germany is the country with the highest annual PV installation world-wide. This remarkable development is based on the following measures in the area of market introduction:

The "Electricity Feed Law" introduced in 1991 was replaced by the "Renewable Energy Sources Act (EEG)" in April 2000. The EEG rules the input and favourable payment of electricity from renewable energies by the utilities. In 2004 the EEG was amended and the feed-in tariffs were adjusted mainly according to changes in accompanying market introduction programmes. The tariffs for new installed PV systems drop year by year by 5 %. Table 1 shows the development of the basic PV tariff. The rates are guaranteed for an operation period of 20 years.

### TABLE 1 – DEVELOPMENT OF THE BASIC PV FEED-IN TARIFF OF THE EEG

| | 2003 | 2004 | 2005 | 2006 | 2007 |
|---|---|---|---|---|---|
| Tariff* (Ct/kWh) | 46,0 | 57,4 | 54,5 | 51,8 | 49,2 |

**For rooftop systems smaller than 30 kW; for bigger systems there are lower tariffs; façade integrated systems get a bonus of 5 Ct/kWh.*

At the end of 2003, the "100 000 Rooftops Solar Electricity Programme" terminated. With a total granted capacity of 345,5 MW and 65 700 systems built, this programme was a real success. The support of PV systems by soft loans is maintained for example by the new programme "Solar Power Generation" [2]. Under this programme 30 284 loans representing a total volume of 237,4 MW equivalents to 946,6 MEUR investments were granted since 2005.

Other measures like programmes of the Federal States (Länder) and the Federal German Environmental Foundation (DBU) are designed for a local or an application specific support of PV. Moreover, a number of utilities have launched initiatives to build PV-demonstration and pilot systems or to provide advice and information.

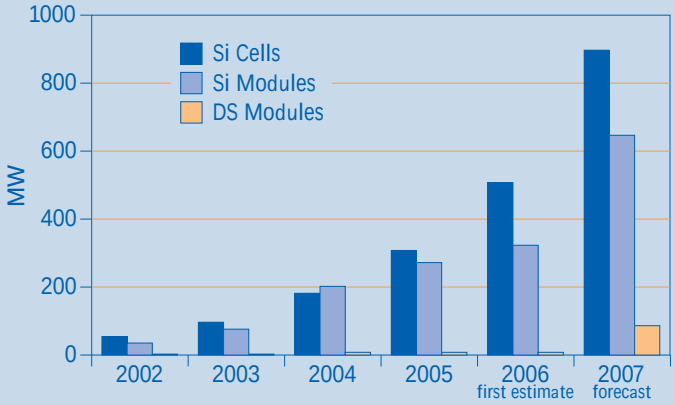



*Fig. 3 - Production of German cell and module companies since 2002 and forecast for 2007 after [6].*

## INDUSTRY STATUS

Based on the measures described above, the German PV industry experienced a period of strong growth over the last years. And it seems that this growth will even ascend in the next few years. The range of companies dealing with PV is expanding along the whole value chain. Especially the capacity of thin film production facilities is expected to grow significantly in the near future; taking advantage of the current global silicon supply shortage. However, for the moment the growth of the market as well as the production is limited by that shortage. And it is estimated that this shortage will maintain until 2008. The production figures given below are based on an analysis of the PV magazine "Photon" [6].

Silicon Feedstock: Wacker, one of the world largest supplier of Silicon for the semiconductor and PV industry, again enhanced its silicon production to 6 200 t in 2006. This is equal to a PV production of approximately 510 MW. An extension to 9 000 t until 2008 is already decided.

With Joint Solar Silicon, Scheuten SolarWorld Silizium and City Solar three additional producers will enter the market in 2007/8 introducing new ways for the production of solar silicon.

Wafer Production: The total production of wafer amounted to 310 MW in 2006 and stayed on almost the same level as in 2005 (300 MW).

The main supplier of silicon wafers is still Deutsche Solar AG in Freiberg. The company produced approximately 180 MW of mono- and multi crystalline wafers. Besides Deutsche Solar there are two further Germany based wafer manufacturers: PV Silicon at Erfurt and ASI at Arnstadt. It is estimated that both companies together sold up to 100 MW in 2006. Silicon ribbons are produced by Schott Solar (EFG-Si-ribbon) in Alzenau and EverQ (String-ribbon) in Thalheim.

From 2007/8 on two other companies will start production, namely Conergy AG in Frankfurt (Oder) and WPI Wafer Production International in Leipzig.

Solar Cell Production: The cell production in Germany shows a steady growth. Starting from 58 MW in 2002 the production achieved 510 MW in 2006, see Fig 3. Currently, mainly eight companies are engaged. These are Deutsche Cell in Freiberg, ErSol Solar Energy in Erfurt, EverQ and Q-Cells in Thalheim, Scheuten Solar in Gelsenkirchen (former Shell Solar), Schott Solar in Alzenau, Solarwatt Cells in Heilbronn and Sunways in Konstanz and Arnstadt.

With Conergy AG and Arise Technologies Corp. (Bischofswerda), a Canada based company,ready to build up production capacities in 2007 and ongoing measures to expand existing plants, an increase in production to almost 900 MW in 2007 seems possible.

The production of solar modules grew again but was once more limited by the shortage of silicon. After assembling of 40 MW in 2002 the output of modules from more than 30 companies reached 330 MW in 2006, see also Fig 3.
Because of the ongoing strong demand for modules and hoping for a better supply with silicon solar cells many manufacturers are aiming for further production extension. Therefore, in 2007 a production of 650 MW seems to be likely.

Thin-film Technologies: In addition to the silicon wafer activities, thin-film technologies from Antec Solar Energy (CdTe), CSG Solar (crystalline silicon), Schott Solar (amorphous silicon) and Würth Solar (CIS) reached a total volume of another 10 MW. These activities were on the same level as in previous years, see Fig 3.

But for the coming years this will change significantly. For 2007 one can expect shipments of more than 90 MW and from 2008 on a production of more than 500 MW seems likely:

- CSG Solar is going to double its production capacity to 20 MW.
- API GmbH, Brilliant 234, Ersol Solar Energy and Schott Solar announced to establish (additional) production capacities of 220 MW of amorphous silicon modules until the end of 2007.
- Avancis (former Shell Solar), Johanna Solar Technologies, Nanosolar Inc., Sulfurcell Solartechnik and Würth Solar are going to invest in CIS technologies. Together, a production capacity of more than 160 MW will be build up during 2007.
- First Solar and Calyxo will start the production of CdTe modules aiming for a capacity of 100 MW and 20 MW respectively.

Besides the manufacturing of wafers, cells and modules, the production of inverter technology shows impressive growth rates. For 2006 a production of 570 MW was estimated [7].

In Conclusion, the German PV industry is not only a fast growing industry but is also offering innovative products along the whole value chain. During the last years, equipment and production companies became the most experienced ones world-wide.
More and more companies are entering into the business making PV to a real opportunity for employment and business in general.

## MARKET DEVELOPMENT

The programmes described above have accelerated the installation of grid-connected PV-systems in Germany significantly. The capacity

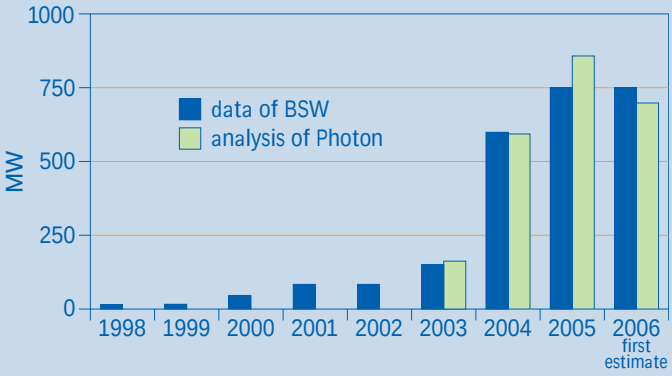



*Fig. 4 – Development of grid connected PV capacity in Germany after [6] and [7]; for the data from 2003 on see text (* first estimate).*

installed in recent years is still a topic of discussion. But meanwhile, the data provided by the BSW (Bundesverband Solarwirtschaft – the German Solar Industry Federation) and the analysis of the Photon Magazine converge [6, 7]. The dilemma is based on the fact that the high number of installations makes it difficult to track each single system. The remaining discrepancy as well as the general development of the German market since 1998 is shown in Figure 4.

A first approximate for 2006 results in an additional installed capacity of around 700 to 750 MW showing a temporary stagnation of the market. The cumulated installations amount to between 2,5 and 2,6 GW at the end of 2006 depending on the data presumed.

In addition to the market of grid connected systems, there is a stable and slow increasing request for stand alone systems. First estimates indicate that in 2006 around 3,5 MW were installed mainly for industrial applications like the automotive sector, traffic signals etc.

However, it is not only the installed capacity which counts. The BSW estimates that meanwhile around 5 000 companies with 50 000 employees are active in the PV business. The turnover in 2006 amounted to 3,8 billion EUR and is still growing [7].

## FUTURE OUTLOOK

After significant growth rates well above the global average the German PV market came to a temporary stagnation in 2006. This effect seems to result from the current shortage of silicon supply as well as from the interdependency between system prices and feed-in tariffs. For 2007 an expansion of the market seems achievable: While the Sarasin study of December 2006 anticipates a volume of approximately 750 MW [8] Photon considers up to 2 GW possible [6].

For 2007, an evaluation of the EEG is scheduled which was already predefined when this law was adopted. The assessment has to be presented to the parliament by the end of 2007. It will cover the status of the market introduction of the renewable energies as well as the electricity production costs of these technologies. If necessary, an adaptation of feed-in tariffs and their degression rates shall be suggested.

At the same time one can observe numerous activities of PV companies in Germany. Many companies are expanding their production capacities or are going to invest into new business opportunities. In total, the production of PV components and systems grows currently much faster than the global average. This seems to be a first step for a change from an importing to an exporting country. In an environment of competition it is important to offer high quality state of the art products. Therefore, the current technical and economical status does not allow standstill. Enhancement of production efficiency and at the same time lowered costs stay on the agenda. For that reason, high-level R&D together with sustainable market supporting mechanisms like the EEG are still needed.

The current situation in Germany and in Europe in general feeds the conviction that PV will continue its way successfully.

## REFERENCES

[1] *An English version of the 5th Energy Research Programme of the Federal Government is available at http://www.bmu.de/english/renewable_energy/downloads/doc/36411.php*

[2] *For information on the soft loan programme "Solar Power Generation" of KfW see http://www.kfw-foerderbank.de/EN_Home/Housing_Construction/SolarPower.jsp*

[3] *Christoph F. Hünnekes, Joachim Nick-Leptin - "THE GERMAN FEDERAL PV R&D PROGRAMME – STATUS AND OUTLOOK" in Proceedings of the 21st European Photovoltaic Solar Energy Conference, Dresden, September 2006*

[4] *D. M. Huljić et al. – „DEVELOPMENT OF A 21 % BACK-CONTACT MONOCRYSTALLINE SILICON SOLAR CELL FOR LARGE-SCALE PRODUCTION" in Proceedings of the 21st European Photovoltaic Solar Energy Conference, Dresden, September 2006*

[5] *K.A. Münzer et al. – „OVER 18 % INDUSTRIAL SCREEN PRINTED SILICON SOLAR CELLS" in Proceedings of the 21st European Photovoltaic Solar Energy Conference, Dresden, September 2006*

[6] *Photon Magazine, November 2006, p. 51 ff and January 2007, p. 29 ff.*

[7] *BSW-Statistik „PV 1990 – 2006" and BSW Fact sheet "Statistische Zahlen der deutschen Solarwirtschaft", see http://www.solarwirtschaft.de*

[8] *Sarasin Study "Solar energy 2006 - Light and shade in a booming industry", December 2006, www.sarasin.ch*

## FURTHER READING ABOUT GERMANY

- Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), see www.bmu.de
- BSW - German Solar Industry Association, see http://www.solarwirtschaft.de

# ISRAEL

PV TECHNOLOGY STATUS AND PROSPECTS: AN UPDATE

DR. H. AVRAHAM ARBIB, DEPUTY CHIEF SCIENTIST AND DIRECTOR, DIVISION OF R&D, MINISTRY OF NATIONAL INFRASTRUCTURES

## GENERAL

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

About 1 MW of peak power has been installed so far; 172 kW were installed in 2005. 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).

A resolution adopted by the Government in November 2002 mandates that at least 5 % of total electric energy be generated from renewable sources by 2016. The Israel Electric Corporation (IEC) is required to purchase electricity from private producers, according to rules set by the Ministry of National Infrastructures. The Ministry is in the process of preparing regulations regarding the purchase by the utility of electricity generated from renewable energy sources. It is expected that these regulations will positively influence also the local PV market.

The Public Utility Authority published in 2006 feed-in tariffs for solar energy, ranging between 0,16 and 0,20 USD/kWh, for systems larger than 100 kW. It is expected these tariffs will encourage mainly solar thermal power systems. However, the PUA is considering the introduction of tariffs for PV systems (including smaller than 100 kW). The IEC has general guidelines relating to the quality of the electricity it purchases.

## INDUSTRY INVOLVEMENT

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

Presently, there is no local production of either PV cells or inverters. The technological infrastructure required to produce all the components needed for integration in PV systems is available; however, due to economical considerations, components such as modules are imported. In spite of this, some unique local 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. Many of these teams cooperate with leading teams worldwide (both in academe and in industry).

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

- DiSP Ltd. is developing a Miniature Concentrating PV (MCPV) system for distributed power applications, in cooperation with Tel Aviv University. The system is designed to provide both electricity and high-grade heat, making it a true Combined Heat and Power (CHP) system. It includes a small (about 1 m diameter) concentrating dish and a high-efficiency CPV module. Preliminary calculations indicate that the power generated by the MCPV may be competitive with grid power. The heat can be provided at temperatures suitable for steam generation, cooling, space and water heating, and process heat. A demonstration unit is currently under construction.
- Researchers from Ben-Gurion University of the Negev designed and participated in the development of the two generations of high-flux photovoltaic concentrating systems being produced, researched and commercialized by the SolFocus Corporation of San Jose, California. They were also co-inventors on the patents for the two concentrator generations (the first being air-filled, 31 cm in linear dimension, and the second being all-glass, 3,1 cm in linear dimension). These are currently 500-sun units (about 625X) with triple-junction ultra-efficient solar cells and completely passive cooling within miniature and ultra-miniature devices. Earlier this year, SolFocus received close to 57 MUSD in investment or investment commitments for the commercialization and first installations; and the first megawatt-level systems are now being prepared for installation based on signed contracts.
- An innovative inverter topology developed at Ben-Gurion University of the Negev overcomes the main deficiencies of present day solutions: the hard switching operation and the problem of connecting a voltage source to the grid. The new approach is designed around a current source rather than a voltage source. This implies that connection of the inverter to the power line is inherently safe since the current source will automatically adjust itself to the voltage of the grid. Consequently, there is no need for extra monitoring, controlling, protecting and current shaping circuitry, improving thereby the reliability of the system. Another important feature of the invention is the soft-switched operation that is possible with the new power stage design. The soft switching operation reduces losses, enables economic utilization of the switching transistors and allows the increase of the switching frequency. Consequently, the size and weight of the inverter are reduced; the

*Fig. 1 - Part of a test stand at the BGNSEC, Sde-Boker, where module degradation is being quantified. The small PV panel (upper left) provides a trickle charge for batteries in a field data logger.*

*Fig. 2 - PETAL, the 400 m² solar dish at Sde-Boker, subjecting the HiConPV CPV module to 1 000X irradiance.*

*Fig. 3 - 640 W grid-connected system, at Kibbutz Lotan (SolarPower).*

*Fig. 4 - 650 W tracking system (SolarPower).*

efficiency and reliability are increased while the cost is in fact reduced, due the better utilization of the components.

- The Solar Energy Laboratory of the Jerusalem College of Technology (JCT), Jerusalem, is pursuing the development of Si solar cell fabrication technology based on the combination of thermal and ion implantation processes. Solar cells under development are thin, have improved optical properties and are suitable for use as bifacial PV converters. High conversion efficiency and decreased fabrication costs are the goals of the JCT activity. Another area of the JCT Solar Energy Laboratory activity is the development of a low cost anti-reflective (AR) glass coating for PV modules. The AR layer deposited by dip-coating provides more than 3 % relative improvement of module energy generation. The coated glass samples are undergoing special tempering treatment for improved resistance to environmental conditions. This program is progressing with an industrial partner. Some samples are presently under extended testing in a leading European glass producing company.
- During 2006, Ben-Gurion University's National Solar Energy Center (BGNSEC) at Sde-Boker embarked upon a 3-year project in collaboration with two German research institutes (Fraunhofer ISE, and TUV), in which it will use its extreme desert conditions and unique AM 1,5 natural sky spectrum to quantify the rate of degradation of PV modules in the power rating range 150-200 Wp (Fig. 1). This project is an extension of the EU 6th Framework PERFORMANCE project in which all three research institutes are also involved. In the project, module temperatures and relevant meteorological data are recorded at 5-minute intervals. In addition, I-V curves will be measured at noontime on clear days, at approximate intervals of one month throughout the 3-year test period.
- Another EU-funded project, HiConPV, in which BGNSEC was involved, finished at the end of 2006. During September 2006, its giant solar dish PETAL (Fig. 2) achieved a world record by subjecting a 10 cm x 10 cm concentrator photovoltaic (CPV) "module" - i.e. the size of a conventional small solar cell - fabricated by partners at the Fraunhofer ISE, to a flux intensity of 1 000 X, and producing more than 1 500 W of electric power. This result helps raise the credibility of a thesis argued in the newly-published IEA Task 8 book "Energy from the Desert II - Practical Proposals for Very Large Scale Photovoltaic Systems," that CPV can provide cost-effective, country-scale solutions for electricity production throughout the Middle East.

## DEMONSTRATION AND APPLICATION

The higher fuel prices have caused increased installation of off-grid systems, replacing diesel generators. In addition, there is growing interest in grid-connected applications (Fig. 3), including tracking systems (Fig. 4).

A large PV project, aimed at electrifying a Bedouin village, was started in 2005. The village of Drijat, in the Negev desert, in which about a hundred families live, is about 6 km from the nearest grid. Electricity was supplied by old and inefficient diesel generators, which only worked a few hours a day. In the first phase of the project, stand-alone PV systems were provided to 20 homes, 6 lighting poles, a school and a mosque. The home systems provide about 1 000 W of peak power each, with batteries storing 14 kWh (enough for two to three days of consumption). The total cost of the first phase was 300 000 USD.

## 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 thousands of school children.

## GOVERNMENT ACTIONS

It is expected that the recently published feed-in tariffs for solar energy will influence favorably the PV market. In addition, a number of actions are being taken to encourage the PV activity. Among them:

- Support of R&D excellence centers through selective funding of projects. The R&D expenditures in photovoltaics of the Ministry of National Infrastructures were only about 75 000 USD in 2006; however, additional funding is available in this area from other research foundations.
- Partial funding of innovative demonstration projects.

# ITALY

PV TECHNOLOGY STATUS AND PERSPECTIVES

S. CASTELLO, ENEA
S. GUASTELLA, CESI RICERCA

## GENERAL FRAMEWORK

The feed-in tariff, which has revamped the Italian PV sector in 2006, is still increasing the interest of designers, architects, investors and the common citizen on the production of electric energy by PV technology.
In spite of the large participation in PV promoting activities and the real availability of prosperous feed-in tariffs, installations have been rather limited also during 2006. This surprisingly has been really macroscopic during this year when only a small fraction of the admitted projects by the Feed-in Programme has been effectively realised. In this contest, the cumulative installed PV power in 2006 increased only of about 12,5 MW reaching the cumulative power of almost 50 MWp. At the same time, the enormous demand of PV plant has not yet been effectively followed by an adequate growth of the national PV industry, although recent initiatives seem to prefigure valuable development plans: i.e., an initiative of the Ministry of Environment on CdTe module production, some shy signals coming from the Ministry of the Economic Development as well as some initiatives aimed at crystalline module production (even if the silicon feedstock shortage problem restrains new operator willing to invest in this field).

## NATIONAL PROGRAMME

The support scheme foreseen by the decrees issued by the Ministry of the Economic Development in July 2005 and in February 2006 is composed of a feed-in tariff for the entire electric energy produced by the PV plant and by the value of the electricity, which can be partially or totally sold to the local electric utility. These incentives are addressed to individuals, registered companies, condominiums and public bodies. The overall power, which is expected to be supported by the second decree, is 500 MWp, of which 360 MWp is assigned to plants up to 50 kWp and 140 MWp for the larger. An annual limit of 85 MW for new PV installations has been fixed. The final target of 1,000 MWp is stated for the year 2015.
To be eligible for the incentive scheme, PV plants must be 1) connected to low or medium voltage grid; 2) ranging from 1 kW to 1 MW; 3) use components which accomplish with technical standards; 4) be put into operation within 1 year from the approval (or 2 years for plants larger than 50 kW).
The tariff of produced electric energy varies with the nominal power of the plant and ranges from 0,445 EUR/kWh to 0,490 EUR/kWh. The duration of the support is 20 years and the tariffs are updated on a yearly basis, taking into account the official inflation rate. A tariff reduction of 5 % per year is applied to PV plants for which the support request is delivered after 2006. Moreover, the electricity produced by the PV plant can be used by owner for its own consumption or sold to the local utility; this benefit is maintained also after 20 years. A tariff increase of 10 % has been foreseen for photovoltaic systems integrated in building structures
For plants larger than 50 kWp, the tariff is subject to a tender mechanism, which favours the tariff with a lower value. For these plants, a bank guarantee of 1,000 EUR/kWp is requested as a penalty, in the case the PV plant is not installed within the deadline fixed by the decree.

*Fig. 1 – Grid-connected 26,7 kW PV system on flat roof in Anterselva, Bolzano, Italy.*

Finally, the decree states that promotion tariffs are 1) reduced by 30 % if combined with fiscal incentives; 2) not applicable to PV plants which have obtained incentives from public bodies exceeding 20 % of investment cost and; 3) not compatible with green certificates.
In the first quarter of 2006, about 3,190 projects have been admitted to the feed-in tariffs; concerning plants up to 50 kWp (corresponding to about 91,2 MWp) and 36 over 50 kWp (28,3 MWp). Taking into account that in the year 2005, there have been admitted about 9,000 projects; up to 50 kWp (197,3 MWp) and 116 over 50 kWp (70,7 MWp) on the whole, since the beginning of the Programme in September 2005. Considering the annual limit of 85 MW introduced in February 2006, there have been positively evaluated projects for a total power of about 388 MWp. The total power of plants up to 50 MW, corresponding to 288 MW, should be installed within 12 months from approval (then, by July 2007 - March 2008 at latest) while the other 100 MW of the plants larger than 50 should be installed within 24 months from approval (then, by July 2008 - March 2009 at latest).
In this phase, the most involved Regions have been Apulia, Basilicata, Sicily and Sardinia, characterised by good solar radiation availability.
In conclusion, taking into account that the maximum power to be supported is 500 MWp, the power still available for incentives in the year 2007 is only 112,3 MWp.

## RESEARCH, DEVELOPMENT AND DEMONSTRATION

Research, development and demonstration activities on photovoltaics devices and systems are mainly conducted by ENEA (the Italian Agency for New Technology, Energy and Environment) and CESI RICERCA (the Institute for Research on electricity and energy sector), with the support, in some cases, of universities and CNR (the National Council for Scientific Research).

*Fig. 2 – 19,8 kW on sloped roof in Brunico, Bolzano, Italy.*

ENEA is the main PV research organization operating in Italy. Its most significant crystalline silicon R&D activities concern the setup and optimisation of fabrication processes of several kinds of innovative cells through laser assisted processes, buried contact and selective emitter technology, advanced screen-printing. Other important activities concern the optimisation of high efficiency crystalline silicon cells (EU Project), the development of thin film cells for BIPV as well as Cu2O solar cells research.
As far as thin films, microcrystalline Si devices are still a main line of activity with the aim of improving the stabilized efficiency of integrated large area modules. A new cluster tool has been installed to begin a new investigation on micromorph tandem solar cell which first result consists in a cell efficiency of 11,3 %.
Last, but not least, ENEA is working on concentrator technologies in order to assess the technical and economical feasibility of this application in Italy for centralised generation of electricity. During the last year, experimental activities were carried out on standard units of 5 kW and concentrating modules.
CESI RICERCA is carrying out activities in research and development on electricity and energy sector, through a Research Fund for the Italian Electrical System financed by the Ministry of Economic Development. An important research consists in the high efficiency solar cells for terrestrial applications, mainly based on three-five compounds. Besides, triple junction solar cells (InGaP/InGaAs/Ge) are under development and qualification. GaAs single junction and multi-junction concentrator solar cells are also manufactured for terrestrial application. In this field, CESI (a Company for service and certification in the electricity sector) is involved in industrial manufacturing of high efficiency solar cells for space and terrestrial applications, mainly based on GaAs.
Furthermore CESI RICERCA is involved in components' characterization and performance evaluation of PV systems and in the analysis and testing of PV modules based on advanced solar cells (thin films, amorphous silicon, etc.) and innovative components (e.g. inverters). In the field of PV systems, CESI RICERCA is involved in research and demonstration activities for electrification of remote communities, funded by MSE.

## IMPLEMENTATION OF SYSTEMS

The total power of PV systems installed in Italy during the year 2006 totalled to about 12,5 MWp. Taking into account the cumulative power reached during the previous years, a cumulative capacity of about 50 MWp results installed at end of 2006, with an increase of about 33 % with respect to the previous year. Most of this increase has been driven by the support mechanism (feed-in tariffs and regional programmes) of on-grid distributed systems, that now, with a cumulated power over 30 MW, account for around 60 % of the total photovoltaic installed. The other primary applications for photovoltaic power systems are represented by:

- off-grid domestic systems, reaching a saturation value of 5,3 MWp in the late eighties;
- off-grid economic industrial applications, constantly increasing, but difficulty assessed in terms of total installed power, estimated around 7,5 MW;
- on-grid centralized systems (6,7 MW), mainly installed at the beginning of 1990's but now expected to be increased due to the feed-in tariffs.

## INDUSTRY STATUS

As far as crystalline silicon technology, two producers of cells and modules (Enipower and Helios Technology) and some companies assembling finished PV products can be identified in Italy.
On the overall, in year 2006 the total production of Enipower and Helios Technology has been of around 10 MW from both single-crystal and multi-crystalline silicon wafers from the international market.
Further companies assembling and encapsulating standard or tailor-made and especially designed modules such as window integrated cells or using coloured cells can be found in Italy. During the last year, the modules produced by such companies totalled to another 10 MWp.
As far as thin films technology, the Minister for the Economic Development (MSE) is promoting a project aimed at developing a pilot plant for CdTe module production. The cost of the project is around 24 MEUR and it will be partly financed by Lombardia Region (9 MEUR). The manufacturing facility with a production capacity around 18 MW/year will be realised by Marcegaglia Group within autumn 2008.
Some Italian industries are actives in the manufacturing of inverters for PV systems. The main manufactures are Elettronica Santerno (located near Bologna), SIEL (Milano), Powerone – Magnetek (an international company with a manufacturing plant in Arezzo) and other small companies. Their production ranges from small single-phase inverters to three phase units up 1 MVA.
Finally, an estimation of the number of companies that install PV systems in Italy reaches about 100 units of specialist PV companies offering consultancy, installation services and component delivery. Moreover, a further 200 units, not full-time working in this sector, have to be counted. The most important operators in this field are associated in the Italian PV firms Group (GIFI).

## FUTURE OUTLOOK

A new edition of the feed-in decree is at present under discussion by the State-Regions forum. The new decree should increase the target of the Italian feed-in tariff from 500 MW to 1000 MW and should eliminate the "licence trade" addressing incentive tariffs only to plants already installed. Besides, the tariffs should privilege building integrate applications and should be related to improvements adopted for energy saving in building sector. Moreover, in this decree should be foreseen the issue of acts aimed at promoting the development of innovative photovoltaic technologies.

# JAPAN

PV TECHNOLOGY STATUS AND PROSPECTS

KOJI MATSUBARA, NEW ENERGY AND INDUSTRIAL TECHNOLOGY DEVELOPMENT ORGANIZATION (NEDO)
OSAMU IKKI, RTS CORPORATION

## GENERAL FRAMEWORK

The dissemination of photovoltaic (PV) systems in Japan is functionally promoted from various aspects through the legal system, national strategies and frameworks of measures implemented by the Ministry of Economy, Trade and Industry (METI) and other ministries and agencies.

The target volume of introduction of PV systems is defined in the perspective for new energy in the "Long-Term Energy Supply and Demand Outlook", prepared by the Advisory Committee for Natural Resources and Energy under METI. Japan's target cumulative volume for PV system installation by FY2010 was set to 4 820 MW. METI has been actively driving forward measures for PV deployment and programs for research and development for PV systems to achieve the target.

"The New Energy Law" established in 1997 defines the responsibility of each sector: the national and local governments, energy consumers, energy suppliers and energy system manufacturers, to introduce and expand new and renewable energy.

Under "The Renewables Portfolio Standard (RPS) Law" established in 2002, which obliges energy suppliers the use of certain percentage of renewable energy, the obligatory usage amount of new and renewable energy has been increased every year. In addition, the Government of Japan established "the Basic Energy Plan" in 2003, in order to materialize the basic policies based on "the Basic Law on Energy Policy" enforced in 2002.

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

In 2005, the Cabinet endorsed the "Kyoto Protocol Target Achievement Plan", and the Plan positioned the utilization and large-scale deployment of new and renewable energy as one of the countermeasures to reduce greenhouse gas emission toward 2010.

In 2006, METI compiled the "New National Energy Strategy", in which the "New Energy Innovation Plan" including promotion of PV system is characterized as one of the major pillars.

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

## NATIONAL PROGRAM

The Japanese Government has implemented research and development (R&D), demonstrative research, model projects, dissemination measures, and introduced legislation to achieve the target introduction capacity of 4 820 MW of PV systems by FY2010 and further deployment of PV power generation thereafter. In the field of R&D, technological development for cost reduction of PV systems, technological development for PV deployment and demonstrative research for large-scale PV system for power supply have been conducted. As a demonstrative research, the Field Test Project on New Photovoltaic Power Generation Technology has been conducted to demonstrate the effectiveness of PV systems employing new PV modules, new components, advanced system technology and newly developed installation methods, etc. and enlarge the application area of PV systems. The Demonstrative Project on Grid-Interconnection of Clustered Photovoltaic Power Generation Systems, in which a large number of PV systems are intensively installed in a community, also has been conducted. Moreover, the Demonstrative Project of Regional Power Grids with Various New Energies has been underway as a demonstrative research of energy supply system, that intensively employ various types of new and renewable energy sources such as PV system, wind power generation, fuel cells, etc. In the model project, regional business models using PV technologies are developed as countermeasures against global warming.

In addition, as for measures for introduction of the PV system, the Government has continuously implemented supporting programs for local governments and private entrepreneurs in order to introduce new and renewable energy.

*Fig. 1 - PV system at Hitaka Works, Hitachi Cable, Ltd., 10 kW, Hitaka-cho, Hitachi City, Ibaraki Prefecture.*

The budgets for major national PV programs implemented in FY2006 are as follows;

1) Research and Development on Photovoltaic Power Generation: 3 100 MJPY
2) Field Test Project on Photovoltaic Power Generation Systems for Industrial and Other Applications: 100 MJPY
3) Field Test Project on New Photovoltaic Power Generation Technology: 11 800 MJPY
4) Demonstrative Project on Grid-Interconnection of Clustered Photovoltaic Power Generation Systems: 1 000 MJPY

*Fig. 2 - PV system at Fujipream agricultural house, 10 kW, Himeji City, Hyogo Prefecture.*

5) Verification of Grid Stabilization with Large-scale PV Power Generation Systems: 700 MJPY
6) Project for Supporting New Energy Operators: 35 300 MJPY
7) Project for Promoting the Local Introduction of New Energy: 5 200 MJPY
8) Project for Establishing New Energy Visions at the Local Level: 1 200 MJPY
9) Project for Promotion of Non-profit Activities on New Energy: 160 MJPY
10) Demonstrative Project of Regional Power Grids with Various New Energies: 2 900 MJPY
11) Model project of PV introduction for global warming countermeasures: 4 100 MJPY

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

## R, D&D

### R&D

At the end of FY 2005 (March, 2006), 3 R&D projects; "Development of Advanced Solar Cells and Modules", "Development of PV System Technology for Mass Deployment" and "Investigation for Innovative Photovoltaic Power Generation Technology", conducted under the "5-Year Plan for Photovoltaic Power Generation Technology Research and Development (FY2001 - FY2005)" by the New Energy and Industrial Technology Development Organization (NEDO) were completed. In FY2006, a new "4-Year Plan for Photovoltaic Power Generation Technology Research and Development (FY2006 - FY2009)" was launched, based on a roadmap for technological development of the PV system, "PV Roadmap toward 2030 (PV2030)". Under the 4-Year Plan, 2 new projects, R&D for Next Generation PV systems and PV System Technology for Mass Deployment, Phase II were started. Details of current projects are as follows.

#### 1. R&D for Next Generation PV Systems

This program aims at establishing elemental technologies to achieve the target PV power generation cost set in PV2030: 14 JPY/kWh for 2020, 7 JPY/kWh for 2030. Based on the outcome of the previous project, "Development of Advanced Solar Cells and Modules" that finished at the end of FY 2005, development of elemental technologies for next generation solar cell started in August 2006. The project covers 5 types of solar cells: thin-film CIS solar cells, thin-film silicon solar cells, dye-sensitized solar cells (DSCs), next-generation ultra-thin crystalline silicon solar cells and organic thin-film solar cells. Besides these topics, fundamental research projects for ultra-high efficiency solar cell and other technologies were started at the same time, as a part of explorative research of technological seeds aiming at higher conversion efficiency, cost reduction and improvement of durability is also conducted under this project.

#### 2. Development of PV System Technology for Mass Deployment, Phase II

This program was a successor program of Development of PV System Technology for Mass Deployment (FY 2001 - FY 2005), aiming at developing technological infrastructure for extensive application and mass deployment of PV system. Projects under this program started in June 2006. Projects to develop evaluation technologies for performance and reliability of PV cell/ module and electricity output were continued. In addition, as environmental technologies for manufacturing process of PV system and disposal of used PV modules, life cycle assessment (LCA) and development of recycle technology of solar cell are conducted.

#### 3. PV systems Advanced Practical Technology

This 3-year program is started in FY2005, as a successive program of Development of Technology to Accelerate the Dissemination of Photovoltaic Power Generation Systems. In FY 2006, the following technological development were conducted: recycling technology of silicon feedstock for solar cells, manufacturing technology of spherical silicon solar cell, high-performance inverter and autonomous PV system technology.

## DEMONSTRATION

6 major demonstration programs are implemented in FY2006: "Field Test Project on Photovoltaic Power Generation Systems for Industrial and Other Applications", "Field Test Project on New Photovoltaic Power Generation Technology", "Demonstrative Project on Grid-Interconnection of Clustered Photovoltaic Power Generation Systems" and "Demonstrative Project of Regional Power Grids with Various New Energies", "Verification of Grid Stabilization with Large-scale PV Power Generation Systems" and "International Cooperative Demonstration Projects on PV Power Generation System".

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

This program started in FY1998 and installations were completed with great success. 740 PV systems with 18 100 kW in total were installed to schools, medical facilities, welfare facilities, factories,

office buildings and private-sector facilities by the end of FY2002. Data collection and analysis have been continued since FY2003. T his program is to be completed in the end of FY2006.

### 2. Field Test Project on New Photovoltaic Power Generation Technology

This field test program aims at leading dissemination of middle-scale PV systems by installation of PV systems employing advanced technologies on trial basis and promoting improvement of performance and cost reduction of those PV systems. This program is regarded as a succeeding program of the Field Test Project on Photovoltaic Power Generation Systems for Industrial and Other Applications. Under the program, the following 4 model technologies are defined: 1) the PV system with new modules, 2) the PV system with building material integrated modules, 3) the PV system with new control systems and 4) the PV system aiming at higher efficiency. Introduction of the PV systems for public facilities and industrial uses are promoted under this program. 262 projects were selected and PV systems totaling 7 161 kW were installed in FY2004. In FY2005, METI enhanced this application area as a prioritized area for PV power dissemination, the number of the selected projects significantly increased to 457, totaling 17 709 kW. In FY2006, 675 projects, totaling 19 454 kW were selected. Cumulative installed capacity of fielded tests conducted by NEDO (FY1992 - FY2006) is expected to be over 70 000 kW.

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

This program started in FY2002 for a 5-year scheme to install grid-connected PV systems equipped storage batteries into 600 households to conduct demonstrative research of a large-scale and intensive introduction of on-grid PV systems. The program aims at establishing grid connection technologies for grid-connected PV systems intensively installed to one area. The specific research objectives are 1) development of technology to avoid restriction of PV system output by using storage batteries, 2) analysis and evaluation of higher harmonics, 3) analysis and evaluation of devices for mis-actuation function to prevent islanding operation, 4) development of applied simulations and 5) evaluation of characteristics of power generation and economical efficiency. Installation of about 550 residential PV systems with storage batteries was completed by the beginning of FY2006. In FY2006, operation test and evaluation of output control, evaluation of new devices for mis-actuation function to prevent islanding operation and so on were conducted.

### 4. Demonstrative Project of Regional Power Grids with Various New Energies

This program was launched in FY2003 to intensively install various types of distributed power sources such as PV systems, fuel cells and wind power generators, etc. in one area, aiming at demonstrating various issues: ensuring quality of electricity, balance between supply and demand of electricity, stability, and studying economical performance of distributed power sources. In FY2003, 3 demonstrative sites were selected across the country: Aichi Prefecture (total 2 225 kW of distributed power generation systems including PV systems totaling 330 kW), Aomori Prefecture (total 714 kW of distributed power generation systems including an 80-kW PV system) and Kyoto Prefecture (total 850 kW of distributed power generation systems including a 50-kW PV system). Demonstrative operation of the power generation systems was started in FY2005. The power generation systems installed on the premises of the 2005 World Exposition (EXPO 2005), Aichi, Japan, were relocated to Central Japan Airport City in Tokoname City of Aichi Prefecture and the demonstrative research was resumed from August 2006.

### 5. Verification of Grid Stabilization with Large-scale PV Power Generation Systems

This demonstrative research aims at establishing a system to stabilize power output of MW-scale PV systems without giving negative impact on the quality of grid electricity, and validating its effectiveness and usefulness. In addition to these objects, the final goal of this research is development of technologies to make the business using future MW-scale PV plant feasible. A 5-MW scale project in Wakkanai City of Hokkaido Prefecture and a 2-MW scale project in Hokuto City of Yamanashi Prefecture were selected and construction was launched in both sites.

### 6. International Cooperative Demonstration Projects on PV Power Generation System

This project is an international demonstrative program, aiming at electricity supply by constructing mainly micro-grid using PV system. Corroborative demonstration research projects are conducted in China, Thailand, Myanmar, Mongolia, Cambodia, Laos, etc.

## IMPLEMENTATION

### The Ministry of Economy, Trade and Industry (METI)

### 1. Residential PV System Dissemination Program

The “Residential PV System Monitor Program” initiated in FY1994 was renamed the “Residential PV System Dissemination Program” in FY1997 to develop the initial market of residential PV system. The program was terminated in FY2005. The subsidy amount was 20 000 JPY/kW and 36 754 residential PV systems, totaling 136,3 MW were installed in FY 2005. During 12 years (FY1994 to FY2005), the total number of PV systems installed under this support measure reached 253 754, 931 575 kW in total. The program highly contributed to the creation of the initial market of residential PV system in Japan.

### 2. Project for Promoting the Local Introduction of New Energy

This program aims at accelerating new energy introduction and enlightenment activities for local residents by supporting the regional projects developed by public bodies for promoting the introduction of new and renewable energy. Subsidy is provided for local public organizations and nonprofit institutions which are going

*Fig. 3 - PV system at Toyooka municipal Hachijo kindergarten, 10 kW, Chuo-cho, Toyooka City, Hyogo Prefecture.*

to introduce and promote power generation using new and renewable energy such as PV power generation, wind power generation, use of solar thermal energy, differential temperature energy, natural gas co-generation, fuel cells, wastes generation, use of waste thermal energy, production of wastes fuel, biomass, utilization of snow and ice and clean energy vehicles. PV systems with 10 kW of output capacity and over are qualified under the program. Recipients can receive the subsidy, the lesser amount of half of installation cost or 400 000 JPY/kW (in case of a specific public body, supported by the local government, one third of the installation cost or 250 000 JPY/kW). 398 systems in total were subsidized from FY1998 to FY2004. 216 systems out of them were PV systems. Total capacity installed was 26 496 kW. In FY2005, 103 systems in total were qualified and 33 systems out of them were PV systems. Total capacity installed was 869 kW. In FY2006, 111 systems in total were qualified and 35 systems out of them were PV systems. Total capacity installed was 1 130 kW. The program allows local governments or nonprofit institutions to understand the benefit of introduction of new and renewable energy and introduce PV systems intensively to school buildings and public facilities, etc. over several fiscal years.

### 3. Project for Supporting New Energy Operators

This program aims at accelerating new energy introduction by supporting the industrial entrepreneurs who introduce 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, biomass, utilization of snow and ice, etc. Private entrepreneurs who start new energy businesses are eligible for guaranteed debt or subsidization. Subsidy is one third of installation cost or below, and 90 % of the debt is guaranteed. The capacity of eligible PV system is 50 kW and over (10 kW and over is also eligible in case of installation of multiple new energy sources). 211 systems in total were qualified from FY1998 to FY2004, and 9 systems out of them were PV systems, 745 kW in total. In FY2005, 66 systems were qualified and 2 systems, 27 kW in total, out of them were installed. In FY2006, 54 systems were selected and 2 systems were PV systems, and the total installed capacity was 160 kW.

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

### The Ministry of Land, Infrastructure and Transport (MLIT)

Under “Guideline for Planning Environmentally-Friendly Government Building (Green Building)”, construction of green government buildings, buildings for central ministries and agencies and local government offices equipped with PV systems and other renewable energy system have been promoted. In addition, MLIT started to utilize PV systems under several measures: promotion of environment-friendly houses and buildings for global environment conservation, introduction of navigation aids using clean energy and a program to reduce $CO_2$ emission in road projects.

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

MEXT continues the “Eco-school Promotion Pilot Model Project” initiated in partnership with Ministry of International Trade and Industry (current METI) in FY1997 and has been promoting the introduction of PV systems to elementary schools, junior high schools and kindergartens. 541 schools all over Japan were designated as the Eco-school pilot model schools by the end of FY2005 (March 2006), and 343 schools among them installed PV systems with an output capacity of 10 kW and over each. In FY2006, 68 schools were newly selected as the pilot model schools and PV systems are to be installed at 44 schools among them. METI, the Ministry of Agriculture, Forestry and Fisheries (MAFF) and the Ministry of the Environment (MoE) are jointly working on this project and promoting model projetcts of environment-friendly schools.

### The Ministry of Environment (MoE)

The Ministry of Environment (MoE) is promoting projects of $CO_2$ emission reduction by use of natural energy under the “Law Concerning the Promotion of Measures to Cope with Global Warming” enforced in FY1998. In addition, it implemented the “Law on Promotion of Green Purchasing” in April 2001, and commodities procured by the national and local governments have to be replaced by environmental-friendly products. Since the PV system is specified as one of the special procurement products, introduction of PV systems to governmental facilities has been in progress. MoE established the “Solar Promotion Program”, a package program for introduction of PV system to achieve measures to reduce $CO_2$ emission by PV technology in FY2005 and officially started full-implementation of the program from FY2006. The major subprograms for dissemination of PV system under “Solar Promotion Program” are 1) Town-wide $CO_2$ 20 % reduction projects (2 projects

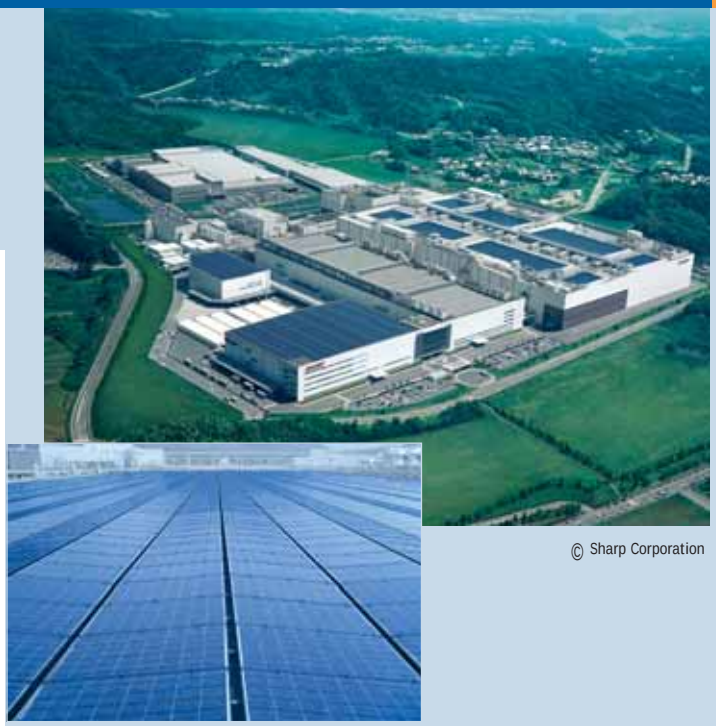




*Fig. 4 - PV system at Sharp Corporation Kameyama Plant, 5,220 kW, Kameyama City, Mie Prefecture (photo courtesy of the Sharp Corporation).*

were selected in FY 2006 and PV power generation was introduced in one project), 2) Model project for common use of MW-scale solar (3 sites were selected for 3-year PV installation projects in FY 2006. Total 3 MW of PV systems will be installed), 3) Model project for advanced introduction of renewable energy (2 model regional projects for $CO_2$ reduction were selected), 4) Project of environment-friendly renovation of schools (3 cases were selected in FY 2006), 5) Solar mileage club project and 6) Project for pioneering introduction of PV system by local governments. In addition, MoE implements the "Model Town Project for the Virtuous Cycle of Environment and Economy;" aiming at achieving city planning including the introduction of PV systems, developed by the local community and the "Project for Developing Technology to Prevent Global Warming," in order to develop practical technology for the introduction of renewable energy, etc.

### The Local Governments and Municipalities

The movement to actively work on environmental issues has been spreading among the local governments and municipalities year by year. Prefectures and other local governments began to set their own target for introduction volume of new energy following the national target for PV system introduction (4 820 MW) one after another. Moreover, local authorities have started their own programs for dissemination of PV system. Over 300 local governments continue to provide their own subsidy or preferential loan programs for residential PV systems even though the national support program for residential PV systems was terminated.

### Utilities

Electric power companies in Japan continue to introduce PV systems to their own facilities and net billing to buy-back surplus PV electricity at the same rate as the retail price of electricity.
They also established "Green Power Fund" in October 2000; aimed at introducing and promoting PV systems and wind power generators. The utilities bill an additional charge as a contribution at 500 JPY/share/month to the 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 FY2001 to FY2005, 598 public facilities including schools across Japan were subsidized through the fund and the total capacity installed was 12 812 kW. In FY2006, 132 sites were selected, and installation of PV systems totaling 2 154,2 kW are underway.
Electric utilities achieved to purchase required amounts of new energy for FY2005 designated under the Renewables Portfolio Standard (RPS) Law that was enforced from FY2003. The usage volume of electricity generated by new energy by utilities for FY2005 was 5 576 TWh in total, including 458 TWh from PV power generation. The accredited facilities for power generation using new energy under the RPS Law was 266 915 systems totaling 3 751 MW. Among them, PV systems are 265 963, accounting for 988 MW of generation capacity.

### Financial Institutes

Some banks and other financial institutes provide preferential financing at low interest rates for introduction of residential PV systems and houses equipped with PV systems. The number of such financial institutions has been increasing year by year. In addition, financial institutes themselves started to introduce PV systems to their own branch offices and other facilities.

## INDUSTRY STATUS

In 2006, the PV industry in Japan made a forward move to be an independent and self-sustainable industry. Key activities observed in 2006 are as follows: 1) Japan Photovoltaic Energy Association (JPEA) announced the revised industrial PV roadmap, "Vision of the Future of the Photovoltaic Industry in Japan 2006 - Aiming to be the World's Leading PV Nation", 2) New entries started operation of pilot plants to commercially produce silicon feedstock for solar cells, 3) PV manufacturers raised production capacity and extended overseas production sites, 4) New entries constructed manufacturing plants of thin-film PV modules, 5) MSK, a manufacturer specialized in PV modules was acquired by Suntech Power in China, 6) Manufacturers of components and raw materials for PV cell/ module enhanced their PV business, and 7) New markets such as MW-scale PV systems have been cultivated.

Highlights of PV cell/module manufacturers in 2006 are as follows.

Sharp enhanced its supply framework in Japan and overseas by raising the production capacity of solar cell to 600 MW/year from 500 MW/year and increasing production capacity of their PV module factory in the UK to 110 MW/year from 50 MW/year. It also launched production of thin-film silicon solar cell and concentrator PV systems in addition to conventional crystalline silicon PV cell/ modules.

Kyocera focused on improvement of conversion efficiency of solar cell and product development of PV systems for individual houses and industrial facilities.

Sanyo Electric completed a new factory and announced its plan to increase production capacity to 600 MW/year in 2010 from 260 MW/year in 2007 and 350 MW/year in 2008.

Mitsubishi Electric enhanced product development of its inverters for PV power generation and started the sales in Europe.

Kaneka announced increase of production capacity of thin-film silicon PV module to 55 MW/year in 2007 and 70 MW/year in 2008 from current 30 MW/year.

Mitsubishi Heavy Industry (MHI) also announced enhancement of production capacity of thin-film silicon PV modules to 50 MW/year from 12 MW/year.

Showa Shell Sekiyu completed the factory of CIGS solar cell with a production capacity of 20 MW/year. Operation will start in 2007.

Fuji Electric Systems completed a flexible amorphous silicon PV module plant with a capacity of 12 MW/year and started production.

Honda Motor started to construct a CIGS PV module plant with a capacity of 27,5 MW/year and will start operation in 2007.

Clean Venture 21 started construction of commercial plant of spherical silicon solar cell in corporation with Fujipream.

MSK, a manufacturer specialized in PV module was acquired by Suntech Power Holdings, a PV manufacturer in China.

In the area of the silicon feedstock production, Tokuyama advanced a mass-scale production test of a 200 t/year-plant of solar-grade polysilicon (SOG-Si) using the Vapor to Liquid Deposition (VLD) process.

Chisso established a new company “Japan Solar Silicon” to manufacture SOG-Si using a $SiCl_4$ zinc reduction process, jointly with Nippon Mining and Toho Titanium.
JFE Steel completed a 100 t/year plant of SOG-Si using an up-grading process of metal-grade silicon and started production.

Nippon Steel started to construct a 500 t/year manufacturing plant of polysilicon for solar cells and entered the business of SOG-Si.

M.Setek started construction of a polysilicon plant with a production capacity of 500 t/year, using Siemens process.

In the area of distribution of PV systems, major manufacturers of pre-fabricated houses such as Sekisui Chemical, PanaHome, Sekisui House, Daiwa House Industry and Misawa Home have been strengthening the sales of houses with PV systems as standardized equipment. In the area of retro-fit houses, sales framework of residential PV systems, consisting of local builders, electric works, roofers, etc., was established under the PV manufacturers’ leadership. Besides these activities, with the growth of the PV system market, manufacturers of inverters and raw material providers for PV cells/modules have been growing.

## MARKET DEVELOPMENT

Through the measures for introducing PV systems, mainly implemented by METI, the market development of residential PV systems and PV systems for industrial and public facilities is underway. The size of the residential PV market grew to 50 000 systems/year through the government support programs for introducing residential PV systems implemented for the past 12 years. After the program was terminated, the PV market in Japan still shows growth without shrinking.
PV manufacturers are working on expansion of the market for residential PV systems for both newly built and existing houses by reducing the price increase while the price of silicon feedstock is soaring. In the newly built residential house market, housing manufacturers enhance efforts for energy conservation and reduction of $CO_2$ emission. Accordingly, some of housing manufacturers adopted PV systems as standard equipment and the number of such companies has been increasing, and major housing companies also followed this movement, as well. These companies strengthen their nation-wide sales activities via TV commercials. Especially, the concept of zero-utility charge houses equipped with PV systems became a new concept for residential houses. This contributes to the expansion of purchasers who recognize economical efficiency for the running cost of a house as well as the environmental value. In the PV market for existing houses, PV manufacturers established sales channels consisting of local builders, electric contractors, electric appliances store and roofers, etc. and cultivate potential buyers in all over Japan.

Through the long-term field test projects, PV systems for non-residential use, such as for public and industrial facilities have seen a significant progress year by year in many aspects: economical efficiency, grid-connection technology, design and installation as well as system efficiency. Consequently, opportunities for market expansion have been increasing and diversified in such areas as application, design, installation sites, power generation capacity and introducers of the PV system and the market development of non-residential area is in progress. As for the installation sites, PV systems have been appearing in a wider variety of places: public facilities (schools, government office buildings, community buildings, water purification plants, welfare and medical facilities) and industrial facilities (factories, warehouses, laboratories, office buildings, commercial buildings). In addition to these sites, recently, PV systems

have been installed to agricultural facilities (farm houses), commercial facilities (shopping malls, family restaurants), railway facilities (station buildings and platforms), road facilities (parking lots and expressway toll booths), financial facilities (banks, etc.), transport facilities (logistics centers, etc.) and resort facilities (hot-spring resorts, etc.). Generation capacity of one installation site has been increased to as large as 5-MW scale. The introducers, who purchase PV systems to install, are very much varied, from large to small-sized local governments, large corporations to sole proprietors, and to public-interest organizations and nonprofit organizations (NPOs). Some companies have been introducing PV systems to their factories and offices nationwide and installing additional PV systems to existing PV-equipped facilities or with other renewable energy systems. Others have been introducing PV systems intensively in specific areas or large-sized PV systems, and the number of such companies has been increasing year by year.
Recently, construction of large-scale PV power stations for electric supply was started with the aim of demonstrative research, and new market development is also expected.

## FUTURE OUTLOOK

The Government of Japan established the "New National Energy Strategy" in 2006 in order to promote transition from the current energy supply framework that depends on petroleum oil and enhance energy security. Several numerical targets to be achieved by 2030 were set in the strategy and specific activities are comprised of four items: 1) Realizing the state-of-the art energy supply-demand structure, 2) Comprehensive strengthening of resource diplomacy and, energy and environment cooperation, 3) Enhancement of emergency response measures and 4) Common challenges.
New energy is considered as one of the four major pillars in the "Realizing the state-of-the art energy supply-demand structure", significantly contributing to the New Energy Innovation Plans laid out in the strategy. Targets for 2030 were described as the New Energy Innovation Plans, based on the following concepts:
1) Specify renewable energy resources which particularly need to be promoted, such as PV, wind power and biomass, and give them strong support, 2) Innovative technology for high-level utilization of energy, 3) Promotion of "demand" and "supply" expansion measures in response to dissemination stages, 4) To increase the industrial structure density of new energy, etc. and improve economic efficiency of the entire new energy industry. As for PV systems, it is targeted to reduce the PV power generation cost to the level of thermal power generation by 2030. Promotional measures for the expansion of "demand" and "supply" through implementation support measures such as subsidies and taxation systems according to the stages of growth will continue. Also targeted is the creation of a group of PV industries. In order to achieve the strategy's target, it is expected that METI will implement measures for R&D and dissemination of PV systems; aiming at cost reduction and further deployment of PV systems. Cost reduction will be achieved via technological development and dissemination will be promoted via PV field test programs to cultivate the PV market for public and industrial facilities.

The Ministry of the Environment (MoE) is also expected to continue to promote model projects of PV systems, as measures to reduce $CO_2$ emission.
It is assumed that the PV manufacturers will advance 1) further cost reduction of PV systems, 2) product development with attention to the detail of application area, and 3) development of new application areas by technological development, enhancement of production capacity and cooperation with other industries using PV system.
These measures by METI and MoE and efforts of market development by the PV industry, other ministries and agencies, local authorities, private companies and individuals are improving the understanding of PV systems and the purchasing intention for PV systems is being raised. Thus, further deployment of PV systems in Japan will continue into the future.

# KOREA

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS
JINSOO SONG, KOREA INSTITUTE OF ENERGY RESEARCH (KIER)
DONGHWAN KIM, KOREA UNIVERSITY, KOREA PHOTOVOLTAIC DEVELOPMENT ORGANIZATION (KPVDO)

*Fig. 1 - 1 MWp PV plant in Kang-Jin located in south west of Korean Peninsula. This plant has a single-axis tracking system with domestic PV modules and four 250 kWp inverters.*

## GENERAL FRAMEWORK

In 2006, the Korean renewable energy budget was 409,5 billion KRW (Korean Won, 940 KRW/US$). Korea has been making a strong effort to increase the renewable energy portion in the "energy mix" to achieve the goal that was announced in December 2003. Korea's renewable energy is targeting to take 5 % of the total energy consumption by 2011. Currently the renewable energy is estimated to be about 2,1 % of the total energy. The Korean government increased the renewable energy budget steadily to 409,5 billion KRW in 2006 from 196,4 billion KRW in 2004 and 324,4 billion KRW in 2005. Korea has strategically selected three technologies; hydrogen and fuel cells, photovoltaics (PV), and wind, for concentrated investment for R&D and dissemination program. The total amount of PV installation in 2006, is tentatively estimated to be about 21 MWp; a rapid increase from about 5 MWp in 2005. The feed-in-tariff (FIT) rate per kW-hr changed from 716,40 KRW to 677,38 KRW for systems larger than 30 kWp. A new program called the Renewable Portfolio Agreement (RPA) started in 2006. Under the RPA, utility companies negotiate with the Government on the amount of renewable energy in their total power supply. The size of PV power plant tends to become larger as demonstrated by the six 1 MWp PV systems completed in 2006. Korean PV industry attracted international attention when Dongyang Chemical Co (DCC) announced to jump into the poly silicon manufacturing business to tackle the silicon shortage issue.

## NATIONAL PROGRAMME

Korea's PV dissemination program targets to reach 1,3 GWp by the year 2012. The annual budget for the roof-top program increased to 49 billion KRW in 2006 from 16 billion KRW in 2005. The total dissemination budget for 2006 was 103,6 billion KRW. The budget for research and development was 19 billion KRW in 2006 up from 14,99 billion KRW in 2005.

## DISSEMINATION PROGRAMS

Details of the dissemination program are listed below:

- The Public Building Program: New public buildings larger than 3 000 m$^2$ must spend 5 % of the total construction budget in installing a renewable facility. This program started in 2004. Up to November 2006, the investment in renewable equipment totaled 122,8 billion KRW including 34,5 billion KRW for PV. As the Government pursues the "New Administration-Oriented City Plan" and the "Plan for Public Enterprise Relocation," new public buildings are planned all over Korea and thus the Program should contribute a lot to the expansion of the Korean PV market.
- Feed-in-Tariff: The Government adjusted the feed-in tariff rate and the cap for the installation in October 2006. For systems smaller than 30 kWp, the price of PV electricity per kW-hr is 711,25 KRW and 677,38 KRW for larger systems. The rate will be valid up to cumulative installation of 100 MWp. The rate will be lowered 4 % per year after 2009. At of the end of 2006, 37 PV power plants were operating with six 1 MWp plants totaling 9,712 kWp. One of the six 1 MWp PV plants is shown in Fig. 1.
- Renewable Portfolio Agreement (RPA): Utility companies are asked to adopt renewable energy in their total power supply. The program is not mandatory as is the case with the renewable portfolio standard (RPS). Donghae Utility Company completed one MWp PV system under this program as shown in Fig. 2. They are benefiting from the feed-in-tariff for the PV-generated electricity.
- Local Energy Development Program: Local government shares 30 % of the installation cost and the central government pays the rest. In 2005, the Government allocated more than 40,0 billion KRW for this program. PV accounted for more than 21 %. Local authorities installed a variety of PV systems to enhance public awareness on PV and to promote PV as indigenous renewable energy sources for their regions. It is worthy to note that several local authorities started "Green Village" projects (Fig. 3 and Fig. 4). The objective of this project is to construct a cluster of homes whose energy is largely supplied by renewable energy sources.

*Fig. 2 - 1 MWp PV plant in DongHae City located on the east coast. The system is installed on the premises of the Donghae Utility Company.*

*Fig. 3 - A green village in Cheonan City located about 100 km south of Seoul which has 32 2 kWp PV roof-top systems.*

*Fig. 4 - Asan green village with a total of 208 kWp grid-connected PV systems for 104 homes.*

*Fig. 5 - 1 MWp PV power demonstration site in Suncheon City, Jeollanam-do.*

*Fig. 6 - A 250 kWp system was installed in 2006 in an apartment complex for 1 215 families in Cheonju City, located about 300 km in the south west of Seoul.*

## RESEARCH AND DEVELOPMENT

Korea's PV R&D program is led by the Korean Photovoltaics Development Organization (KPVDO) since 2004. The Government commissioned the planning and management of R&D projects with KPVDO. Previously, Korea Energy Management Corporation (KEMCO) performed the role. The program mostly consists of industry-oriented research work. Twenty five projects have been formulated with the participation of 35 companies, 8 national research institutes and 21 universities. The budget was 9,14 billion KRW in 2004, 14,99 billion KRW in 2005 and 19 billion KRW in 2006.
Two projects initiated in 2006 are noteworthy: poly silicon manufacturing project and 130-micron thick Si solar cell technology development. Through one of the demonstration programs initiated in 2004, a 1 MWp system was installed in Suncheon City in 2006 (Fig. 5).

## DISSEMINATION PROGRAMME OUTCOME

The Korean PV market surpassed the 1 MWp-landmark and reached 2,55 MWp in 2004. The market further expanded to reach 4,99 MWp in 2005. The market consists of 1,013 kWp for homes, 976 kWp for public buildings, 650 kWp for educational institutes, 525 kWp for industrial purposes, 215 kWp for commercial purposes, and 1,224 kWp for feed-in-tariff application. Classified by size, systems less than 3 kWp totaled to 1,405 kWp, between 3- 200 kWp totaled to 2,734 KWp and over 200 kWp totaled to 850 kWp. Over 5 900 roof-top systems were installed in 2006 as opposed to 907 systems in 2005.

As a new residential application, PV system was applied to a multi-family housing facility as shown in Fig 6. This new application is a monumental one since more than half of Korean housings are now multi-family types.

The grid-connected distributed sector has been intensively promoted under the framework of the "Roof-top and Feed-in Tariff Program," the "Local Energy Development Program," and "Public Building Program".

The total cumulative installed PV power is shown in Fig. 7. The total installed capacity of PV systems in Korea was 13,524 kWp at the end of 2005. The total PV power installed during the year 2005 was 4,999 kWp, doubling the amount reached in 2004 (2,553 kWp). Korean industry estimated that PV market of 2006 would reach up to 20 MWp including 6,5 MWp for roof-tops and 7,5 MWp for feed-in tariff.

## INDUSTRY STATUS

Until 1999, High Solar Company (a spin-off from LG Siltron Co.) continued to produce solar cells but stopped its operation in 2000. In 2002, two new companies entered into single crystalline Si cell production. KPE (former Photon Semiconductor & Energy Co.) significantly increased its production capacity from 0,5 MWp to 6,0 MWp in 2004 and added a 2nd manufacturing line of 30 MWp in 2006. KPE produced 25 MWp in 2006 and 30 % of the amount supplied to the domestic market. A new company, Millinet Solar, is constructing a 30 MWp solar cell line scheduled for operation in the middle of 2007. For polysilicon area, DCC announced their investment

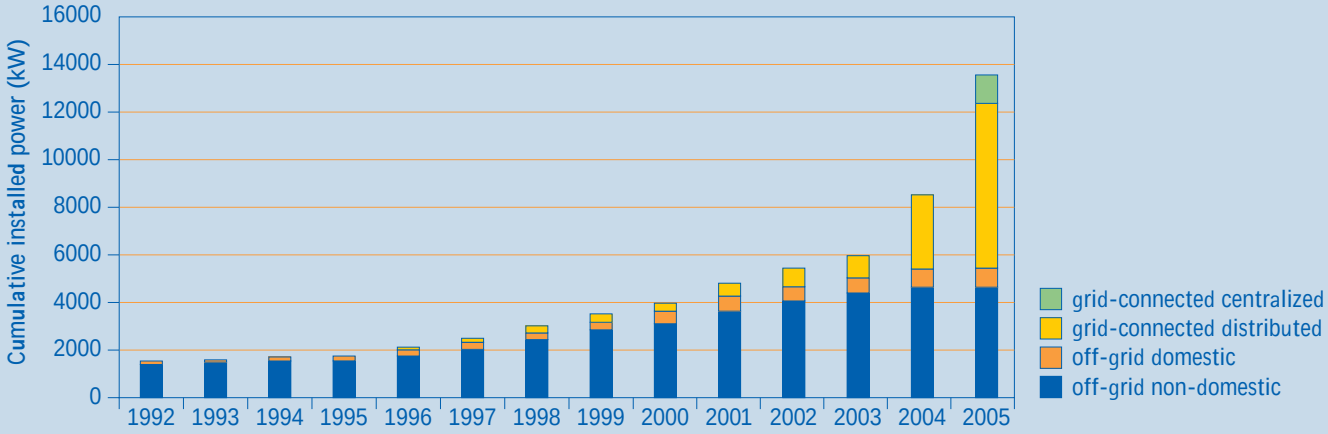



*Fig. 7 – The cumulative installed PV power in Korea.*

in a 3 000 ton production facility scheduled for commercial production in 2008. In the wafer area, LG Siltron set up a 10 MWp plant of single crystalline silicon wafer. Woongjin established a joint venture, Woongjin Energy, with US-based Sunpower, for single crystalline ingot production. In 2006, Korean module manufacturers produced 26 MWp modules with 125 MWp annual production capacity. This was only a four times increase compared to the production figure of 6,4 MWp in 2005. The largest module manufacturer, Symphony Solar Co., produced 10 MWp with a 50 MWp production capacity. Hyundai Heavy Industries produced 5 MWp with a 10 MWp production capacity for export market such as Spain. Kyung Dong Solar produced 4 MWp with a 20 MWp production capacity. S-Energy produced 3 MWp with a 20 MWp production capacity. Solartech, LS IS, and Unison are also participating in PV module manufacturing business. As of 2005, the total module production capacity was about 95 MWp per year. In 2004, Korean manufacturers produced about 2,7 MWp of PV modules. The price was about 4,500 KRW/Wp on the average in 2006.

Until 2004, Hex Power Systems Co. was the only inverter manufacturer for grid-connected systems. During 2005 and 2006, Hanyang Electrics and Willings joined the PV inverter market. Six companies with 11 models received Korean PV certification for roof-top PV systems. These companies produced various products with a capacity 1 - 100 kW. The prices for 3 kW inverters for roof-top application dropped sharply to 1,8 million KRW in 2006 compared to 2,5 million KRW in 2005 and 3,6 million KRW in 2004 due to new companies participation and imported products.

Global High-Tech Co. produces lead-acid batteries of the tubular plate stationary type. The unit price of the battery with a capacity 2,000 Ah/100hr is about 1,000 KRW.

More than sixty companies are participating in the installation business and S-Energy, a leading system installer and module producer has nearly 20 % market share in Korea. In 2006, KEMCO selected 20 PV system installers for roof-top market for subsidy application. In 2006, roof-top PV system price was set at 9,8 million KRW per kWp with VAT and 70 % subsidy.

In 2007, KEMCO announced new installation prices with different applications. The standard price for a fixed PV system is 9,55 million KRW; for a tracking PV system is 11,7 million KRW; and for a BIPV system is 14 million KRW per kWp. Higher price setting is expected to activate BIPV market combined with the Public Building Program.

## FUTURE OUTLOOK

Under Korea's new national PV plan, the goal increased to 100 000 roofs and 70 000 buildings for a total capacity of 1,3 GWp by the year 2012. An explosive market growth is expected between 2006 and 2012. The foundation for mass deployment was set into place in the year 2006 especially for roof-top and feed-in tariff market. In the future, the BIPV market is expected to play an important role due to the "New Administration-Oriented City" and "Many Innovation Cities" programs under which the Korean government will construct public buildings throughout Korea until year 2012. The Korean government recognizes that the PV industry will grow and take up to 10 % of the world market by the year 2012 with the export amounting to 3 billion USD and employing 50 000 people. The strategies for promoting the distribution of PV systems are described below. The whole program 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.
- Set up the test sites and villages for demonstration. Establish "green villages" throughout Korea starting from Daegu and Kwangju. For new buildings, encourage the installation of 10 kWp PV systems and 20 kWp PV systems for factory buildings.
- Maximize the subsidy program that has a strong short-term effect. Further promotion should be pursued by "green pricing" and other tax incentives.

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

# MEXICO

PV TECHNOLOGY STATUS AND PROSPECTS IN MEXICO

JAIME AGREDANO, J M HUACUZ
ELECTRICAL RESEARCH INSTITUTE (IIE)

*Fig. 1 - Valle de las Misiones Grid-connected PV Systems in Mexicali.*

*Fig. 2 - PV Panoramic view of the Valle de las Misiones Neighborhood in Mexicali.*

## GENERAL FRAMEWORK

PV systems installations in Mexico in 2006 increased by a factor of almost two in comparison with the previous year. Rural electrification remains as the major PV application in this country, but grid connected PV systems appeared as a new market segment that is gaining interest from government entities and private investors. The GEF-supported program for agricultural applications (mainly water pumping for small irrigation and livestock watering) ended in 2005. The Mexican implementing agency for this program, FIRCO, in charge of this program reports its consolidation and by the end of the program reports that more than 800 additional installations were made by the end of 2006; without financial support from national or international bodies.

## NATIONAL PROGRAMME

The initiative for a new law to foster the use of renewable energy resources in Mexico is still pending on approval by the Senate. Even though there is no specific mention of PV in the bill, provisions are included to facilitate market entry of technologies, which are not yet cost-effective. A new rural electrification program with renewable energy, to be co-funded by the GEF, the World Bank and the Mexican Government, has been in the planning stage for some time and is expected to be implemented in four southern states during 2007. Preliminary studies show that in more than 50 % of the communities, PV could be the best technical and economical alternative.

## RESEARCH AND DEVELOPMENT

Technical guidelines for the interconnection to the grid of PV systems of up to 30 kWp in capacity were drafted by IIE upon request from the national electric utility. It is anticipated that, once officially approved, these guidelines will become the standard for interconnection of PV systems to the national grid in Mexico. Assembly factories for PV modules have been in production for some years in northern Mexico under the “maquiladora” scheme, i.e., for export only. The first plant for module assembling for the internal market was planned to start operations in southern Mexico some time during 2006. However, start up of operations was postponed due to delays in equipment supply. It is estimated that the plant will start operations during the first semester of 2007.

## IMPLEMENTATION

In 2006, the Baja California State Government, with technical support from IIE, launched an initiative to build a PV neighborhood of 500 low-income houses in the city of Mexicali, in northwest Mexico, with one grid-connected PV array of 1 kWp each. The initiative aims at testing innovative financial mechanisms, including net-metering. The first phase of the initiative will consist of 220 such installations; of which the first 110 systems came on line in December 2006 and the rest will be completed during the first months of 2007. The city of Mexicali is located in a desert valley and has very high ambient temperatures from May through October, which forces the use of air conditioners. Hence, electricity consumption increases by almost a factor of 5 from winter to summer time, imposing a burden on household economics, since the electricity bills also increase in the same proportion. It is expected that PV can help shave midday summer peaks in the domestic sector.

## MARKET DEVELOPMENT

The Mexican PV market during 2006 was a little below 1 MWp, which reflects a market recovery in comparison with the previous year. The best estimation of the market segmentation was as follows. Rural electrification 511 kWp, water pumping systems with a total capacity of 33 kWp; 110 kWp for grid connected PV systems; and 55 kWp in professional applications (telecommunications, off-shore oil platforms, cathodic protection, and eco-tourism ),and 340 kW of non defined off grid applications. Thus, the cumulative PV capacity installed in Mexico by the end of 2006 was 19,7 MWp. Sales of PV modules in the duty-free zone along the Mexico-USA border are not accounted for due to the lack of official information, but would represent an important market.

## FUTURE OUTLOOK

Grid-connected PV is attracting the attention of the national electric utility, government officials and private investors as an alternative to support the electrical grid in some regions. Forthcoming changes in the regulatory framework allowing net-metering, as well as innovative financial mechanisms will certainly result in a growing market for PV technology. As said before in this report a new Rural Electrification effort is bound to start during 2007 in which PV will most probably play an important role for at least 50 % of the 50,000 houses to be electrified according to current plans.

# THE NETHERLANDS

PPV TECHNOLOGY STATUS AND PROSPECTS
JOB SWENS, SENTERNOVEM, WILLEM VAN DER HEUL,
MINISTRY OF ECONOMIC AFFAIRS

## GENERAL FRAMEWORK

The 2006 Dutch energy policy aimed at and supported the implementation of proven and almost competitive renewable energy technologies to realise the short term Kyoto and European targets. For energy technologies applicable on the longer term, such as PV, the Dutch policy was focussed on at price reduction through research and technology development (RTD) leading to an implementation on the longer term.
Being one of the priorities in the Dutch Energy Research Subsidy (EOS) programme, PV RTD progressed with success. Again 2 new fundamental research projects and 1 industrial research project were granted, receiving a total support of 2,3 MEUR. Also the first and promising results of the FOM / Shell projects, aiming at new concepts such as photon management, quantum dots and photonic crystals were reached and presented.
Various industrial PV initiatives continued in 2006. Ubbink Solar officially opened its module production facilities ECN started the construction of a RGS pilot plant (fig. 1) and Scheuten Solar is considering the erection of a CIS modules production plant.
ECN, Econcern and several other partners are also preparing the construction of a centre of excellence in the field of Si-cell and -module technology. As this is projected in the province of Limburg, this province, already hosting Solland Solar and Scheuten Solar may become a centre of PV development and production in the Netherlands.
In the absence of an effective support scheme, the implementation of PV in the Dutch market dropped to almost zero in 2006. The estimated 0,3 MW that was still installed was generated mostly by local subsidies, such as the 3,00 EUR /Wp investment subsidy in the province of North Holland.

## NATIONAL PROGRAMME

As mentioned above, in 2006 the Dutch National Programme concentrated on RTD.

RTD was supported through the EOS (Energy Research Subsidy) programme. The programme consists of five sub-programmes aiming at new ideas, fundamental research, knowledge transfer, demonstration and unique opportunities respectively:

- NEO: New Energy Research, focussing on new, unconventional ideas. This programme is mainly intended for inventors. The programme covers all new energy options.
- EOS LT: Long term energy research, focussing on a selected range of promising energy saving-or renewable energy technologies, with expected serious impact between 2020 and 2050.
- ES: Collaboration projects, focussing on technology transfer from research to industry, in order to convert technologies into products. This programme replaces the energy part of the IS (Innovation Subsidy for Collaboration Projects) programme, which appeared ineffective for energy technologies.
- EOS Demo: Projects, focussing on testing and demonstrating new energy saving- or renewable energy applications in a realistic user environment.
- Transition UKR: “Unique Opportunities Scheme”, focussing on improvement of material- and energy use and on the application of renewables, in general and biomass, in particular.

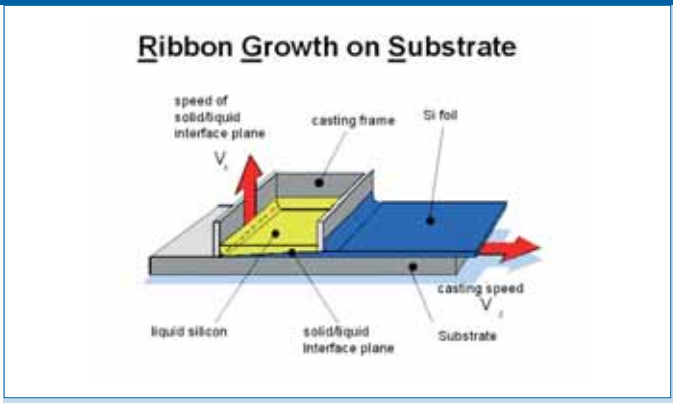



*Fig. 1 - The principle of RGS production.*

NEO, ES and Transition UKR have a broad character, supporting all activities in the field of energy research areas.

For the EOS - LT sub-programme 5 priority areas were selected:

- Energy efficiency in industrial and agricultural sectors
- Biomass
- New gas / clean fossils
- Built environment
- Energy generation and networks / grids

EOS - Demo largely follows the EOS - LT topics, aiming at the implementation of the results thereof. Within the EOS - LT areas, PV is well addressed (4 out of 26 subtopics).
In 2006, the total budget for the energy focussed programmes added up to slightly more than 77 MEUR. Part of this budget was allocated for activities in pre-selected consortia.
The EOS LT PV RTD activities were internationally connected through the SenterNovem participation in PV-ERA-NET. In this EC funded project agencies of 11 EU member countries exchange programming experience and results and initiate joint RTD activities.
SenterNovem also represents the Netherlands in the Mirror Group of the European PV Technology Platform. through this network SenterNovem expresses and explains the Dutch PV Policy in the European PV community and informs the Dutch ministries about the vision and approach of the European PV community towards PV, in general and PV RTD, in particular.

For implementation of PV in the market some generic instruments were available in 2006:

- The MEP scheme (Environmental Quality of Electricity Production), which subsidizes solar electricity up to 18 August 2006, at 0,097 EUR (on top of the revenues from the electricity sales).
- Net metering, which obliges utilities through the amended Dutch electricity law to purchase renewably produced electricity up to 3 000 kWh from private producers at the consumer electricity price (around 0,20 EUR/kWh).
- The EIA (Energy Investment Rebate), allowing a tax deduction of 44 % for investments in energy efficiency and renewable energy. The EIA scheme is only applicable for enterprises.

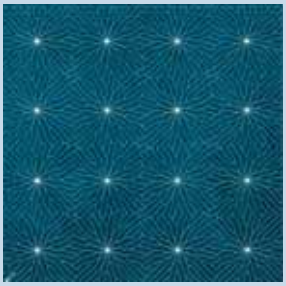


Fig. 2 - PUM – cell with wrap-through back face contact.

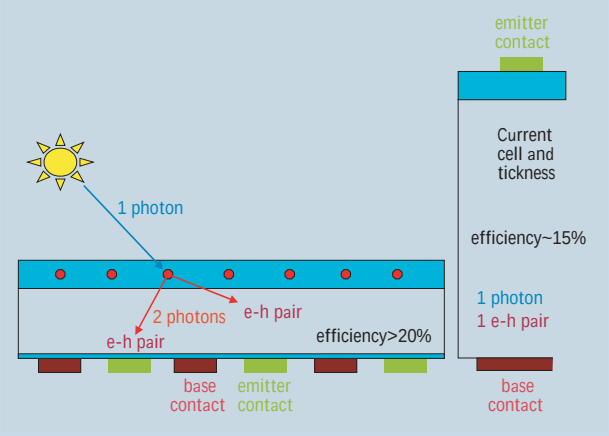



Fig. 3 - Combined down conversion and back face contacts (EOS project QC Passi).

Fig. 4 - PV façade of the Alkmaar Town Hall.

## RESEARCH AND DEVELOPMENT ACTIVITIES

In 2006, the RTD activities continued along the three existing main lines for PV RTD in the Netherlands:

- Solving the silicon shortage problem by reducing the silicon consumption per Wp and developing production processes for SoG (solar grade silicon). RTD activities include the improvement of the NUON – Heliantos (previously AKZO – Heliantos) roll-to-roll process, reduction of the wafer thickness at Solland Solar and industrialisation of the RGS technology at ECN (Fig.1).
- Improving cell production processes, using new cell concepts and new or improved production technologies. Here two projects stand out: 1) continuation of the development of CIS cells based on 0,2 mm CIS coated glass spheres, homogeneously distributed over a grid-shaped substrate at Scheuten Solar and 2) Development of a production process for PUM (Pin Up Modules) at Solland Solar, using a wrap through back face contact design (Fig.2).
- Improving the efficiency of future generation cells through hetero-junctions and up- and down conversion of photons (Fig.3). In this field several projects, running or initiated in 2005, were still ongoing in 2006.

Apart from these there was a very interesting set of projects, funded by Shell and FOM. These projects mainly concentrate on the fundamental new steps to increase the effficiency of PV conversion. Some examples are up- and down conversion of electrons through, for example, nanocristaline particles containing rare earth metal ions, synthesis of molecules and polimers with specific PV properties and use of rest energy through reduction of the electron – hole interaction in quantum dots.
The main players in the fundamental Dutch PV RTD activities are ECN, Solland Solar, Scheuten Solar, NUON – Heliantos (Formerly AKZO), TNO, the Universities of Utrecht, Eindhoven, Groningen and Delft and FOM-AMOLF.
As the programme's focus for PV was on (long term) RTD, very little RTD work was done in the field of BOS.
At the international level, Dutch PV RTD centres and industries collaborate in several networks, amongst which the CrystalClear project, which is co-ordinated by ECN and started early 2004. In 2006 another ECN co-ordinated project, PV Upscale was granted. Other significant ongoing PV RTD or PV RTD related projects with Dutch participation are amongst others Flexellence, Full Spectrum, Crrescendo, PV-ERA-NET and the PV Policy Group.
The bilateral co-operation projects between ECN and the French institutes CNRS and CEA, initiated within the PV-ERA-NET project, were granted in both France and the Netherlands. The first results are promising and both parties have to benefit strongly from the collaboration.

## INDUSTRY STATUS

Based on the strong growth of the world PV market and the excellent knowledge position of the Dutch PV research groups, the 2005 revival of PV industrial activities continued. In March 2006, the Ubbink Solar PV module factory, a joint venture of Centrotec Sustainable AG and Econcern, was opened in Doesburg; RGS Development, a joint venture of Sunergy Investco, Deutsche Solar and ECN, started to build a pilot production plant for RGS (Ribbon Growth on (re-usable) Substrate) wafers in Broek op Langedijk and ECN Petten and ISC Konstanz initiated the erection of the joint front-end silicon cell technology research institute FESTpv.
Scheuten Solar also started the preparation of a CIS module factory. Whether that factory will actually be situated in the Netherlands or in North-Rhine Westphalia will be decided early 2007.
The AKZO - Heliantos project, earlier left by Shell Solar was taken over by the energy company NUON.

## DEMONSTRATION PROJECTS, IMPLEMENTATION AND MARKET DEVELOPMENT

The implementation of PV, decreased further from 1,6 MW in 2005 to an estimated 0,45 MW in 2006. The only significant implementation (probably half of the total 2006 implementation), was realised by Besseling Installatie b.v. in Alkmaar, using the regional North Holland support mechanism of 3,00 EUR / Wp (fig.4).
The EU supported project, "City of the Sun Project", at the HAL location (between Heerhugowaard, Alkmaar and Langedijk) experienced a standstill during 2006.

## FUTURE OUTLOOK

In the framework of the "energy transition" programme, a combined effort by the government and market parties, solar-PV was designated to become one of the "transition-paths". A transition path is a promising long term energy technology (> 2020) which will receive focussed attention in certain RD&D programmes (incl. demo) and market deployment. Whether a market implementation support scheme will be developped within this energy transition programme will be decided upon also in the beginning of 2007. In the field of RTD, even more international collaboration is expected, as the first joint international calls of PV-ERA-NET are expected to be launched in 2007. Furthermore some new and expanding industrial activities are foreseen for 2007: Solland Solar expects to double the production capacity, and a strong group of investors aims at the construction of a Solar Grade Silicon production plant.

# NORWAY

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

*Fig. 1 - Semitransparent solar cells under installation at the new opera house in Oslo (photo Ida Bryhn, Erichsen & Horgen AS).*

## GENERAL FRAMEWORK

The Norwegian electricity system is mainly supplied by hydropower. Increased usage and very little increase in production, i.e. new power plants, has lead to growing import. Increased import of fossil based electricity has increased the interest in renewable electricity production, such as wind and small hydro, but also in bioenergy as a substitute to electric space heating. There has also been an increased interest in research and development of ocean energy, such as wave and tidal. Norway has no public schemes for supporting PV systems. Due to this, there are few large PV systems, and the main market for PV in Norway continues to be related to off-grid recreational applications and special areas such as lighthouses and telecom. The Norwegian energy agency, Enova, has supported some PV installations.

## NATIONAL PROGRAMME

The energy research programme "Renergi" (www.renergi.com) in the Norwegian Research Council funds industry oriented research, basic research and socio-economic research within the energy field, including renewable energy sources. The total funds for PV-related R&D projects were appr. 7,5 MNOK for 2006. Most of the R&D projects are focused on the silicon chain from feedstock to solar cells. Other programmes in the Research Council also fund solar research, e.g. fundamental material research and production processes. The total funding for solar cell research was 14 MNOK.

## RESEARCH AND DEVELOPMENT

There are four main R&D groups in the institute sector of Norway:

- NTNU (Norwegian University of Science and Technology) Trondheim: Focusing on silicon feedstock, refining and crystallisation.
- SINTEF Trondheim and Oslo: Focus on silicon feedstock, refining, crystallisation, sawing and material characterisation.
- Agder University College: Research on silicon feedstock with Elkem. Energy park with PV, solar heat collectors, heat pump, heat storage and electrolyser for research on hybrid systems.
- IFE (Institute for Energy Technology): Focus on silicon solar cell design, production and characterization and investigations of the effect of material quality upon solar cell performance. The IFE solar cell laboratory contains a R&D pilot line dedicated to the production of crystalline silicon solar cells and solar cell and material characterization laboratories. PV-systems activity is linked to research on distributed renewable energy hydrogen systems.

At SINTEF Architecture and buildings, PV research has been done on building integration and PV in urban planning. One project activity is innovative use of solar cells in buildings, where the solar cells are integrated in the building structure and energy system. In 2005 this research group joined PVPS Task 10. Within the framework of Task 10 "Urban Scale PV Applications", Subtask 2: "Planning, Design and Development", Norway is responsible for developing a computer based tool for analysing the integration of PV in the built environment.

SINTEF Materials and Chemistry has substantial activity related to photovoltaics and solar cell technology. The activities are centered around two aspects; - new sources and production methods for silicon to solar cell applications and - fundamental research on materials for photovoltaics. In their work on new sources for feedstock to the solar cell industry, they are involved in a number of EU projects

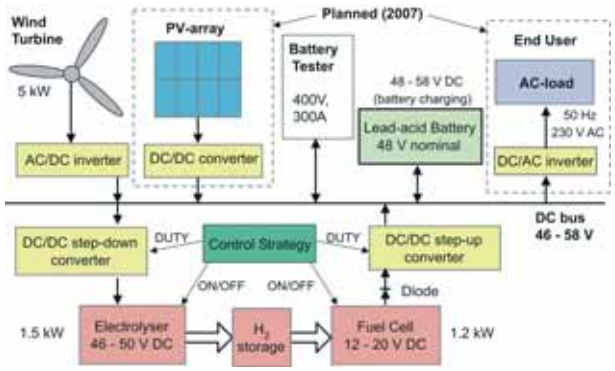



*Fig. 2 - Renewable energy hydrogen system laboratory at IFE (including plans for integration of PV-system in 2007) (photo Øystein Ulleberg, IFE).*

*Fig. 3 - Production of silicon feedstock at Elkem Solar (photo Elkem Solar).*

and programmes in collaboration with European industry, universities and research institutes. Here can specifically be mentioned the strategic targeted project FoXy within the 6th Framework, which is coordinated by SINTEF and has a wide range of participants from across Europe.

Within the field of photovoltaic materials research SINTEF works in close collaboration with the rapidly growing Norwegian industry in this sector, with financial support from the Norwegian Research Council. Our main industrial partners in this field are Elkem, REC and REC-ScanWafer, while NTNU and IFE are our main partners on the R&D side. In particular, the project Crystalline Silicon Solar Cells - Cost Reduction can be mentioned. In this project, fundamental research on silicon as a photovoltaic material is conducted in order to lower the cost of electricity from solar cells. The project is supported by the RENERGI program within the Norwegian Research Council.

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

Institute for Energy Technology (IFE) is an autonomous research foundation with about 550 employees. IFE's activity on solar electricity is comprehensive, stretching from basic research on the production of silicon feedstock, through solar cell modelling and design, solar cell process development and optimisation, characterisation of silicon solar cells to modelling and analysis of integrated PV-systems. IFE has a full inline solar cell processing line for crystalline silicon solar cells. In addition, advanced characterisation laboratories for solar cells, as well as material, electrical and optical properties are also present.

IFE's activity on integrated PV-systems is mainly linked to the institute's research activities on distributed renewable energy hydrogen (RE/$H_2$) systems. PV-systems with medium-term hydrogen energy storage have the potential to play an important role in various power applications. PV/ $H_2$-systems are well suited for high-cost applications, such as remote telecommunication stations and uninterrupted power supply (UPS). However, there exists limited knowledge on how to integrate systems with hydrogen energy technology components, such as electrolyzer, hydrogen storage, and fuel cell.

IFE has been doing both theoretical (modelling) and experimental work on RE/$H_2$-systems since 1995. A schematic of the latest RE/$H_2$-system laboratory at IFE (including plans for integration of a PV-system in 2007) is shown in the figure. Advanced controls for PV and wind based hydrogen systems have been developed and tested in this laboratory. A new national research project (2007-2009) based on the existing experimental facilities at IFE is under way. The objective here is to further rationalize and optimise the controls and hardware required for distributed RE/$H_2$-systems. The focus is on developing highly energy efficient and compact hydrogen storage solutions distributed RE-systems, including PV-systems.

The RE/$H_2$-systems laboratory at IFE will be upgraded with state of the art PV and PEM electrolyzer technology. Novel system configurations using various short-term energy storages (supercapacitors) in combination medium-term energy storages (advanced batteries and thermal buffers) and long-term energy storages (electrolyzer/hydrogen storage/fuel cell systems) will be tested and integrated into a system with an AC-demand. The project is linked to a bi-lateral collaboration between IFE and the National Institute of Advanced Industrial Science and Technology (AIST) in Japan, who have similar RE/$H_2$ system activities and laboratories. The project will also include a PhD-study on distributed solar energy based hydrogen systems. IFE is currently seeking EU-partners, particularly on the hardware side.

## IMPLEMENTATION

The main market for PV in Norway continues to be related to off-grid applications. This refers to both the leisure market (cabins, leisure boats) and the professional market (primarily lighthouses/lanterns along the coast and telecommunication systems).
Up to 1992, the leisure market, dominated by new installations in cottages and recreational homes grew rapidly. After 1992, this market slowed down due to saturation. However, some cabins have been fitted with additional power to serve new demands like TV and refrigeration. However, most sales are for new installations or expansions only.
In the 1990s, PV powered coastal lighthouses emerged as a

*Fig. 4 - The 17,6 kWp installation on the roof of Oslo Innovation Centre in Oslo (photo Norsk Solkraft as).*

significant new market. Even north of 70°, lighthouses may be powered by PV, provided the battery bank has sufficient capacity. The programme was launched by the Norwegian Coastal Administration in 1982 and was completed in 2000-2001. Approximately 1 840 installations with a total of 3 600 modules are now supplying lighthouses and coastal lanterns along the Norwegian coast. The smallest are equipped with one single module of 60 W, the largest with arrays counting up to 88 modules. A large number of the systems are powered by 3 to 4 modules of 60 W. The average is 135 W per installation. The cumulative installed PV power capacity is 215 kW.
Norway does not have any incentive schemes supporting the installation of PV systems, and consequently, there are very few grid-connected systems. The Norwegian energy agency, Enova, has supported some projects. Some building integrated installations have, however, been built during the last few years. Among these are NTNU in Trondheim (16 kW), the BP administration building in Stavanger (approximately 16 kW), a low-energy dwelling at Hamar (2,2 kW), a private residence in Bergen (1,2 kWp), Vest Agder Clinic in Kristiansand (4,9 kWp) and the DNV headquarters (annual production of 1,900 kWh). Other projects being planned or built:

New Opera House in Oslo: The most exciting building integrated project under construction is the use of transparent double glass modules on the southern façade of the new Opera house of Norway, to be located in the Oslo Harbour area. This is part of an EU project EcoCulture. The total glass area is 450 m$^2$, and the solar cell will comprise 300 m$^2$ of this. The power output will be 35 kWp, and the estimated energy output is 20 000 kWh/year. The cell types are ASE single crystalline black with light grey screenprint which are imbedded in glass panels. The panels (3,4 m x 1,8 m) are produced by Saint Gobain Solar and are the world's largest.

Oslo Innovation Centre (Forskningsparken) / CIENS – Blindern, Oslo: The purpose of the Oslo Innovation Centre's PV roof installation is that the newly established Oslo Center for Interdisciplinary Environmental and Social Research (CIENS) can have direct access to and knowledge of the effectiveness of large scale PV in the country's largest city. The PV installation is part of a renewable energy research study, where the costs and yields of the building's various RE sources will be monitored over the coming years to reveal what is the optimal RE solution for buildings in this region. ENOVA, Innovation Norway and the ENØK-fund Oslo Municipality have sponsored the installation.

The 120 m$^2$ grid-connected PV system consists of a total of 94 modules arranged in three strings of 31-32 modules each. The total output is 17,6 kWp. The modules, manufactured by GPV Sweden, are delivered by GETEK AS. Thethree inverters, one for each string, are made by SMA (SB 5000 TL). The system was put in operation in October 2006, and has a real-time monitoring system installed to allow close tracking and analysis of both operational behaviour and the energy production. The system is expected to produce 17 000 kWh per year.

## INDUSTRY STATUS

Elkem Solar was established in 2001. Its main objective is to develop a process for feedstock to solar cell production. With the developed metallurgical route, ES has the potential to be an important player in this market. During the last years of development, feedstock from ES has been tested industrially. Silicon from ES (ES-Si) has been mixed with standard feedstock in the range 25 to 65 per cent, and the obtained solar cell efficiencies are similar to what is obtained with standard charge. From being a research organisation, ES is now building up production capabilities. 2,7 billion NOK is now being invested in a industrial production plant. The plant will start up in 2008, produce about 5 000 tons Si and have 140-150 employees.

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. REC conducted a large stock emission in 2006.

NorSun AS is a new Norwegian company in wafer production. The vision of NorSun AS is to become the leading and most cost effective producer of high efficiency mono-crystalline silicon wafers for the international photovoltaic (PV) industry.

NorSun will build its first wafer production facility in the Aardal community, in the western parts of Norway. The building of the plant is scheduled to start in January 2007, whilst the production start is scheduled for late 2007/early 2008. The plant's capacity in the first production stage will be close to 130 MWs. The number of employees is estimated to be around 100. Even in the first stage, this plant will be one of the largest of its kind in the world.
Through an agreement with the Finnish company Okmetic, a well-established company within the semiconductor industry, NorSun has secured access to key technology and expertise in mono-crystalline silicon ingot pulling. Okmetic will also be in charge of the training NorSun's operating staff. Subsequently, Okmetic will be consultants for the establishment of the production processes in the Årdal facility.

# PORTUGAL

PV TECHNOLOGY STATUS AND PROSPECTS
PEDRO SASSETTI PAES, EDP S.A.

*Fig. 1 - 124 kWp amorphous silicon plant (Lamelas) (photo courtesy of Jayme da Costa, S.A.).*

## GENERAL FRAMEWORK

The national PV policy is part of the general framework on Renewables, which is one of the government's energy policy priorities as established by the Cabinet Resolution 169/2005.

Improving energy efficiency, reducing $CO_2$ emissions and increasing the use of renewable energy sources (RES) are some of the core objectives of this policy. Under this perspective, the promotion of market deployment of renewable energy (RE) technologies can be regarded as a major policy objective, leading to increasing security of supply, through the diversification of energy sources, while reducing the environmental impact associated with the energy system.

## NATIONAL PROGRAMME

The government established ambitious goals for RES-E to be reached by 2010, allowing Portugal to be able to meet the targets agreed to under the 2001/77/CE Directive – 39 % of the gross electricity consumption from RES by 2010. Wind power will form the bulk of the new installed capacity (from the current 1 000 MW to about 5 100 MW by 2010), while PV's contribution is set to increase from the current level of about 3 MW to a 150 MW goal.

Besides indirect market instruments (taxes), the only mechanism presently in force for supporting market deployment of RE technologies is a feed-in tariff mechanism. Incentives on investment, namely under the PRIME programme (2000-2006), are currently suspended. A new incentive scheme is only expected to be in force by 2007, under the new European Union Framework Programme (structural funds).

The main legal framework related to PV includes:

- Decree-Law 312/2001 defining the conditions regulating the awarding and management of grid interconnection points for Independent Power Producers (IPP).
- Decree-Law 33-A/2005 establishing a range of favourable feed-in tariffs for RES electricity. This decree revised the feed-in tariff established in Decree-Law 399-C/2001 and, at the same time, clarified the timeframe in which the tariff is in force: 15 years or until the system attains a production of 21 GWh/MW, which is equivalent to a reference final yield of 1 400 kWh/kWp per year. The feed-in tariff mechanism will only be applicable to new s ystems until the 150 MW capacity target is attained.
- Declaration of Rectification (April 2005) issued by the Portuguese Directorate-General for Geology and Energy (DGGE), which altered the feed-in tariff formula, affecting mainly PV installations and resulting in a incentive decrease of about 18 %. The current values are: 0,28 EUR /kWh for systems with installed power above 5 kWp (0,32 EUR/kWh in 2004) and 0,45 EUR/kWh for systems up to 5 kWp (0,54 EUR/kWp in 2004).
- Decree-Law 68/2002 regulating the delivery of electrical energy into the low-voltage grid (micro-generators, including PV, with a maximum connection power of 150 kW). This framework, also known as "Producer-Consumer" law, was introduced essentially in the context of demand-side policies. Unlike IPP, the Producer-Consumer has presently an obligation to consume at least 50 % of the generated electricity. The excess generated electricity can be exported to the grid and is also benefiting from a feed-in tariff. For PV, this tariff is approximately 0,31 EUR/kWh, guaranteed for the first 10 years of operation.

As far as technology development in companies is concerned, there are presently three different support programmes: DEMTEC (demonstration projects), SIPIE (industry development) and SIME-IDT (industrial research and implementation).

Indirect market development mechanisms for renewables include reduction of VAT rate from 21 % to 12 % on renewable equipment, custom duties exemption and income tax reductions (up to about 750 EUR for solar equipment).

## RESEARCH, DEVELOPMENT AND DEMONSTRATION

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

- CENIMAT: Department of Materials Science, Faculty of Sciences and Technology (New University of Lisbon) – amorphous silicon.
- LAFS: Laboratory of Photovoltaic Applications and Semiconductors (University of Lisbon) – EZ-ribbon growth of wafers. This Laboratory signed a 0,6 M R&D contract with BP Solar in 2006.
- Department of Ceramics and Glass Engineering/UIMC (University of Aveiro) – nano-technologies for PV.

Applied research and demonstration are performed in several institutions such as Public Research Institutes (INETI – National Institute for Engineering, Technology and Innovation; IN+ - Centre for Innovation, Technology and Policy Research), Energy Agencies (ADENE and regional agencies), utilities (EDP) and private research institutes (INESC Porto - Institute for Systems and Computers Engineering). Besides these institutions, associations such as SPES (National Solar Energy Society) and APISOLAR (solar manufacturers and installers association) are also involved in dissemination activities.

One of the most significant initiatives launched in 2006, within the empirical research mentioned, was an international design competition – Lisbon Ideas Challenge: Urban Design with Photovoltaics – under the auspices of the IEA-PVPS Programme (Task 10) and with sponsorship from PME Investimentos (www.lisbonideaschallenge.com.pt). 132 expressions of interest were submitted from over 30 countries, of which 23 projects were actually submitted. From the 23 submitted projects, 10 were short-listed and out of these 4 were distinguished. Power Fold, from a young Portuguese team of architects from Atelier Data, was the winner of the Best Business Idea Prize, while Sunrise Apartments from Gino Koendraat, Netherlands, PV 4 All from the architect Joseph Cory, Israel and Sun Square from Rui Palma, Portugal, received Honourable Mentions.

The second edition of this competition will focus on the development of an urban renovation strategy with integration of photovoltaic technologies in a low-income neighbourhood of Lisbon – Bairro Padre Cruz – allowing for the competition to be more inclusive to the city.

## IMPLEMENTATION

From 2002 to 2004, about 128 MWp PV capacity (corresponding to 104 MVA at the grid interface) were allocated by DGGE under the IPP framework. Among this capacity is the world's largest centralised PV plant (~62 MWp or 49 MVA at the grid interconnection), to be installed in east Alentejo (Moura municipality).

Nevertheless, in 2005 DGGE decided to suspend the quarterly allocation of grid interconnection points for PV due to the huge amount of requests received (more than 3 000), which exceeded largely the national target of 150 MW and lead to a bottleneck in the evaluation process. This process remained frozen in 2006, while the government started preparing the legal framework revision allowing attributing the remaining 22 MWp.

In 2006 only a few of the already licensed grid-connected installations were realised, of which:

- 124 kWp amorphous silicon system, the largest so far installed in Portugal, located in Lamelas (north of Portugal) and owned by Cavalum, Produção de Energia, Lda.
- 64 kWp plant based on c-Si modules mounted on single-axis trackers, in Alqueva (Moura municipality, south of Portugal). The project was promoted by EDIA, the company who manages the infrastructures associated with the Alqueva Dam.

Another significant large-scale project is underway: the 11 MWp power plant, in Serpa (south of Portugal) started construction in 2006. By the end of the year, 7 MWp were already erected. The project, promoted by Catavento (a Portuguese IPP company), uses PV and single-axis tracking technology from Powerlight Corporation (USA) and is being carried out with the involvement of GE Energy Financial Services, who is responsible for the project finance operation and will own the plant.

The Moura project, which should have started in 2006, entered a new phase after the long negotiations with the government to establish the feed-in tariff and consolidate the industrial component of the project, as well as the launching of an international tender for investor's selection. As a result of this tender, the Spanish company Acciona Energía acquired 100 % of AMPER Central Solar, S.A. capital, the licensed IPP promoter, and will likely develop the project in the period 2007-2010. So far, there is no detailed information available on the industrial aspect of the project, which will involve the construction of a PV module manufacturing facility in Moura municipality.

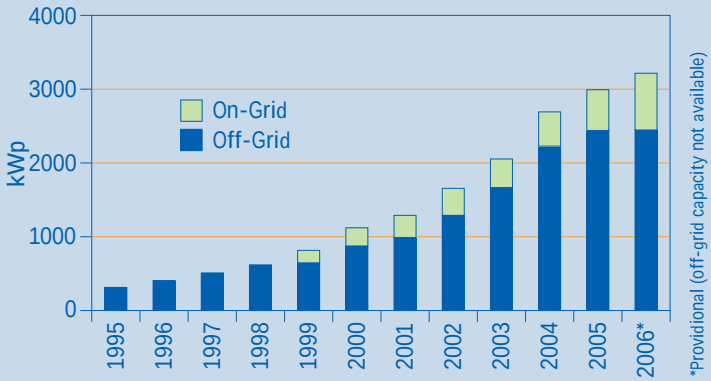
Another large-scale application, the PSIA power plant - a 2,15 MWp system using modules from Kyocera mounted on 2-axis tracking systems - in south Alentejo (Almodovar municipality), was also delayed for administrative reasons and is only expected to start operation by the end of 2007.

## INDUSTRY STATUS

Energy Photovoltaics, Inc. (EPV), a solar energy manufacturer in New Jersey (USA), established a joint venture with Solar Plus, S.A. of Lisbon (Portugal), with a value of about 20 MUSD, for the implementation of a 5,5 MWp per year thin-film (amorphous silicon) photovoltaic module manufacturing facility in Oliveira do Bairro (north of Portugal). EPV will supply and install its Integrated Manufacturing System (IMS). The facility will employ about 100 people and will start production in 2007.

Lobo Solar is manufacturing Shell Solar module (mono- and multi-crystalline) in its assembly plant located in Évora. The maximum annual production capacity is 17 MWp. The factory employs about 90 people.

*Fig. 2 - 64 kWp one-axis tracking system (Alqueva) (photo courtesy of EDIA, S.A.).*




*Cumulative Installed PV Power (Portugal).*

Batteries for PV stand-alone applications (solar type and stationary) are also manufactured in Portugal (Tudor and Autosil).

A dozen companies are supplying and installing PV modules and BOS components imported from the EU, USA and Japan. A few of these companies also manufactures small power electronics devices for stand-alone PV applications.

## MARKET DEVELOPMENT

The Portuguese PV market presents a yearly steady growth of about 25 % rate, but remains strongly based on stand-alone applications. Only a few of the grid-connected installations approved so far were realised in 2006 (~200 kWp). It is worth noting that the installed capacity goal of 150 MW to be attained in 2010 is exclusively targeted at grid-connected systems under the IPP scheme. Considering that only about 500 kW cumulative power of this type of systems has been realised, one can conclude that the goal realisation rate is still close to zero.

For this reason, the market structure compared to previous years remained almost unchanged (~80 % off-grid and ~20 % on-grid). The total cumulative installed capacity by the end of 2006 is slightly over 3 MWp.

However, some of the already licensed power plants (e.g. Serpa, Amodôvar) are expected to be operational in 2007, adding more than 13 MWp to the current grid-connected installed capacity. This will completely change the current market structure, which will be dominated by on-grid applications.

## TABLE 1- PORTUGAL'S TOTAL INSTALLED PV CAPACITY END 2005

| YEAR | STAND-ALONE (kWp) | GRID-CONNECTED (kWp) | TOTAL ANNUAL POWER (kWp) | CUMULATIVE POWER (kWp) |
|---|---|---|---|---|
| Up to 1995 | 324 | 12 | | 336 |
| 1996 | 88 | 0 | 88 | 424 |
| 1997 | 98 | 5 | 103 | 527 |
| 1998 | 100 | 21 | 121 | 648 |
| 1999 | 50 | 146 | 196 | 844 |
| 2000 | 216 | 84 | 300 | 1 144 |
| 2001 | 115 | 51 | 166 | 1 310 |
| 2002 | 285 | 73 | 358 | 1 668 |
| 2003 | 396 | 5 | 401 | 2 069 |
| 2004 | 554 | 78 | 632 | 2 701 |
| 2005 | 215 | 73 | 288 | 2 989 |
| 2006* | n.a. | 227 | n.a. | >3 200 |

**Provisional data.*

## FUTURE OUTLOOK

As noted above, the PV market in Portugal is expected to expand significantly in the next few years, from the current 3 MWp to about 130 MWp, based on the already licensed plants provided they are carried out, in particular the Moura power plant that represents nearly half of that capacity.

Nevertheless and in spite of the apparently attractive feed-in mechanisms, market deployment has not been consistently triggered, which derives directly from administrative barriers generated within the licensing process, currently too complex and time consuming, together with the successive changes of the legal framework in the past 3-4 years; affecting namely the feed-in tariff conditions and lowering the attractiveness of PV investments in Portugal. Also, the 5 kWp cap for eligibility for the highest tariff rate seem inadequate and should therefore be revised.

Furthermore, the official suspension of requests for PV since 2005 brought the market to a stall, as the other possible alternative – the Producer-Consumer Framework - is not considered at all to be attractive; especially for companies used to operating within the IPP framework. This may lead to a negative market stop-and-go effect, affecting the PV development in Portugal.

Besides the need of a stable framework, other measures should be adopted aiming at accelerating the permit procedures, especially for small grid-connected systems. The government is preparing adequate legislation on this subject to be in force by the end of 2007.

One of these measures, already pointed out in several fora, is the harmonisation of the IPP and the Producer-Consumer framework, which would, in principle, contribute to overcome barriers at the small-scale, low voltage grid-connected systems. For larger systems, with installed power above 100 kWp, the general IPP procedure would be applied.

The building integrated PV market (BIPV), one of the most promising although almost inexistent in Portugal, will require the establishment of specific building codes and regulations (e.g. building safety, local authorisation procedures, etc.), as well as information campaigns in order to increase the awareness of PV among the main building actors.

# SPAIN

PHOTOVOLTIAC TECHNOLOGY STATUS AND PROSPECTS

JAVIER SANZ, CENTRO NACIONAL DE ENERGIAS RENOVABLES, CENER

## GENERAL FRAMEWORK AND NATIONAL PROGRAMME

2006 should be considered as a transition period in which the effervescence of the activity developed under the umbrella of the Royal Decree 436/2004 has been counterbalanced by an announcement in the Royal Decree Law 7/2006 of a new Royal Decree that should draft a new feed-in tariff scheme. Nevertheless, it is demonstrated that the scheme currently applicable is working fair enough and the deployment of PV facilities has gained strong momentum. It is not just that important investors perceive PV as a reasonable business but also modest individuals also have access to become an owner of a plant or part of a plant.

The deployment of installed capacity that is feeding the grid, in accordance with CNE figures, reached 76 MW in November 2006 and this figure is expected to grow at the end of the year 2006 nearly doubling 2005 total figures. In other words, 2006 activity has reached the same installed capacity than what was achieved during the previous 10 years.

This growth has permitted a continual lowering of costs and prices in most system components; modules instead, showed an increase in prices during 2006 due a misalignment between the demand and the industrial capacity. Nevertheless, the shortfall on modules supply because of a lack of raw material softened at the end of the year, as first indications are reaching the market and that modules are again in stock.

As expected, one of the main effects of the new legal framework has been the increase of the facilities average size. The new Royal Decree will continue the stimulation of bigger facilities and the average size will be somewhere between 2 and 5 MW. Not just the investor agents, like venture capital funds and financial entities, but large engineering and industrial groups, including electrical utilities, are looking with interest at investing in these installations. At the beginning of 2006, the TMR (average tariff for the electricity to an average Spanish consumer) was increased by 4,8 % thus increasing in the same percentage the tariff for the kWh injected by the photovoltaic installation in the distribution network in Spain for a total value of 0,44 EUR/PV-kWh. This tariff is frozen until the new Royal Decree comes into force.

It is worth noting that the objective of the new “Plan de las Energias Renovables (PER)” which is targeting 400 MW in 2010 is well aligned with the sector development.

The investors do not rely on direct support for investments, as the feed-in tariffs scheme is sufficient enough to provide a reasonable return. Experience has shown that subsidies to investments adds much bureaucracy and are quite complicated and time consuming. Experience is also showing that a feed-in tariff system should be sufficient to give the necessary support to grid-connected photovoltaic power systems (PV). Of course, this is not the case for isolated systems, for which direct support for investments is necessary.

*Fig. 1 - A 1,5 MW size grid-connected solar plant with different technology on the tracking system (photo courtesy of Tudela Solar, Navarra).*

Nevertheless, there are still some problems to be solved. One of them is the bureaucratic approval process that involves many different agents such as local and central governments, utilities, system operators and control authorities (environmental, industrial, etc.). Extremely long approval processes can kill many initiatives and in any case, seriously affect the business situation.

## RESEARCH, DEVELOPMENT AND DEMONSTRATION

The national platform PTFV has been drafting the new research needs for the forthcoming years. The main lines of activity can be summarized as follows:

- New materials: thin film technology, purity, semi-conductive substrates, hetero-union concepts, silicon of “solar type”, etc.
- Production technologies to manufacture solar cells.
  - Industrial automation
  - Efficiency.
- PV modules: building integration, certification.
- PV systems: Station balance, tracking systems, control and remote management, concentration mechanisms.
- Grid integration: inverters, energy qualit.

*Fig. 2 - Another 1,5 MW size grid-connected solar plant with different technology on the tracking system (photo courtesy of ERCAM, S.A., Guadalajara).*

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

## MARKET DEVELOPMENT AND FUTURE OUTLOOK

As previously mentioned, indicative and non-official figures point to more than 80 MW at December 2006 as the installed PV grid-connected capacity in Spain. This figure shows how strong the market development is when compared to 2005 (41 MW), 2004 (16 MW) and 2003 (9,2 MW).

Although there has been no formal closure on 2006 figures, it can still be predicted that the growth of installed capacity will literally double, compared to the previous year.

The perspectives for the immediate future are optimistic. The public perception of PV is more and more favourable, and the support mechanisms seem to be working adequately. The 100 kW size limit in the tariff will be deleted and the MW size plant will become common.

# SWEDEN

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS
MARIA HALL, SWEDISH ENERGY AGENCY; MONIKA ADSTEN, ELFORSK AB AND ULF MALM, UPPSALA UNIVERSITY

*Fig. 1 - The museum of technology in Malmö, Sweden, has a roof top system of 393 m² (50,1 $kW_p$) poly crystalline modules and a facade system of 124 m² (17,5 $kW_p$) mono crystalline modules (photo Martin Nilsson).*

## GENERAL FRAMEWORK

The aim of the Swedish energy policy is to secure the supply of electricity and other forms of energy at internationally competitive prices, both for the short and the long terms. The way to accomplish this is to create favorable conditions for efficient use of energy and cost-efficient energy production with minimum negative impact on health, environment and climate.

Carbon emissions from the Swedish electricity production are very low, with the bulk of the electricity supply, approximately 150 TWh per year, generated by nuclear power (50 % of the electricity production) and hydropower (40–45 %, depending on precipitation). Although growing rapidly, mainly due to the introduction of a national renewable electricity certificate system in 2003, the contributions of wind power and biomass-fuelled combined heat and power to the national electricity supply are rather small (about 0,6 % and 5 % respectively).

Sweden and the other Nordic countries liberalized their electricity markets relatively early. To further integrate the Nordic energy market, a great deal of effort is now going into improving the transmission system and using modern technology to increase the transmission capacity between the Nordic countries and to Continental Europe.

The price of the electricity certificates is too low to have an impact on the deployment of photovoltaics (PV), and the total installed PV capacity is less than 5 MW. However, in 2005 an investment subsidy for PV was introduced, the results of which are now beginning to show in the statistics. Public perception is still clouded by the misconception that PV is unsuitable for Swedish (climatic) conditions, apart from vacation cottages in remote locations. However, the investment subsidy has already raised awareness within sectors that previously have not been exposed to PV. The attitude of utilities varies – some are generally positive to PV, being involved in research and demonstration projects, while others are openly sceptical. The cost of grid-connection and metering requirements remain contentious issues in some situations.

The two main bodies responsible for implementing energy policy measures are the Swedish Energy Agency and the state utility Svenska Kraftnät. However, the National Board of Housing, Building and Planning, the Swedish Consumer Agency, the Swedish National Electrical Safety Board, the Swedish Agency for Innovation Systems, the Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning, the Swedish Research Council and the county administrative boards also help implement measures in the sphere of energy policy.

As a result of the 1973 oil crisis, the first governmental energy R&D programme was launched in 1975. Ever since, energy R&D has been a major component of Swedish energy policy. In the spring 2006, the Government presented a bill with directions for the continuing energy R&D programme. The focus of the bill is on research, development, demonstration and commercialization activities to develop technologies and processes needed for the long-term transition to a sustainable energy system.

## NATIONAL PV PROGRAMME

The Swedish Energy Agency (www.energimyndigheten.se) is the national authority for issues regarding the supply and use of energy. Its main task is to implement the Swedish energy policy programme, which is decided by the Swedish parliament. The aim of the programme is to develop a more sustainable energy system and to secure energy supply. Main emphasis is on energy efficiency and on the development and promotion of renewable energy such as biomass, hydropower, wind power and PV.

PV is part of the national long-term energy research programme, which is managed by the Swedish Energy Agency and has a budget of about 90 MEUR per year for the period 2006–2008. The agency provides funding for PV research, co-financed technological development, demonstration and business development. The budget for PV is in the range of 2–2,5 MEUR per year, depending on which projects are currently running. Additional funding for PV research in Sweden can be received from e.g. the Swedish Research Council, the Nordic Energy Research programme and private foundations.

In addition to international cooperation through the IEA PVPS, Sweden is participating in PV-ERA-NET, which is an EU-funded network for national programme managers and financers. The PV-ERA-NET project started in October 2004 and runs over four years. The objective of the project is increased collaboration and coherence between the national PV R&D programmes in the European Research Area.

## RESEARCH, DEVELOPMENT AND DEMONSTRATION

During the period 1996–2004, the Swedish Energy Agency and the Swedish Foundation for Strategic Environmental Research funded a joint programme for PV R&D, the Ångström Solar Center at Uppsala University. When the programme ended, the participating research groups were separated organisationally but continue to maintain focus on PV, with funding from the Swedish Energy Agency and other sources. The thin film CIGS research remains at Uppsala University and the focus is on CIGS deposition by co-evaporation (www.asc.angstrom.uu.se). The technology is on the verge of industrial realisation and a spin-off of company, Solibro AB, was launched in 2003 (see Industry Status below). The aim of the university research is to achieve high performance and simultaneous cost reduction while utilising processes and materials that minimize the impact on the environment. For the development of the next generation CIGS technology, elimination of

*Fig. 2 - PV modules with dual function: electricity generation and solar shading, at the Student Union and the school Mellanhedsskolan (lower left) in Malmö, Sweden. The modules are semi-transparent glass-glass modules of 2x1,5 m (photo Martin Nilsson).*

cadmium from the buffer layer, minimization of the thickness of the active layer and increased process speed are the main objectives.

The research on dye-sensitized (Grätzel) solar cells, which is performed at the Center of Molecular Devices (www.moleculardevices.se) at the Royal Institute of Technology in Stockholm and at the public-private partnership company IVF AB, aims at developing nanostructured dye-sensitized electrochemical cells and modules that can be manufactured at very low cost. Due to the relatively low conversion efficiency, the competitiveness for this technology is primarily in the area of niche products, e.g. for indoor applications. Basic research is aimed at finding new combinations of dyes and electrolytes, which can increase the cell efficiency and stability in order to reach the long-term objective of manufacturing efficient and inexpensive solar cells for large scale electricity production.

The SolEl programme is a national R&D programme with a focus on PV systems and their applications. The programme is financed by the Swedish Energy Agency, Swedish utilities, manufacturing companies (PV and other) as well as building companies and an architects' foundation. The budget is approximately 0,5 MEUR per year. The present programme period runs until the end of 2007. The programme is managed by Elforsk AB, which is the Swedish electrical utilities' R&D company (www.elforsk.se).

The main objectives of the SolEl programme are to support technological development, demonstration of applications, analysis of performance and costs of PV systems (both technical and non-technical) as well as information dissemination.

As a part of the information dissemination effort, the SolEl programme follows and reports to Swedish organisations on the international development of PV, and serves as a reference group for participation in the IEA PVPS. The programme is used as national forum for exchange of information about PV.

Examples of projects funded by the programme are feasibility studies for PV projects, studies on the added value of PV, development of concentrating and PV/thermal systems as well as monitoring of the performance of grid-connected systems (www.elforsk.se/solenergi). The latter is closely related to the activities in IEA PVPS Task 2.

The interest in the programme from the building industry has increased during the last couple of years, due to the rapid international development of building-integrated photovoltaics (BIPV). This has led to a shift of focus more towards BIPV, with planning tools for architects and builders being developed (available at www.solcell.nu/html). Other examples of projects and activities are regional PV seminars, international study tours, handbooks and guidelines for the housing sector.

## IMPLEMENTATION AND MARKET DEVELOPMENT

The market for PV in Sweden has traditionally been dominated by domestic stand-alone PV systems. The majority of these systems are small and predominantly used to supply electricity to recreational homes where grid-connection is not available. Apart from the off-grid domestic market, there are off-grid non-domestic systems, supplying electricity for tele-communication systems, lighthouses, etc., and a few grid-connected systems. Until last year, the grid-connected systems that were installed were mostly demonstration projects intended to demonstrate the PV technology in general or for the purpose of research. Until May 2005, the lack of market support for PV resulted in a comparatively slow development of the PV market in Sweden. Total cumulative PV power installed amounted to approximately 4 MW. The installed grid-connected capacity was 226 kW.

From 15 May 2005 until 31 December 2008, an investment subsidy has been made available for the installation of PV systems in public buildings. The subsidy is a part of a comprehensive investment programme for energy efficiency and renewable energy in public buildings such as sports centres, conference halls, churches, schools, airports, railway stations, etc. There is a cap of about 17 MEUR, which corresponds to approximately 3 MW in additional capacity. The subsidy functions as a tax deduction of 70 % of the investment costs for a completed system installation, with an upper limit per building of 0,55 MEUR. It covers both material and labour costs. The programme was specifically designed to promote the development of professional know-how among installers, architects, project developers, etc. The subsidy scheme has jump-started the domestic market for PV in Sweden. By the end of October 2006, applications for 9 MEUR (corresponding to approximately 1,5 MW installed) had been approved. The Swedish Energy Agency expects that all 17 MEUR will be fully subscribed by Q4 2007, mainly due to the high interest shown by city authorities in Sweden's three largest cities (Stockholm, Gothenburg and Malmö). Hence the total installed PV capacity in Sweden will almost double in three years time and the installed capacity of grid-connected BIPV applications will increase more than tenfold.

Until 2006, a 60,4 kW PV system, which was installed on the IKEA building in Älmhult in 1997, was the largest installation in Sweden. However, within the subsidy scheme a couple of 60–70 kW systems have been realized, for example a 69 kW installation on a museum in Malmö, and there is an application for financial support for an 80 kW system to be installed at the Ullevi stadium in Gothenburg.

*Fig. 3 - A total of 31 $kW_p$ split into two identical systems at Solängen retirement home in Gothenburg, Sweden; Project Developer & Source: Switchpower; System Operator: MedicHus/City of Gothenburg (photo Switchpower).*

There are still very few grid-connected residential systems in Sweden, mainly due to the high prices of PV systems, the high cost of grid-connection and the lack of financial support for private PV installations.

## INDUSTRY STATUS

The Swedish PV industry has grown significantly over the last couple of years. In 2005, the industry launched the Scandinavian Photovoltaic Industry Association, SPIA, based in Stockholm (www.solcell.nu). The association's objectives are to promote R&D and policy support mechanisms as well as to improve general conditions to accelerate PV market deployment in the Nordic region. The members include manufacturers of solar photovoltaic equipment, component supply industry, national experts and project developers from Denmark, Sweden and Norway.

Today, there are four companies in Sweden that produce PV modules. All of them buy cells from abroad and assemble modules, which are to a large extent exported. The most established module producer in Sweden is Gällivare Photovoltaic AB (GPV). GPV is a fully owned subsidiary of the German company SolarWorld AG. In 2005 GPV shipped about 17 MW of modules. Further increase of production capacities are foreseen for 2006. The module manufacturer ArcticSolar AB was started in 2001 and increased its production volume until 2005, when the production volume was reduced due to difficulties in obtaining cells. This bottleneck led to a decrease of the production volume to approximately 3,5 MW in 2005. The company is jointly owned by the manager (10 %), the German company Alfasolar (45 %) and the Finnish company Naps Systems (45 %). The modules produced at ArcticSolar are exclusively exported and sold under the Alfasolar and NAPS labels. ScanModule AB, which is a subsidiary of the Norwegian Renewable Energy Corporation (REC), commenced its module production in 2003 and has undergone rapid expansion to become the largest module manufacturer in Sweden, with 160 employees in 2006. The fourth PV module manufacture company is PV Enterprise Sweden AB, which was founded in 2003. During 2005, the production amounted to approximately 4 MW of modules, but the company was strongly restricted by the difficulties to obtain cells from the world market.

Despite the new investment subsidy, the annually installed PV capacity in Sweden only constitutes a small fraction of the approximately 40 MW per year of modules produced. The share of the production that is exported varies from manufacturer to manufacturer, but is generally more than 90 %.

A growing number of small to medium-sized enterprises exist, which design, market and sell PV products and systems. There are currently no feed-stock or cell manufacturers in Sweden, nor any manufacturers that produce PV specific balance of systems components.

In November 2006, the Swedish company Solibro AB, which has been scaling up the processes for the production of thin film CIGS, announced the formation of a joint venture with the world's second-largest manufacturer of silicon solar cells, the German company Q-Cells AG. Q-Cells will hold a share of 67,5 % in the new company Solibro GmbH, which will commercialise the Swedish CIGS thin-film technology. There are plans to build an initial factory in Thalheim, which will have an annual production capacity of 25–30 MW.

Independently from Solibro AB, another company, Midsummer AB, has developed another production process for CIGS solar cells. The founders of Midsummer AB have experience from e.g. the thin film and semiconductor industries. The aim is to reduce the production cost of CIGS cells by combining knowledge from these industries, experience from mass production and an unconventional manufacturing process. Midsummer AB is currently exploring commercial possibilities.

Low-concentrating combined photovoltaic/thermal systems are a Swedish niche, in which research and development has been conducted for more than ten years. Recently, the company Arontis Ltd has been established to commercialise this technology. Arontis Ltd's first product is a 8X concentrating, east-west oriented, sun tracking PV/T system that produces electricity and hot water simultaneously.

## FUTURE OUTLOOK

The high costs of grid-connection and obligatory metering are obstacles for the deployment of PV in Sweden. The government is aware of these problems and an assessment of possible solutions is expected to start during 2007.

A critical point in the development of the Swedish PV market will be when the current support scheme ends in December 2008. At that time there ought to be a subsequent support scheme in place or the "boom" that PV in Sweden is experiencing right now will probably come to a sudden halt.

The Swedish Energy Agency is assessing the Swedish PV research and plan to partly re-organize the R&D funding for PV. It is expected that the co-operation between national funding organisations will increase as well as international coordination, for example among the PV-ERA-NET countries.

## FURTHER READING ABOUT PV IN SWEDEN

Sweden – Country Information:

- www.energimyndigheten.se/PV
- www.elforsk.se/solel
- www.solcell.nu

# SWITZERLAND

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

*Fig. 1 - 200 kWp solar power system on the football stadium St. Jakob in Basel (architect: Herzog & de Meuron, PV design, installation and photo: energiebüro®).*

## GENERAL FRAMEWORK

Throughout 2006, the framework for photovoltaic technology development in the public sector did not experience particular changes: Research and development activities persisted on the level of previous years whereas support for new pilot and demonstration systems continued to be very limited. The latter poses a barrier to the rapid transfer of results from R&D into industrial solutions and products. On the other hand and driven by the rapid growth of the worldwide photovoltaic market, industry development continued to be strong.

Different matters related to energy policy are presently on the political agenda. In part, this concerns the introduction of a $CO_2$ tax on fossil fuels. The legal basis for the introduction of such a tax is defined by the Carbon Law which has been in force for a number of years. Following the introduction of voluntary measures for the mobility sector through the creation of the Climate Cent Foundation in 2005, the introduction of a $CO_2$ tax on fossil fuels in the heat and power sector continued to be debated in the parliament during 2006. The second issue on the policy level, of greater relevance for photovoltaics, is a new proposal for a liberalisation of the electricity market. After the rejection by public referendum of the first attempt on this subject in 2002, a new law has been proposed. Within this proposal, a goal of additional 5 400 GWh from “new” renewable energies by 2030 is formulated. During 2006, there was a strong debate on this subject in the Swiss Parliament. To support the deployment of renewable electricity, a levy of 0,6 cCHF/kWh was proposed, yielding a total annual amount of 320 MCHF.
The feed-in tariff model was decided as the support scheme to be used. The main debate on this part of the new law concerned the contributions from the different renewable energies and in particular whether photovoltaics should also benefit from a limited support. At the end of 2006, the debate was still ongoing with differences between the two chambers of the parliament on the issue of photovoltaics (meanwhile, a consensus was reached that photovoltaics should also benefit from the support of the feed-in tariff scheme). If the matter progresses as planned, the details will be worked out throughout 2007 and the new framework would become effective in 2008. This would represent a major advance for the Swiss photovoltaic market deployment. Ideally, it would allow the photovoltaic sector to have a steady albeit limited growth over the years to come.

Finally, the framework for the energy research remains otherwise unchanged: The energy research strategy is defined by a 4 year energy RTD master plan, presently for the period 2004 – 2007. The master plan developed by the Federal Commission for Energy Research (CORE), in cooperation with the Swiss Federal Office

*Fig. 2 - Solar water pumping applications in Mali (photo: Solsuisse).*

of Energy (SFOE), is based on strategic policy goals (energy & environment, science & education, industry & society). By the end of 2006, work for the next 4 year energy RTD master plan, covering the period 2008 – 2011 was terminated and ready for discussion with the different stakeholders.

## 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. As indicated above, activities in pilot and demonstration projects were limited during 2006. 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 marketplace. Thorough component – in particular for photovoltaic modules and inverters – and system analysis aims at increasing efficiency, reliability and performance. Accompanying measures to raise the quality and reliability of photovoltaic power systems include work on standards and design tools. On the market side, deployment is presently mainly driven by voluntary green power marketing programmes of utilities. Finally, the programme places 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. However, photovoltaics is generally not a priority and support through direct subsidy schemes is presently limited to a few cantons.

Through the bias of Task 9 of the IEA PVPS Programme, the subject of technology co-operation with developing countries continues to be expanded. During 2006, the recently formed interdepartmental platform for the promotion of renewable energy in international co-operation – REPIC – was continued (www.repic.ch) and supported photovoltaic projects of Swiss entities in developing countries (Fig. 2).

## RESEARCH, DEVELOPMENT AND DEMONSTRATION

The Swiss Photovoltaic RTD Programme is based on a 4 year RTD master plan, presently covering the period 2004 – 2007. Overall, 50 projects, supported by various national and regional government agencies, the research community and the private sector are conducted in the different areas of the photovoltaic energy system. Market orientation, cost reduction, industrial viability and transfer as well as increased efficiency and reliability are the main objectives of the technical R&D.

For solar cells, the main focus remains on thin film solar cells with projects in a wide variety of materials (amorphous and microcrystalline silicon, compound semiconductors, dye-sensitised cells). During 2006, emphasis on transfer from R&D to industrial processes and products continued. Work on thin film silicon at the University of Neuchâtel concentrated on the efficiency and reproducibility of micromorphous solar cells as well as the rapid large area deposition of its individual layers of amorphous and microcrystalline silicon, including work on transparent conductive oxides (TCO). In the area of thin film silicon, strong co-operation with the companies VHF-Technologies and oc oerlikon (formerly Unaxis Solar) continued. During 2006, the equipment manufacturer oerlikon extended its activities as a leading supplier of manufacturing systems of thin film silicon solar cells on glass. With regard to CIGS solar cells, the Federal Institute of Technology in Zurich focused the work on high efficiency flexible CIGS cells on plastic and aluminium. During 2006, the spin-off company FLISOM, active in this solar cell technology, received different awards as a promising and innovative high-tech company. For dye-sensitised solar cells, work continued on new dyes and high temperature stability of the devices. Flexible solar cells were also a subject for this technology. Exploratory work was undertaken on new solar cell concepts (organic solar cells) at the Swiss Federal Laboratories for Materials Testing and Research EMPA.

Emphasis continues to be given to the application of building integration, both for new solutions involving thin film solar cells as well as for new mounting systems and structures for sloped roofs and facades.

With the ongoing market development, quality assurance of products and systems, as well as standardisation, continue to be of high priority. The centres of competence at the Technical Universities of Burgdorf and Lugano carefully evaluate products such as PV modules, inverters and new systems. Long term experience with the operation of photovoltaic power systems is carefully tracked for a number of grid-connected systems, ranging between 10 and almost 25 years of operation. Continuous development of system solutions has resulted in a number of industrial products which are increasingly being exported.

Following the example of the project SolarImpulse (www.solar-impulse.com) by Bertrand Piccard for a non-stop flight around the world in a solar powered airplane, another visionary project of this kind was announced in 2006: The project PlanetSolar (www.planetsolar.org) plans to sail around the world by a boat powered by solar photovoltaic energy. The concept study of the

*Fig. 3 - Concept of the solar boat for a cruise around the world by solar power (photo: Planet-Solar).*

boat (Fig. 3) foresees a trimaran of 30 m length and 16 m width powered by 180 m² of solar cells corresponding to some 30 kW peak power, yielding an average cruising speed of 10 knots.
International co-operation continues to form a strong pillar of the R&D activities with 10 projects running in the 5th and 6th Framework RTD programmes of the European Union during 2006, of which 3 are integrated projets. Swiss research groups are participating in the new integrated projects PV-ATHLET and PERFORMANCE.
International projects are also carried out as part of programmes such as the European Space Agency: The project ENVISOLAR aims at the increased use of satellite based solar radiation information in solar energy industries. The co-operation within the IEA PVPS programme has remained a further strategic activity for which target-group specific dissemination continued: In 2006, a workshop for the financial and investment community was organised in Zurich under the leadership of the Swiss and Japanese Task 1 experts (see also Task 1, p. 12). Founded in 2005, a national IEA PVPS pool receiving support from the electric utilities of the city of Zurich, the Cantons of Basel as well as Geneva, the Mont-Soleil Association and SWISSOLAR contributed to the Swiss expert participation in IEA PVPS. The support to Swiss IEA PVPS activities could thus be broadened, in particular for activities in Tasks 2 and 10.
On the programme level, international co-operation is also taking place through the PV-ERA-NET project (www.pv-era.net) and the European Photovoltaic Technology Platform (www.eupvplatform.org).

## IMPLEMENTATION

For the time being, market implementation of PV systems continues to be mainly driven by green power marketing schemes of utilities. 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. Solar electricity is thus part of mixed green power products, according to naturemade star® labelled brands. With a strong and consistent marketing approach, typically around 5 % of the customer base can be attracted to pay the comparatively high prices for solar electricity, in the best cases. With mixed products, more customers can be attracted. Market implementation is further supported by regional initiatives, for example in the cantons of Basel and Geneva. Small scale private, domestic and non-domestic systems form a complementary part of the Swiss photovoltaic market which is served by local businesses. With the ongoing policy debate in parliament and the accompanying media coverage, a growing interest can be observed from a broad public in this market segment.

## INDUSTRY STATUS

Some years ago, Swiss industrial PV products covered mainly system components such as inverters, both for grid-connected and stand-alone applications, components for electrical connection, mounting systems for building integration and custom designed PV modules. Over the past years, industrial activities in the area of solar cells, solar modules and manufacturing equipment for both of these areas have considerably increased.

In the inverter area, some products have achieved a high export rate. The Sputnik Company produces grid-connected inverters at a capacity of 145 MW DC/year and presently ranks as number 3 in the European market. The Studer Company produces stand-alone inverters and is also very successful in exporting. On the PV industry supply side, different products count among the world leaders, e.g. for wire-sawing machines from HCT as well as from Meyer & Burger; and measuring equipment for PV module manufacturers from Belval.

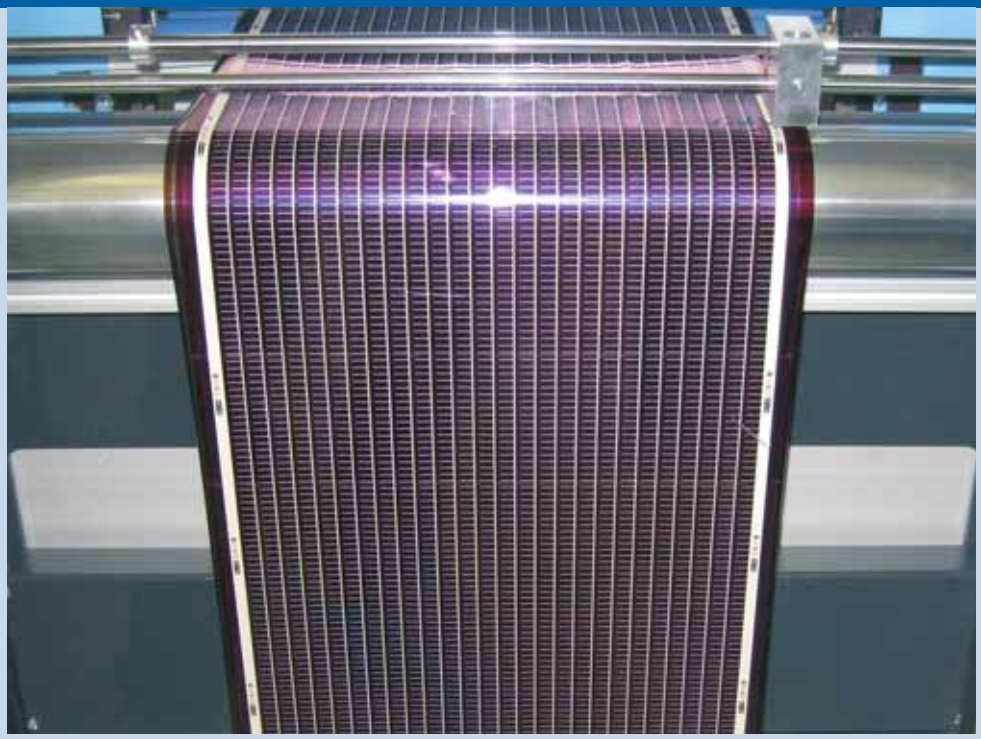


*Fig. 4 - Manufacturing of amorphous silicon solar cells on flexible substrates by VHF-Technologies (photo: NET).*

Solar plugging systems are offered by Multi-contact as well as Huber & Suhner. The Alustand® and SOLRIF® mounting systems for building integrated applications have been very successful on the market. Sarnafil, which has developed a flexible, watertight flat roof PV system based on thin film silicon solar cells, is taking part in a joint venture with the American company Solar Integrated Technologies (SIT).

As indicated above, industrial activities evolve in the field of process equipment (oerlikon) and products based on thin-film technology (Flexcell® from VHF-Technologies, FLISOM). In 2006, oerlikon received a number of large orders for industrial production equipment of amorphous silicon solar cells. During 2006, VHF-Technologies (Fig. 4) built a 2 MW pilot production line for thin film silicon solar cells on flexible substrates. The German company Q-cells has selected VHF-Technologies as one of its diversification options in thin film solar cells with an investment of some 7 MEUR. The goal of this operation is to industrialise VHF's technology, in particular for building integration applications. Furthermore, Swiss Solar Systems (3S) is building some of the world's largest PV module laminators. 3S has continued the strategic cooperation with the German company Schmid and is the first Swiss manufacturer dedicated solely to photovoltaics which has gone public in 2005. In 2006, other Swiss photovoltaic industries have made their IPO.

Based on the long term experience and the large number of installed systems, considerable know-how is available amongst engineering companies for the design, construction and operation of a large variety of different applications, ranging from small scale, stand alone systems for non-domestic, professional applications and remote locations, over small domestic grid-connected systems to medium and large size grid-connected systems in various types of advanced building integration. The export volume of Swiss photovoltaic products is estimated to 400 MCHF in 2006; thus corresponding to roughly 10 times the size of the national market. 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 is manifested by the regular investment analysis reports published by the Bank Sarasin.

## MARKET DEVELOPMENT

The market development has been mainly driven by green power marketing schemes of utilities, supported by promotional programmes and actions in some cantons. The annual market volume for grid-connected systems is estimated to a value around 2,5 MWp, similar to previous years. The total installed capacity has thus risen to about 30 MWp (Fig. 5), corresponding to about 4,3 Wp/capita. The PV energy statistics have been established by tracking the energy produced by grid-connected PV systems and their statistical distribution since 1992 (Table 1). The total energy production of grid-connected photovoltaic systems up to 2005 is thus approaching 18 GWh.

## 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

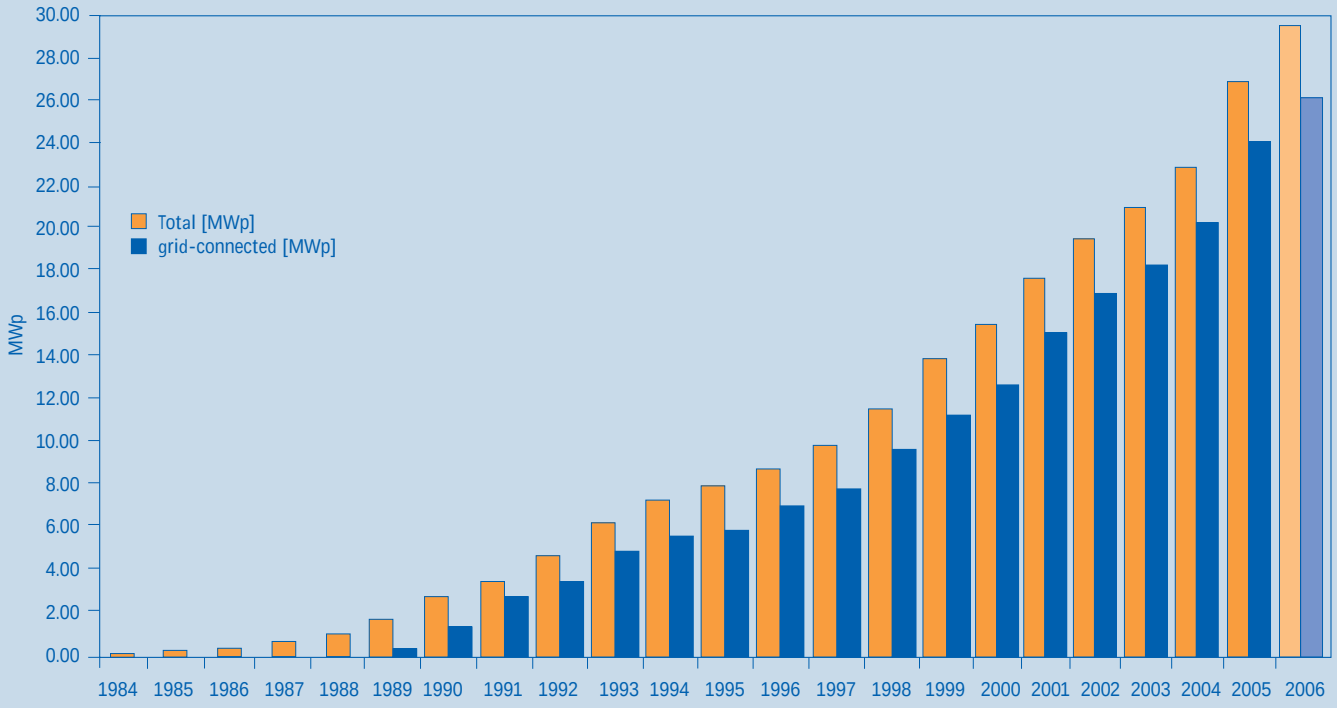



*Fig. 5 - Evolution of the installed photovoltaic capacity in Switzerland between1984 and 2006 (total and grid-connected, estimated values for 2006).*

all levels will continue, related to activities in the 7th Framework Programme of the European Union, the European PV Technology Platform, the IEA PVPS programme and increasingly in technology co-operation projects. Stronger co-operation with other European PV RTD Programmes will be established in the framework of the PV-ERA-NET project.

With the chances rising for an increasing national market through the introduction of a feed-in tariff scheme in 2008, the year 2007 may well bear the characteristics of a transition year. Although the support scheme will be valid retroactively for photovoltaic systems installed one year back, the confidence of the investors in the new framework remains to be seen. Furthermore, stronger marketing activities will need to be undertaken in order to reach new customers.

## TABLE 1: SWISS PHOTOVOLTAIC ENERGY STATISTICS FROM 1989 - 2005 (GRID-CONNECTED SYSTEMS)

| Year | Number of New Systems | Total Number of Systems | Installed Capacity [MWp DC] | Energy Production [MWh] | Specific Energy-Production [kWh / kWp] |
|---|---|---|---|---|---|
| 1989 | 60 | 60 | 0,3 | | |
| 1990 | 110 | 170 | 0,8 | 400 | |
| 1991 | 210 | 380 | 1,8 | 1 100 | |
| 1992 | 110 | 490 | 3,1 | 1 800 | 800 |
| 1993 | 110 | 600 | 4,0 | 3 000 | 810 |
| 1994 | 80 | 680 | 4,8 | 3 500 | 800 |
| 1995 | 60 | 740 | 5,4 | 4 000 | 815 |
| 1996 | 80 | 820 | 6,2 | 4 700 | 825 |
| 1997 | 130 | 950 | 7,4 | 6 000 | 880 |
| 1998 | 150 | 1 100 | 9,2 | 7 100 | 860 |
| 1999 | 125 | 1 225 | 11,0 | 7 700 | 770 |
| 2000 | 100 | 1 325 | 13,0 | 10 000 | 810 |
| 2001 | 125 | 1 450 | 15,0 | 11 000 | 800 |
| 2002 | 75 | 1 525 | 17,0 | 12 000 | 810 |
| 2003 | 75 | 1 600 | 17,9 | 15 100 | 875 |
| 2004 | 100 | 1 700 | 19,5 | 15 700 | 815 |
| 2005 | 200 | 1 900 | 23,8 | 17 800 | 850 |

*(grid-connected systems)*

# UNITED KINGDOM

PV TECHNOLOGY STATUS AND PROSPECTS
SARAH DAVIDSON, SENIOR ENGINEER, IT POWER LTD.

*Fig. 1 - PV in schools is being prioritised by the UK Government and supported by the Low Carbon Buildings Programme (photo courtesy of Sustainable Energy Installations).*

## GENERAL FRAMEWORK

Implementation of UK energy policy is delivered by a Sustainable Energy Policy Network which includes representatives from the Department of Trade and Industry (DTI), Department of the Environment, Food and Rural Affairs, the Department of Communities and Local Government and the Department of Transport.

The Renewables Obligation (RO) is the Government's key mechanism for encouraging new renewable generating capacity. It was introduced in 2002 and requires licensed electricity suppliers to source a specific and annually increasing percentage of their sales from eligible renewable sources. For 2006/07 the level of the RO is 6,7 % rising to 15,4 % in 2015/16. Suppliers can meet their obligation by either presenting Renewable Obligation Certificates (ROCs); paying a buyout price (GBP 33,24 per MWh in 2006/07 rising each year with inflation); or a combination of the two. Renewable Obligation Certificates (ROCs) are issued to generators for every 1MWh of eligible renewable electricity that they generate. These ROCs can then be sold to suppliers. At the end of an obligation period the money in the buyout fund is recycled to those suppliers who presented ROCs on a pro rata basis.

The Government's report on the Energy Review: "The Energy Challenge" was released on 11 July 2006. The review focused on the two major long-term challenges in UK energy policy: the need to tackle climate change by reducing carbon dioxide emissions; and the need to deliver secure, clean energy at affordable prices.

As part of the 2006 Energy Review, the Government announced a number of proposals for changes to the Renewables Obligation as well as proposals for aggressive implementation of the Microgeneration Strategy to remove barriers to household renewables. The proposed changes to the RO include providing differentiated levels of support to different technologies and extending the level of the RO to 20 %. A preliminary consultation on these changes was published in late 2006 and will be followed by further consultation. The earliest these proposals could be implemented would be 1 April 2009. Alongside this consultation a consultation on some more limited changes to the RO was also published including changes to make it easier for small generators to access the benefits of the RO. Subject to Parliamentary approval these changes will be introduced from 1 April 2007. Details of these consultations can be found at http://www.dti.gov.uk/consultations/page34162.html.

The International Energy Strategy was launched in October 2004, and states that the UK Government will tackle climate change, curb carbon emissions and diversify the energy mix to reduce dependence on fossil fuels. The Strategy was reviewed in Autumn 2006 looking again at international energy and climate security policies, taking into account the findings of the Government's Energy Review.

The Stern Review Report on the Economics of Climate Change is an independent review carried out for the British government and released in October 2006. The review discusses the effect of climate change and global warming on the world economy and has attracted a great deal of positive attention. It makes a number of strong recommendations and concludes that there is still time to avoid the worst impacts of climate change, if strong action is taken now. Its recommended actions include:

- Expanding and linking emissions trading schemes around the world
- Doubling support for energy research and setting international product standards for energy-efficiency
- Fully-integrating climate change adaptation into development policy, so that rich countries honour their pledges to increase support.

## NATIONAL PROGRAMME

The UK's National Programme for photovoltaics consists of the following elements:

- Research and development, under the DTI's Technology Programme and various programmes of the Engineering and Physical Sciences Research Council (EPSRC)
- Field trials and demonstrations, under DTI programmes
- Participation in international programmes (EC and IEA)

The overall goal is to develop the capabilities of industry and to encourage sustainable growth in the market by removing barriers to the deployment of PV. Research and development programmes are focused on cost reduction and novel PV materials.

The UK PV Domestic field Trial (PV DFT) is the first widespread monitoring of PV systems in domestic buildings in the UK. It has used the design, construction and monitoring of 28 projects and 474 PV systems to collect information on buildability, reliability, maintainability and PV performance under real UK climate and operating conditions. The results are being added to the PVPS Task 2 database.

Along side the Domestic Field Trial, the UK Large Scale Field Trial for building integrated photovoltaics has been implemented to raise awareness and create confidence in the application of PV and increase UK capabilities in the application of the technology. The final of a total of eighteen high profile projects on public buildings was completed during 2005 and monitoring is ongoing.

The Major Demonstration Programme provided capital grants for quality PV projects between 2002 and 2006.

During 2006, the Government launched its Microgeneration Strategy. The term microgeneration includes solar photovoltaics, small wind turbines, micro hydro, solar thermal, ground/water/air source heat pumps, bio-energy, renewable CHP, micro-CHP (combined heat and power) and fuel cells. The objective of the new Microgeneration Strategy is to create conditions under which microgeneration becomes a realistic alternative or supplementary energy generation source for the householder, communities and small businesses. A new grants programme forms part of the implementation of the strategy.

## RESEARCH AND DEVELOPMENT

Research in the UK is largely funded by the Engineering and Physical Sciences Research Council (EPSRC). In addition to companies' internal research activities, some pre-competitive industrial Research and Development projects are supported by the Department of Trade and Industry (DTI) mainly under the Technology Programme. The DTI's Technology Programme funds industrially focused collaborative research. During 2006 the DTI sought proposals for research leading to cost reductions in silicon PV modules, process development for thin film PV and research into novel PV cells.

The EPSRC Sustainable Power Generation and Supply (Supergen) Programme currently supports two multi-disciplinary consortia focused on advanced PV materials:

- The 'Photovoltaic Materials for the 21st Century' consortium was launched during 2004 and aims to develop low-cost thin-film solar cell devices fabricated from inorganic semiconductors. Technical achievements so far include the development of an innovative electrochemical deposition method for copper indium diselenide (CIS) PV. This thin film process has the potential for considerable cost reductions.
- The Supergen Exitonic Solar Cells consortium, led by the University of Bath, is researching dye and nanoparticle- sensitized and organic cells which may offer the possibility of low toxicity, flexible and easy to manufacture PV materials. Consortium members are concentrating on understanding the factors which limit efficiencies as well as on combining their expertise to devise entirely new types of solar cell.

## IMPLEMENTATION

The new Low Carbon Buildings Programme forms part of the above mentioned Microgeneration Strategy and provides grants for microgeneration technologies including PV for householders, community organisations, schools, the public sector and businesses. The UK wide scheme aims to demonstrate how energy efficiency and small scale renewables will work hand in hand to create low carbon buildings. Minimum energy efficiency standards must be met before applying for a grant. Up to 50 % funding will be available from for new PV projects, subject to maximum levels per kW. Larger projects compete for funding in quarterly funding rounds.

*Fig. 2 - PV cladding is part of the new Manchester College of Arts and Technology (MANCAT) building, incorporating pioneering design and building innovation (photo courtesy of solarcentury.com).*

Figures for the PV capacity installed during 2006 are not yet available but early indications point to similar growth to that experienced in 2005 with around 3MW being installed during the year. This brings the total cumulative installed capacity to approximately 14MW. The majority of systems being installed are grid connected building mounted installations.

## INDUSTRY STATUS

Crystalox is a producer of multi-crystalline silicon blocks and saw continued growth in annual production capacity during 2005, increasing its production by 32 % compared to 2004.

Sharp, with its PV module manufacturing facility in Wrexham continues to be the single largest employer in the UK PV industry. The facility is set to double its annual capacity from 110MW (as of February 2007) to 220MW.

Small quantities of BIPV are manufactured by Romag, the specialist glass manufacturer in Consett, County Durham.

## FUTURE OUTLOOK

The implementation of the Microgeneration Strategy including the low carbon buildings programme will support continued growth in the UK's PV industry. Forthcoming activities include a new accreditation scheme for products and installation and ongoing work to increase the knowledge base of the construction industry.

PV implementation is also growing as a result of the planning requirements of local governments. Several local governments now place a specific requirement on developers of new buildings to incorporate renewable energy systems into new developments over a certain size. Other initiatives encouraging the use of renewable energy in buildings include the new Code for Sustainable Homes which was published in 2006. Since PV is ideally suited for building integrated applications and use in urban areas it is hoped that these positive policies will increase demand for PV and support ongoing growth.

# THE UNITED STATES OF AMERICA

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS IN THE U.S.A.

SUSAN MOON AND SUSANNAH PEDIGO, NATIONAL RENEWABLE ENERGY LABORATORY, GOLDEN, COLORADO
WARD BOWER, SANDIA NATIONAL LABORATORIES, ALBUQUERQUE, NEW MEXICO

## GENERAL FRAMEWORK

The photovoltaic (PV) industry, a growing and profitable sector in the economy, is playing an increasingly important role in the global pursuit of clean, renewable energy technology solutions. To a significant degree, research and development (R&D) has contributed to the PV industry's success. In the United States, research laboratories continue to play an important part in the evolution of the solar industry, from continually feeding the R&D pipeline with next-generation PV technologies to partnering with industry to improve manufacturing processes, which enables solar to play a bigger role in meeting energy demands.

The U.S. Department of Energy (DOE) Solar Energy Technologies Program (SETP), part of the Office of Energy Efficiency and Renewable Energy, is responsible for developing solar energy technologies that convert sunlight to useful energy and make that energy available to cost-effectively satisfy a significant portion of U.S. energy needs. The SETP supports R&D addressing a wide range of applications, including on-site electricity generation, thermal energy for space heating and hot water, and large-scale power production.

The SETP has created a management structure that blends program administration with scientific oversight. Program administration is done by a relatively small DOE staff that focuses on implementing Administration policy. Two DOE national laboratories—the National Renewable Energy Laboratory and Sandia National Laboratories—provide scientific oversight of the solar R&D tasks being performed by universities, industry, and other national laboratories. Laboratory management of the tasks enables detailed technical evaluations to become a part of the programmatic decisions made by DOE.

The bulk of the SETP Photovoltaic Subprogram's activities are carried out through two primary research centers: the National Renewable Energy Laboratory (NREL) in Golden, Colorado, and Sandia National Laboratories (SNL), in Albuquerque, New Mexico. Brookhaven National Laboratory (BNL), in Upton, New York, provides program support in the area of environmental health and safety. NREL, SNL, and BNL are all partners in the National Center for Photovoltaics (NCPV), which provides guidance to DOE PV research efforts. In addition, DOE's Golden Field Office (GO), in Golden, Colorado, administers and manages contracting activities assigned by headquarters.

The PV Subprogram's research is focused on increasing domestic capacity by lowering the cost of delivered electricity and improving the efficiency of modules and systems. The program emphasizes long-term innovative research, thin-film development, manufacturing R&D, and systems development and reliability. Long-term research is focused on "leapfrog" technologies such as polymers and nanostructures. In thin films, new levels of efficiency and stability in prototype modules have been achieved, as well as higher laboratory cell efficiencies. Near-term research is focused on reducing cost through manufacturing advancements and improving system reliability.

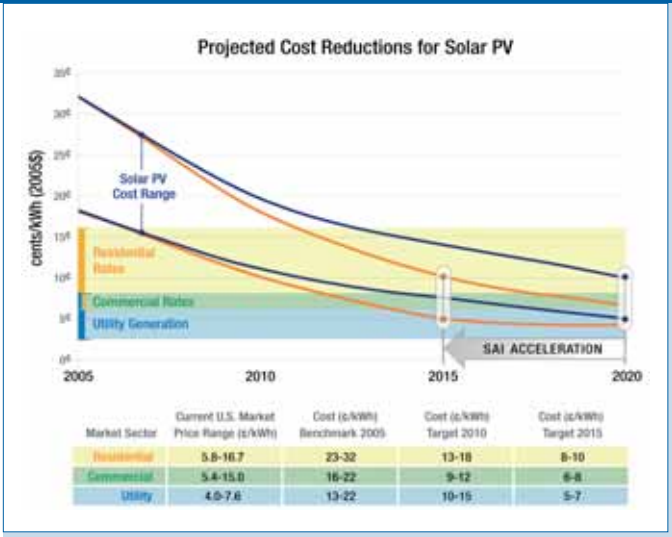



*Fig. 1 - Solar America Initiative (SAI) brings increasingly cost-competitive PV systems to market between now and 2015, with benefits accruing from the early SAI years. (DOE)*

An important feature of DOE research in solar technologies is the goal to fund high-risk, high-return research, development, and testing of PV components and systems. These efforts are undertaken in partnership with the PV industry and universities to bring clean, affordable electricity to the marketplace.

In 2006, PV generated excitement in the United States, with advances in state-level policies in favor of solar and other clean technologies. Public Support for PV appears to be increasing as well, as evidenced by support of the PV incentives mentioned later in this report. Early in the year, the Solar America Initiative (SAI) was announced in support of the President's Alternative Energy Initiative, laying the groundwork for the SAI to be rolled out in Fiscal Year (FY) 2007. The SETP leads the SAI.

## NATIONAL PROGRAMME

### Mission and Goals

The SETP mission is to improve U.S. security, environmental quality, and economic prosperity through public-private partnerships that bring reliable and affordable solar energy technologies to the marketplace. The goals are to reduce the cost of solar energy to the point that it becomes competitive in relevant energy markets and for solar technology to reach a level of market penetration to enable a sustainable U.S. solar industry.

The primary mission of the SAI is to reduce the cost of PV technologies to the point that PV-generated electricity is cost competitive with conventional electricity sources by 2015. As Figure 1 indicates, the 2015 PV goals are 0,08–0,10 USD/kWh in the residential sector, 0,06–0,08 USD/kWh in the commercial sector, and 0,05–0,07 USD/kWh in the utility sector. Achieving these goals will require reducing installed PV system costs by 50–60 % between 2005 and 2015, from 5,50-8,50/Wp to 2,25–3,50/Wp in 2005 USD. This initiative accelerates the achievement of these goals by 5 years. (Wilkins, 2006)

The SETP made a budget request for 148 million USD in FY 2007 for the Solar America Initiative. This is a 65 million USD (78 %) increase over the FY 2006 appropriation, to accelerate the development of PV technologies. As of this writing, the U.S. Congress is operating under a continuing resolution and final budget approvals are still pending for FY 2007.

The SAI enhances DOE's business strategy of partnering with U.S. industry to accelerate commercialization of improved PV systems that can meet aggressive cost and installed capacity goals. The Initiative is split into two areas of emphasis:

*Technology Pathway Partnerships* emphasizes PV component R&D and system designs, including low-cost approaches for manufacturing.

*Market Transformation* emphasizes non-R&D activities aimed at reducing market barriers and promoting market expansion and complements the core R&D and engineering activities of the SAI.

To accelerate attainment of systems goals, SAI will employ public-private partnerships to pursue component and system technologies. The industry-led project teams will demonstrate manufacturing approaches that deliver low-cost, high-reliability commercial products. Ultimately, by 2015, the efforts of the SAI will contribute to making PV electricity cost competitive with traditional energy sources in all U.S. sectors without government support.

By 2015*:

- PV electricity will be cost-competitive in all sectors—residential, commercial, and utility—without government support.
- PV will provide approximately 5–10 GW of electricity generating capacity in the United States—roughly the current electricity generation capacity of New Mexico—enough to power 1–2 million households.
- U.S. industry grows from 1 billion USD/year to 10 billion USD/year, creating 30 000 new jobs for American workers.
- Roughly 10 million metric tons per year of $CO_2$ emissions will be avoided.

By 2030*:

- PV will provide approximately 70–100 GW of electricity generating capacity in the United States —roughly the current electricity generation capacity of California and New York combined—enough to power 10–20 million households.
- PV systems provide roughly 40 % of all new electric capacity in the United States.
- U.S. industry grows from 10 billion USD/year to 30 billion USD/year, creating 80 000 new jobs for American workers.
- Roughly 150 million metric tons per year of $CO_2$ emissions will be avoided.

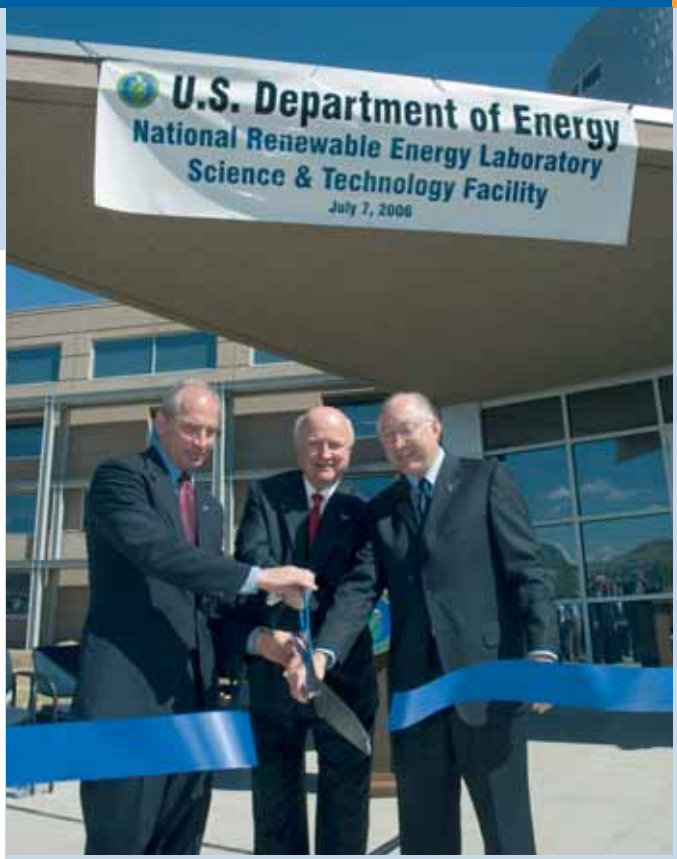



*Fig. 2 - U.S. DOE Secretary of Energy Samuel Bodman (middle) cuts the ribbon with Colorado Congressman Bob Beauprez (left) and Colorado Senator Ken Salazar (right) to officially open the DOE National Renewable Energy Laboratory's Science & Technology Facility, in Golden, Colorado (photo NREL).*

* Estimates include SAI-PV benefits only. The addition of SAI-concentrating solar power activities at FY 2007 funding levels raises these benefit estimates by roughly 10 % in both 2015 and 2030. (Wilkins, April 2006)

The SETP is in the early stages of a selection process to choose participants in both the Technology Pathway Partnerships and Market Transformation areas of the Initiative. Funding awards are anticipated to be made sometime in spring 2007. (www.eere.energy.gov/solar/solar_america/)

## RESEARCH, DEVELOPMENT, AND DEMONSTRATION

There are three areas of SETP-sponsored PV research, development, and demonstration: fundamental research, advanced materials and devices, and technology development. Below are brief descriptions of these areas and selected 2006 highlights.

### Fundamental Research

Fundamental Research investigates the physical mechanisms of charge carrier transport, band structure, junction formation, impurity diffusion, defect states, and other physical properties of PV materials and devices, as well as the identification and development of processes for fabricating PV materials and devices. Among the research topics are innovative ideas and technologies with the potential to "leapfrog" current approaches, leading to new, nonconventional concepts that could dramatically improve cost effectiveness in the long term.

July 7, 2006, marked the ribbon-cutting ceremony for NREL's new Science & Technology Facility. The 71 000-square-foot, state-of-the-art facility is designed to help accelerate the development and commercialization of promising new energy technologies, particularly in solar, hydrogen, and building-related energy technologies. The facility has space for 75 full-time researchers and features an 11 500-square-foot Process Development and Integration Laboratory (PDIL), which will allow NREL and industry researchers to work together to develop new PV manufacturing processes. This cooperative research will help reduce the time it takes to move new technologies from the laboratory bench to commercial manufacturing.

The following are Fundamental Research topics and sample 2006 accomplishments.

Measurements and Characterization—Provides test, measurement, and analysis support and research for the SETP, including national laboratories, external research partners in university and industry laboratories, and PV manufacturers.

- Completed capability to evaluate multiple-junction concentrator cells and modules to 1 000X with the lowest possible uncertainty.
- Investigated local open-circuit voltage and current flow in amorphous and nanocrystalline mixed-phase silicon solar cells.

Electronic Materials and Devices—Carries out research in semiconductor materials, device properties, and fabrication processes to improve the efficiency, stability, and cost of PV.

- Made rapid performance improvements in crystalline silicon heterojunction solar cells with amorphous silicon (a-Si:H) layers deposited by hot-wire chemical vapor deposition. The research team achieved an NREL-confirmed conversion efficiency of 17,83 % for a 1-square-centimeter cell with both a front heterojunction emitter and a back heterojunction contact fabricated entirely below 200°C at NREL. This is the best published cell efficiency on a p-type Si wafer by the a-Si:H/c-Si heterojunction technology.
- Fabricated high-efficiency (19,52 % confirmed) copper indium gallium diselenide (CIGS)-based solar cells using a single-layer, NREL-developed, chemical-bath-deposited CdZnS buffer layer. NREL has been the world leader in fabricating the most efficient CIGS thin-film solar cells since 2002.

Crystalline Silicon Project—Directs fundamental crystalline silicon R&D involving universities and national laboratories.

- The Georgia Institute of Technology developed and applied its PV module manufacturing cost model in conjunction with the Solar Advisor Model from NREL to show that 18–20 %-efficient low-cost cells with screen-printed contacts using 100- to 200-µm-thick c-Si wafers can reduce the levelised cost of electricity to 0,05–0,10 USD/kWh. Georgia Tech also achieved a cell efficiency of 17,6 % (confirmed by Fraunhofer ISE) on 149 $cm^2$ float-zone Si by controlling the contact firing process.
- North Carolina State University refined its near-field scanning optical microscopy for the nano-characterization of PV materials. This requires correspondingly higher spatial resolution instrumentation and techniques to study the role of finer, less active structural defects on device performance. Imaging of the cell performance within the vicinity of these structural defects allows for near-field photocontrast mapping of features smaller than 200 nm.

High-Performance Photovoltaics—Explores the ultimate performance of PV technologies, aiming to approximately double their sunlight-to-electricity conversion efficiencies.

- Boeing Spectrolab demonstrated a 40,7 %-efficient GaInP/GaInAs/Ge cell that was verified by NREL at 236 suns. Researchers have been working toward the "40 % barrier" for the past two decades. In the 1980s, multijunction solar cells achieved about 16 % efficiency, and NREL broke the 30 % barrier in 1994. Today, most satellites use these multijunction solar cells, and Spectrolab, a subsidiary of The Boeing Company, recently produced its two millionth solar cell using this multijunction technology. The new Spectrolab cell, developed with DOE funding, could lead to more affordable solar power systems on Earth, costing as little as 3 USD/watt to install and producing electricity at a cost of 0,08 to 0,10 USD/KWh.
- Researchers investigated the design of shallower acceptors in ZnO. They proposed new concepts to overcome p-type doping difficulty in wide-gap semiconductors such as ZnO, which is an important transparent conducting oxide for solar cells. The researchers showed that by manipulating the wavefunction character of the defect states, they can design defect complexes that can significantly lower the acceptor transition energy levels, thus providing a new opportunity to make p-type ZnO.

Solar Resource Characterization—Addresses solar resource assessment including access to data and characterization of the solar resource.

- The NREL Pyrheliometer Comparison (NPC) was conducted at the Solar Radiation Research Laboratory (SRRL) September 25, 2006 through October 6, 2006. Calibration traceability to the World Radiometric Reference (WRR) is determined by the measurements from seven electrically self-calibrating absolute cavity radiometers maintained by the World Radiation Center in Davos, Switzerland. International Pyrheliometer Comparison in Davos transfers the WRR to regional and national calibration centers. NREL's reference radiometer group is the basis for each NPC and transfers the WRR to participants who bring their radiometers to the SRRL. The 2006 total was 34 participating radiometers operated by the 16 participants, including the National Aeronautics and Space Administration, National Oceanic and Atmospheric Administration, Environment Canada, Lockheed Martin, SNL, and Pacific Northwest National Laboratory.

*Fig. 3 - PV can be used in many ways to reduce electrical loads created by buildings. These PV shingles, developed with support from the U.S. DOE, can take the place of regular asphalt shingles (photo NREL).*

Environmental Health and Safety—Minimizes potential EH&S impacts associated with current and future PV energy systems and applications.

- At BNL, established a laboratory for studies on recycling of spent PV modules and manufacturing scrap, using hydrometallurgical separation technologies. Also, a patent application was approved related to separating Cd from Te in the CdTe recycling processes.

### Advanced Materials and Devices

The Advanced Materials and Devices effort carries out research in semiconductor material properties, device mechanisms, and fabrication processes to improve the efficiency, stability, and cost of PV. The effort focuses on thin films, module manufacturing methods, and module reliability. The following are Advanced Materials and Devices research areas and sample 2006 accomplishments.

Thin Film PV Partnership—Directs subcontracted and collaborative R&D in thin films including CIS and CIGS, CdTe, amorphous silicon, and film silicon.

- The Thin Film Center of Excellence (Institute of Energy Conversion, University of Delaware) provided both valuable insights and services. The Center implemented vapor transport deposition of CdTe solar cells and fabricated and analyzed 450 solar cells. A significant effort of their work has been to characterize the role of impurities (in the CdTe absorber and during "contacting") on cell performance.
- Two Technology Partners expanded manufacturing facilities in the United States (First Solar 85 MWp and Uni-Solar 60 MWp). A third Technology Partner, Global Solar, announced plans to expand in 2007.
- Production of thin films in the United States grew from 12 MWp in 2003 to an estimated more than 70 MWp in 2006.

PV Manufacturing R&D—Assists the U.S. PV industry through cost-shared manufacturing R&D.

- Completed the development (achieved manufacturing-line-ready status) of at least three in-line diagnostic processes initiated in FY 2002 awards from the In-Line Diagnostic, Intelligent Processing (IDIP) Solicitation, with at least five of the U.S. PV industry partnerships involved in the IDIP solicitation having reported a minimum of 22 in-line diagnostic processes that have been implemented on U.S. PV production lines.

PV Module Reliability R&D—Develops and applies advanced measurement techniques, diagnostic methods, and instrumentation to help mitigate degradation, reduce module costs, and improve performance. To conduct these activities, NREL and SNL develop and apply advanced measurement techniques, diagnostic methods, and instrumentation. The intent of this R&D is to optimize the time and funding applied to advancing module technologies from the prototype to the commercial production stage, with respect to meeting acceptable performance, reliability, and cost requirements.

- Upgraded and maintained accelerated module testing capabilities (e.g., environmental chamber upgrades, new hail gun) essential to industry partners, and made progress toward becoming an accredited Certified Testing Body Testing Laboratory (quality system development) in a Cooperative Research and Development Agreement with Underwriters Laboratories.
- Collaborated with numerous industry partners to develop new encapsulants, provide adhesion and water vapor transmission values, perform water ingress modeling, and provide infrared imaging for cracked cells and shunt problems.

Inverter and Balance-of-Systems (BOS) Development—Supports engineering advancements through characterization and validation feedback of newly developed power electronics and BOS hardware and establishes suitability for incorporation of new inverters, controllers, and BOS into integrated systems.

- Assessed 15 alpha and beta inverter and controller prototypes for conformity to utility interconnection requirements, performance objectives, and manufacturing objectives. The "High-Reliability Inverter Initiative" continued toward higher reliability at no increase in unit cost, namely, via the improvement of meantime between failures to more than 10 years. This advance has a significant positive impact on calculated levelised cost of energy of PV systems. Micro-inverter development unveiled significant design advances to address thermal and environmental failure modes.

### Technology Development

The Technology Development activity advances PV performance and systems engineering, improves systems reliability, and develops technology suitable for integration into residential and commercial building structures. The following are Technology Development research areas and sample 2006 accomplishments.

PV Systems Engineering—Characterizes performance and reliability of emerging PV technologies, assists with development and implementation of codes and standards, and provides world-class solar irradiance capabilities, measurements, and standards.

- The 2005 National Electrical Code (NEC) was published with the 42 changes proposed by the SNL "Industry Forum" with new allowances for ungrounded PV arrays and improved but relaxed disconnect requirements. Work on the 2008 NEC progressed to address new technology issues related to safety and installations.
- Los Angeles Department of Water and Power revised its solar energy

rebate program from one providing a rebate amount based on system size to one based on the estimated energy output predicted by NREL's PVWATTS. (http://rredc.nrel.gov/solar/codes_algs/PVWATTS/) Consequently, rebate amounts will now depend on parameters that determine energy production: size, tilt, azimuth, fixed or tracking, and location of the PV system.

System Evaluation and Optimization—Provides laboratory and field-test information to establish the performance and reliability of current PV systems and identifies opportunities for improved system design and component integration in next-generation systems.

- Operated the PV System Optimization Laboratory, which can perform detailed performance and long-term reliability research on 14 separate nominally 3-kW PV systems with multiple array/inverter combinations. Numerous new module and inverter technologies are being studied. Working with SNL, both General Electric and Xantrex are currently active in Phase III of the "High-Reliability Inverter Initiative" and have extensive and critically timed commercialization plans for the products developed out of this program. Xantrex expects to use the fundamental high-reliability design as a basis for its next-generation family of products. GE plans to vertically integrate its newly acquired PV module manufacturing capabilities with the new inverter development into its existing new-construction housing market.

Domestic PV Applications—Provides a focal point for DOE activities through developing projects, disseminating information, promoting public awareness, managing subcontracts, and providing technical assistance.

- The National Western Stock Show in Denver, Colorado, is recognized broadly as one of the foremost livestock shows and rodeos in the world. The Stock Show celebrated its 100th anniversary in 2006 and was heavily advertised in the local and regional media, leading to record attendance of more than 700 000. The event marked NREL's 11th year of hosting free workshops on renewable energy for the farmer, rancher, and homeowner. About 600 people attended these workshops. Farmers and ranchers, particularly in the large, remote ranches of the western United States, are pioneers in using PV and other renewables and are hungry to learn of the newest technologies.

Building-Integrated PV—Fosters widespread acceptance of PV-integrated buildings by overcoming technical and commercial barriers and facilitating the integration of PV into the built environment through technology development, applications, and key partnerships.

- Published a technical report detailing the 2005 Solar Decathlon university competition. The full report, which gives an overview of the competition, including final results, team strategies, and detailed descriptions of each home, is available on the Solar Decathlon Web site, www.eere.energy.gov/solar_decathlon. Early in 2006, DOE announced the selection of 20 teams for the 2007 Solar Decathlon, a competition to design and build energy-efficient solar homes. DOE will award each team 100 000 USD over the next two years. Sixteen of the teams are from 13 states—California, Colorado, Georgia, Illinois, Kansas, Maryland, Massachusetts, Michigan, Missouri, New York, Ohio, Pennsylvania, and Texas—and the remaining four are located in Puerto Rico, Canada, Germany, and Spain. This will be the first time that a team from Germany has participated in the competition.

PV System Analysis—Performs systems performance and cost modeling, market/value/policy analysis, and benchmarking projects.

- Expanded the number of default markets/systems included in the Solar Advisor Model and expanded partnered activities on commercial and utility-scale systems to further refine determinations of life-cycle cost, system reliability, and system availability. In addition, developed a working version of the Solar Deployment Systems model with an initial set of scenarios and expanded work on PV value analysis to include both identifying best practices and information sharing, aimed at helping to inform state-level policymaking.

Regional Experiment Stations—Provides technical support to the SETP, including reducing systems costs, improving systems reliability, improving system performance, and removing barriers to deployment.

- Four inverters were placed in service for long-term performance testing at two locations, the Southeast Regional Experiment Station in Cocoa, Florida, and the Southwest Regional Experiment Station in Las Cruces, New Mexico.
- Technical assistance and installer workshops to the industry and users have resulted in an evolving design review and approval standard that provides guidance for uniform designs and system documentation. This activity promotes a level of quality recognized and practiced by other industries that develop products in successful markets and advances domestic and international standards and codes.

### Outreach and Technology Transfer

The increased attention on clean energy technologies and a national push to reduce U.S. dependence on foreign oil brought many high-level visitors to the national laboratories in 2006. The roster of visitors included: President George Bush, Energy Secretary Samuel Bodman, and U.S. Senator Ken Salazar; dignitaries and industry representatives from China, France, India, Japan, Jordan, and Taiwan; and representatives from a range of U.S.-based organizations, such as building material manufacturers, financial analysts, major trade associations, and national TV networks.

## IMPLEMENTATION

### Industry Roadmap and Technical Plans

In 2003, the *U.S. PV Industry Roadmap* www.seia.org/roadmap.pdf, developed by the Solar Energy Industry Association (www.seia.org) with inputs from industry and university partners as well as the SETP, stipulated that "success of PV in the United States 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." (SEIA, 2003) In the time following the roadmap development, the SETP worked with industry to lay the groundwork for a "Systems-Driven Approach" (SDA). Goals for the SDA were established through a consensus approach among a broad set of engaged PV stakeholders. Since that time, however, this pragmatic approach to results-oriented R&D has evolved into the Solar America Initiative (mentioned previously). The market projections of the Initiative were established through computer modeling performed by DOE and present more conservative market growth estimates than industry. The SETP estimates that through the Initiative, PV will provide approximately 5–10 GW of electricity generating capacity by 2015 and 70–100 GW of U.S. electricity generating capacity by 2030.

### Federal and State Policies Promote PV

The *U.S. PV Industry Roadmap* states, "Effective policies sustained over time increase solar power production, dramatically grow markets, improve technology, and reduce costs." (SEIA, 2003) The success of well-known PV programs such as those in California and New Jersey have supported this statement. In the United States, policy activity at Federal and state levels to promote PV is increasing. In 2006, the Energy Policy Act of 2005 took effect and offered consumers and businesses Federal incentives for many renewable energy and energy efficiency technologies. The Act established a 30 % tax credit for qualified PV system expenditures to a maximum of 2 000 USD for equipment placed in service during 2006–2007. The U.S. PV industry was able to promote the extension of this incentive for one more year to 2008 and efforts are under way to promote extending and expanding the credit in future years.

An understanding of the regulatory environment in the United States is critical to understanding the market potential for PV. Despite the Federal tax credit that is currently available, the United States does not have a coordinated national program to develop PV markets. Net-metering standards dictate the value of PV and allow system owners to sell back electricity to the local utility (economic benefit). Interconnection standards provide uniformity across utility service territories and render the entire process transparent for installers and consumers (infrastructure benefit). A lack of consistent net-metering (economics) and interconnection (infrastructure) standards from state to state creates barriers to growth of the U.S. PV market. Despite these barriers, more than 20 states have renewable portfolio standards, requiring that a certain proportion of a utility's generating capacity or energy sales be derived from renewable resources. In 2006, Washington State passed an initiative mandating energy efficiency and renewable portfolio standards. The initiative calls for utilities to pursue all cost-effective conservation measures and to acquire 15 % of the energy delivered to customers from renewable energy by 2020. (www.secstate.wa.gov)

In Arizona, the state approved a requirement mandating that utilities acquire 15 % of the total energy delivered to their customers from renewable energy by 2025. (www.cc.state.az.us/) For more information on state incentive programs, see the Database of State Incentives for Renewable Energy at www.dsireusa.org.

California has moved to the forefront of the renewable energy development and greenhouse gas emission control with the creation of new initiatives. The most notable state PV incentive program is the California Solar Initiative (CSI). Enacted in 2005, the CSI is the biggest PV program in U.S. history in the largest PV market in the nation. In August 2006, Governor Arnold Schwarzenegger signed into law SB1, a critical piece of legislation to advance CSI. The original bill allotted 2,9 billion USD for solar energy rebates in California over 10 years. The goal is to increase the solar capacity installed on California rooftops by 3 000 MW by 2017. The initial PV incentive levels were set at 2,80 USD/watt effective January 1, 2006, to be reduced by an average of approximately 10 % annually. The latest bill in support of CSI added another 150 million USD to the Public Utility Commission's (PUC) proposed 3,2 billion USD. The increased funding will provide 50 million USD for R&D and 100 million USD in incentives for solar thermal technology. Other critical elements of the initiative involve systems of less than 100 kW, for which the PUC approved a 2,50 USD/watt subsidy for residential and commercial projects and 3,25 USD/watt for systems installed by governments and non-profits. According to the California PUC Web site, the CSI uses performance-based incentives for larger systems and "expected performance-based buydowns" for smaller systems as the basis for distributing the allocated funds in lieu of upfront rebates. For more information on the program, visit the California PUC Web site at www.cpuc.ca.gov.

The revised New Jersey Renewable Portfolio Standard (RPS) requires utilities to obtain 22,5 % of delivered power from qualifying renewable energy sources by 2021. The new RPS targets also include a 2,12 % solar set-aside estimated to be about 1 500 MW of PV by 2021. In 2006, 10 MW of grid-connected PV power was installed under the program. Recently, the New Jersey Board of Public Utilities determined that the current PV rebate program is not appropriately designed to meet the solar targets established in the bill and is looking at how best to shift from rebates to a performance-based approach. To learn more about the options the board is considering, please visit www.njcleanenergy.com.

It is likely that the adoption of performance-based incentives in California and New Jersey, the two largest PV markets in the United States, are the beginning of a growing trend around the country away from the more common upfront rebates based on the installed

*Fig. 4 - These building-integrated PV roof tiles were installed as part of a demonstration project with the City of Palo Alto, California (photo NREL).*

PV system capacity. Historically, the "rebate approach" has been used to offset the upfront installation cost of a system. Innovative subsidy programs that do not tie incentives to system size or manner of deployment are making the installation of building-integrated PV and large-scale solar farms more appealing. These incentives are being devised to encourage the design and construction of systems that maximize energy output. Economies of scale are also driving the development of larger PV system installations. In 2006, the United States saw several large systems completed in Massachusetts (500 kW in Brockton), California (910 kW in Oakland for the U.S. Postal Service), and Arizona (375 kW at the Luke Air Force Base). (Maycock, December 2006) In addition, SunEdison announced the development of the world's largest PV system installation for 18 MW at a Nevada Army base. (Maycock, March 2006) High-profile companies are also "going green" and raising the visibility of solar. In October 2006, the Internet search engine Google announced plans to build a 1,6 MW system at its corporate headquarters.

## INDUSTRY STATUS

According to *PV News*, U.S. PV cell production grew 30,9 % from 2005 to 2006, reaching 201,6 MW. This gowth, according to Prometheus Institute, was due mostly to increased production of First Solar (60 MW) while many other U.S. producers were effected by the polysilicon shortage. World cell production exceeded 2 500 MW-dc in 2006, a 40 % increase over 2005 (Maycock, 2007). Also, in 2006 Shell Solar sold its Camarillo, California, plant, a fully integrated single-crystal silicon facility, and its Washington State plant to SolarWorld. Shell Solar shifted its focus from silicon-based technology to thin films in Europe. At the same time, GE is continuing to rebuild the solar business purchased from AstroPower; and BP Solar, United Solar Ovonic, and First Solar all increased their U.S. cell production. Another U.S. company, Evergreen Solar, added significant new production in Germany. World production of PV cells exceeded 1 700 MW in 2005 in spite of tight feedstock supply (Maycock, March 2006).

A consequence of the rapid growth of PV has been the emergence of a solar-grade silicon supply shortage. This shortage is believed to be temporary, with new supplies and capacity coming on line between 2006 and 2008. In the meantime, however, this has created an opportunity for thin-film PV and concentrator technologies, which do not use polysilicon feedstock, to accelerate their move from the laboratory into manufacturing and large-scale production. Driven in large part by increases in electricity prices, concern about climate change, need for energy security, and pro-solar policies, the demand for PV and thus silicon is expected to continue to grow in the United States.

According to PV News, in 2006, PV installations in the United States experienced strong growth, with grid-tied systems growing by 60 % over 2005. According to Prometheus Institute and a study done by the Interstate Renewable Energy Council, 100 MWp dc of grid-tied PV were installed in 2006, up from 63,3 MWp dc in 2005 (Maycock, 2007).

## MARKET DEVELOPMENT

The Solar America Initiative, announced in 2006, represents the U.S. DOE's most comprehensive effort thus far in support of PV market development. The two-pronged approach to accelerating markets and bringing the cost of PV to grid parity by 2015 tackles technical and non-technical barriers to market transformation. This initiative is the largest PV commercialization effort to occur in the United States, based on (1) the scale and complexity of the formal alliances with industry, university, and non-governmental organizations to guide those efforts, and (2) the level of accountability by potential partners to perform the necessary work in conjunction with DOE.

The main objectives of U.S. market development efforts are to provide technical support in assisting market growth and to retrieve technical performance, cost, and reliability information from fielded applications. This information is fed back to researchers, providing direct, market-based data that can drive decisions. Deployment facilitation activities are geared to produce an impact on overall market volume across the spectrum of market sectors, including residential, commercial, industrial/utility, off-grid, and international.

In addition to the work of the SAI, the SETP addresses market deployment opportunities in a variety of ways. For example, DOE's Solar Decathlon brings college and university teams from around the world to compete in designing and building houses that demonstrate the benefits of solar technologies. The next Decathlon will occur in Washington, D.C., in October 2007 and promises to be the most exciting event yet with the inclusion of more international participants.

International partnerships also play a role in market development because much of domestically produced solar products are currently shipped overseas, and international solar markets will continue to grow in the foreseeable future. Therefore, knowledge and information from solar activities outside the United States continue to provide business opportunities to U.S. solar companies in developed markets, such as Japan and Europe, and developing markets, such as India and China. The SETP also supports the International Energy Agency (IEA), specifically through the IEA Photovoltaic Power System Implementing Agreement. Activities include technical assistance, demonstration of the technical feasibility of new technologies and applications,

training, development and promotion of norms and standards, and fostering business development, such as facilitation of joint-venture agreements between foreign and U.S. companies.

To facilitate continued market growth, the SAI Market Transformation work will focus on eliminating non-technical barriers for PV commercialization. Working groups are proposed to develop appropriate and reasonable codes, standards, and certification programs. In addition, the SETP focuses support on collaborative efforts with standards organizations, including the National Fire Protection Association, the Institute for Electrical and Electronic Engineers, the American Society for Testing Materials, Underwriters Laboratories, and the International Electrotechnical Commission. Specific opportunities in this arena are improved utility interconnection standards that include communications and controls for grid stabilization, a standardized communications protocol for inverters and system controllers, hardware certifications to improve consumer confidence, and standardized practices for certification of PV system designers and practitioners, assuring up-to-date knowledge on advances in technology, safety, or interconnect practices.

*Fig. 5 - The Solar Decathlon competition takes place on the Mall in Washington, D.C. (photo NREL).*

## FUTURE OUTLOOK

The U.S. PV industry believes that the next 10 years are critical for worldwide solar power development. This period will determine which nations reap the economic, environmental, security, and reliability values that solar power offers. Actions by government and industry will determine whether solar power is catapulted to a new level and whether the United States will regain its position at the forefront of solar power development. Investment decisions over the next decade for research, new manufacturing, and creating new markets will determine where solar power will thrive. (SEIA, 2003)

### Industry Targets and Projections

The Solar Energy Industry Association (SEIA), the U.S. trade association of the solar industry, convened an executive forum in 2006 to begin a dialogue about the shared vision of the industry's future. The executives that met forecasted a global PV market of 20 GW per year by 2015 and identified a high-end goal of 50 GW. According to an article by Rhone Resch (SEIA's Executive Director) in Photon International, to achieve this, the chief executive officers (CEOs) of the companies agreed to work together toward that ambitious goal. The CEOs also determined that the United States represents the largest untapped national market for PV and "that solar could represent 10 to 20 percent of incremental installed capacity in the U.S. by 2015". The group also concluded that grid parity for PV in the United States could be reached with a 50 % cost reduction over 10 years. To realize this vision, the group determined that "the PV industry must secure a long-term extension of the Federal investment tax credit (ITC), as well as long-term state incentives." (Photon International, August 2006) Sustained energy behind this vision will need to come from a unified industry voice coupled with strong communications strategies directed at key stakeholders, according to Resch. To learn more about SEIA's vision for the PV industry, please visit www.seia.org.

### Looking Ahead

The year 2007 represents a ramp-up of political discussions in preparation for the 2008 U.S. Presidential election. Energy security and climate change are bipartisan issues that have already been elevated to the top of the national political agenda. Diversification of energy sources and conservation are already emerging as common themes in security and climate discussions. As pro-solar policies are implemented at state and local government levels, PV is poised to become a bigger player in the energy mix. Government standards will have the potential to drive innovation and efficiency.

The efforts of the Solar America Initiative pay tribute to the potential of solar energy in the United States. The DOE Solar Program is working through concerted R&D efforts via public/private partnerships to reduce the cost of solar energy systems and to maximize solar energy's promise over the next 10 to 25 years. The aggressive goals of the SAI will require the involvement of new participants and unprecedented innovation. Solar energy represents an opportunity to diversify the U.S. energy portfolio using a clean energy source while creating jobs in high-tech manufacturing, installation, and operation of solar power equipment. Ultimately, the hard work and innovation of the PV industry and its collaborators will contribute to the growth of the U.S. economy and the clean energy industry in the 21st century.

Sources:

*Arizona Corporation Commission Website. www.cc.state.az.us/.*
*Accessed January 26, 2007.*

*California Public Utilities Commission Website. www.cpuc.ca.gov.*
*Accessed January 26, 2007.*

*EERE Network News, various 2006 issues. www.eere.energy.gov/news/enn.cfm*

*Go Solar California! Website. www.gosolarcalifornia.ca.gov/.*
*Accessed January 27, 2007.*

*Maycock, Paul. "PV News". Pace of Massive Solar Electric Systems Quickens.*
*Vol. 25/No. 12, p. 1. December 2006. www.pvenergy.com.*

*Maycock, Paul. "PV News". PV Cell Production. Vol. 25/No. 3, p. 14-5. March 2006.*
*www.pvenergy.com.*

*Maycock, Paul. "PV News". U.S. Market Analysis. Vol. 25/No. 5, p. 4-5. May 2006.*
*www.pvenergy.com.*

*New Jersey's Clean Energy Program Website. www.njcep.com.*
*Accessed January 27, 2007.*

*Resch, Rhone. "Photon International". SEIA's Viewpoint. p. 53. August 2006.*

*Solar Energy Industry Association. Our Solar Power Future:*
*The U.S. Photovoltaics Industry Roadmap. September 2003. www.seia.org.*

*Washington Secretary of State Web site. www.secstate.wa.gov.*
*Accessed January 26, 2007.*

*Wilkins, Frank. "SAI Overview". U.S. DOE Solar Energy Technologies Program.*
*SAI/TPP Chicago Technology Exchange Meeting. April 2006.*
*www1.eere.energy.gov/solar/solar_america/tpp_meeting_4-19-2006.html*

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

## OVERALL OBJECTIVE

Task 3 was established in 1993 to stimulate collaboration between IEA countries in order to improve the technical quality and cost-effectiveness of photovoltaic systems in stand-alone and island applications.
When the first programme (1993-1999) was approved, the stand-alone photovoltaic sector was largely comprised of solar home systems for rural electrification, remote 'off-grid' homes in industrialised countries and PV consumer goods. PV hybrid systems and niche off grid applications such as PV powered bus shelters were also being introduced in certain countries.
As part of this programme, a number of documents were published as information about installed stand-alone PV systems worldwide. These included a lessons learned book featuring case studies from each country, as well as a survey of PV programmes in developing countries.

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

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

### TASK 3 Aimed:

- To collect, analyse and disseminate information on the technical performance and cost structure of PV systems in these applications
- To share the knowledge and experience gained in monitoring selected national and international projects
- To provide guidelines for improvement of the design, construction and operation of photovoltaic power systems and subsystems
- To contribute to the development of improved photovoltaic systems and subsystems"

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

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

## SUBTASK 1: QUALITY ASSURANCE

### Activity 11: Critical Review of Implementation of Quality Assurance Schemes

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

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

To identify and establish practical performance assessment guidelines.

## SUBTASK 2: TECHNICAL ISSUES

### Activity 21: Hybrid Systems

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

### Activity 22: Storage Function

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

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

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

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

## PUBLICATIONS

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

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

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

## SCOPE FOR FUTURE ACTIVITIES

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

The newly proposed programme objective has lead to the initiation of the new Task 11, " PV Hybrid Systems within Mini-Grids;" which received approval for its Workplan at the 26th IEA PVPS ExCo Meeting, October 2005.

## DELIVERABLES - WHERE TO GET THEM?

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

## PARTICIPANTS

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

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

## CONTACT INFORMATION

For information, contact the former Task 3 Operating Agent or visit the IEA PVPS website.

Former Task 3 Operating Agent:
Mr. Philippe JACQUIN
PHK Consultants
17 bis, Rue Jean Marie Vianney
FR-69130 Ecully
Tel.: 33-(0) 4 78 33 3614
Fax: 33-(0) 4 78 33 3808
Email : philippe. jacquin@phkconsultants.com

# COMPLETED TASKS
# TASK 5: GRID INTERCONNECTION OF BUILDING INTEGRATED AND OTHER DISPERSED PHOTOVOLTAIC SYSTEMS

## OVERALL OBJECTIVE

The objective of Task 5 was to develop and verify technical requirements, which served as the technical guidelines for grid interconnection with building-integrated and other dispersed PV systems. The development of these technical requirements included safety and reliable linkage to the electric grid at the lowest possible cost. The systems to be considered were those connected with a low-voltage grid, which was typically of a size between one and fifty peak kilowatts. Task 5 was officially concluded in 2003.

## MEANS

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

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

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

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

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

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

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

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

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

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

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

## TASK 5 REPORTS AND WORKSHOP PROCEEDINGS:

Task 5 produced the following reports and workshop proceedings:

### Task 5 Reports

1. "Utility aspects of grid interconnected PV systems", IEA-PVPS T5-01: 1998, December 1998
2. "Demonstration tests of grid connected photovoltaic power systems", IEA-PVPS T5-02: 1999, March 1999
3. "Grid-connected photovoltaic power systems: Summary of Task V activities from 1993 to 1998", IEA-PVPS T5-03: 1999, March 1999
4. "PV system installation and grid-interconnection guideline in selected IEA countries", IEA-PVPS T5-04: 2001, November 2001
5. "Grid-connected photovoltaic power systems: Survey of inverter and related protection equipments", IEA-PVPS T5-05: 2002, December 2002
6. "International guideline for the certification of photovoltaic system components and grid-connected systems", IEA-PVPS T5-06: 2002, February 2002
7. "Probability of islanding in utility networks due to grid connected photovoltaic power systems", IEA-PVPS T5-07: 2002, September 2002
8. "Risk analysis of islanding of photovoltaic power systems within low voltage distribution networks", IEA-PVPS T5-08: 2002, March 2002
9. "Evaluation of islanding detection methods for photovoltaic utility-interactive power systems", IEA-PVPS T5-09: 2002, March 2002
10. "Impacts of power penetration from photovoltaic power systems in distribution networks", IEA-PVPS T5-10: 2002, February 2002
11. "Grid-connected photovoltaic power systems: Power value and capacity value of PV systems", IEA-PVPS T5-11: 2002, February 2002

### Task 5 Internal Reports (Open to Public)

1. "Grid-connected photovoltaic power systems: Status of existing guidelines and regulations in selected IEA member countries (Revised Version)", IEA-PVPS V-1-03, March 1998
2. "Information on electrical distribution systems in related IEA countries (Revised Version)", IEA-PVPS V-1-04, March 1998

### Proceedings of Final Task 5 Workshop

1. Introduction and table of contents
2. Flyer of the workshop
3. List of participants of the workshop
4. Final programme of the workshop
5. Key note speech
6. Islanding detection methods
7. Probability of islanding in power networks
8. Risk analysis of islanding
9. Conclusions of task V islanding studies
10. Recapitulation of first day
11. Overview of (inter)national interconnection guidelines for PV-systems
12. State of the art inverter technology and grid interconnection
13. Impacts of PV penetration in distribution networks
14. Power value and capacity of PV systems

### DELIVERABLES - Where to get them?

All reports are available for download at the IEA PVPS website: http://www.iea-pvps.org
A Task 5 CD-ROM including all the reports was published for distribution. This can be ordered at the contact address below.

## CONTACT INFORMATION

For information, contact the former Task 5 Chairman or visit the PVPS website:
For the Task 5 Chairman:
Mr Tadao ISHIKAWA
CRIEPI
2-11-1 Iwato-kita Komea-shi
JPN - 2018511, Tokyo
Email: ishikawa@criepi.denken.or.jp

# COMPLETED TASKS
# TASK 6 - DESIGN AND OPERATION OF MODULAR PHOTOVOLTAIC PLANTS FOR LARGE SCALE POWER GENERATION

## OVERALL OBJECTIVE

Task 6 officially completed its activities in May 1998. The main objective of this Task was to further develop large-scale modular photovoltaic plants for peaking and long-term baseload power generation in connection with the medium-voltage grid.

## MEANS

The Task 6 work was performed by structural engineers and PV industry experts. The work was structured into four sub-tasks, for a total of fifteen activities.

### SUBTASK 10: Review of Design and Construction Experiences of Large-Scale PV Plants

To perform, on the basis of the Paestum Workshop results, an in-depth review of existing large-scale PV plants aimed both to identify the remarkable technical solutions adopted in such plants and the main common criteria applied for their design, installation, operation, monitoring, and to perform a detailed cost analysis of the plants taken into account.

### SUBTASK 20: Review of Operational Experiences in Large-Scale PV Plants

To perform, also utilising the work in progress of Subtask 10 and on the basis of the Paestum Workshop results, an in-depth review of operational experiences in existing large-scale PV plants. The analysis of the acquired data was focused on the comparison between the expected and actual results, both technical and economical; the information flow was continuously updated through acquisition of data from all the plants in operation.

### SUBTASK 30: Development of Improved System Design and Operational Strategies for Large-Scale PV Plants

Based on the work of Subtasks 10 and 20, the evaluation work, together with the information gathering activity, let the assessment of most appropriate, innovative technical options for modular design of large-scale PV plants. Both PV and BOS components were dealt with, taking into account: performances improvement, costs reduction, and realisation simplification.

The co-operation among utilities and industries of many countries offered the opportunity to review in detail the performance data and the technical aspects which determined the design approach of the largest PV plants in the world, and to develop improved system design, and operational strategies for such plants.

### SUBTASK 40: Outlook of Perspectives of Large-Scale PV Plants

Based on the assumption that large grid connected PV power plants have proven their applicability under the technical point of view, the Subtask was aimed at identifying the path in order to let such plants become a substantial option and play an increasing role in a future oriented energy concept in OECD countries, as well as in developing countries.

## TASK 6 REPORTS AND WORKSHOP PROCEEDINGS

Task 6 produced the following reports and workshop proceedings from 1993 to 1998:

1. The Proceedings of the Paestrum Workshop.
2. A PV Plant Comparison of 15 plants.
3. The State of the Art of: High Efficiency, High Voltage, Easily Installed Modules for the Japanese Market.
4. A document on “Criteria and Recommendations for Acceptance Test.”
5. A paper entitled: “Methods to Reduce Mismatch Losses.”
6. Report of questionnaires in the form of a small book containing organized information collected through questionnaires integrated with statistical data of the main system parameters and of the main performance indices.
7. The “Guidebook for Practical Design of Large Scale Power Generation Plant,” edited by the Japanese expert.
8. The “Review of Medium to Large Scale Modular PV Plants Worldwide.”
9. Proceedings of the Madrid Workshop.

### DELIVERABLES - Where to get them?

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

## CONTACT INFORMATION

For information contact the former Operating Agent of Task 6 of visit the IEA PVPS website:

Mr Alberto Iliceto
CESI S.p.A.- SFR/ERI
Via Rubattino, 54
20134 Milano
Italy
Fax: +39 (0)2 2125.5626
Email: iliceto@cesi.it
Web: http://www.cesi.it

# COMPLETED TASKS
# TASK 7 - PHOTOVOLTAIC POWER SYSTEMS IN THE BUILT ENVIRONMENT

## OVERALL OBJECTIVE

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

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

For this, active involvement of urban planners, architects and building engineers is required. Task 7 motivated the collaboration between these groups and PV system specialists, utility specialists, PV and building industry and other professionals involved in photovoltaics.

Task 7 considered all grid connected systems other than classified as "ground based arrays". Primary focus of this Task was on the integration of PV into the architectural design of roofs and facades of residential, commercial and industrial buildings and other structures in the built environment (such as noise barriers, parking areas and railway canopies), and on other market factors, both technical and non-technical, that need to be addressed and resolved before wide spread adoption of PV in the built environment will occur. Task 7 officially started on January 1, 1997 and finished end 2001. In 2002, the last reports and deliverables were published. At the end of 2003 there remained only one outstanding issue: the publication of the book "Designing with Solar Power". This book is expected in Spring 2005.

### SUBTASK 1: Architectural Design of Photovoltaic Power Systems in the Built Environment

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

### SUBTASK 2: Systems Technologies for Photovoltaic Power Systems in the Built Environment

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

### SUBTASK 3: Non-Technical Barriers in the Introduction of Photovoltaic Power Systems in the Built Environment

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

### SUBTASK 4: Demonstration and Dissemination of Photovoltaic Power Systems in the Built Environment

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

## TASK 7 REPORTS

Task 7 produced the following reports from 1999 to 2002:

1. Literature Survey and Analysis of Non-technical Problems for the Introduction of BIPV Systems, B. van Mierlo & B. Oudshoff, IVAM Environmental Research, 1999. To be ordered at IVAM Environmental Research, NL, Fax + 31 20 525 58 50
2. PV in Non Building Structures - A Design Guide, M.A. Romero, EcoCode-Miljö och Architectur, 1999. To be ordered at Energiebanken, SE, Fax: +46 652 13 427
3. Potential for Building Integrated Photovoltaics, M. Gutschner, Nowak Energy Technologies AG, 2001. To be ordered at NET, CH, Fax: +41 26 49 40 034
4. Guidelines for the Economic Evaluation of Building Integrated Photovoltaics, P. Eiffert, National Renewable Energy Laboratories, 2002. To be ordered at NREL, USA, website: www.nrel.gov/buildings/highperformance.
5. Market Deployement Strategies for Photovoltaics in the Built Environment, R. Haas, Technische Universität Wien, 2002. To be ordered at Technische Universität Wien, AT, Fax: +43 1 588 013 7397
6. Innovative electric concepts, H. Wilk, Energie AG, 2002. To be ordered at Energie AG, AT, Fax: +43732 9000 3309
7. Reliability of Photovoltaic Systems, H. Laukamp, Fraunhofer Institute für Solar Energiesysteme, 2002. To be ordered at Fraunhofer Institute für Solar Energiesysteme, GE, Fax: +49 761 4588 217
8. PV/Thermal Solar Energy Systems, Status of the Technology and Roadmap for future Development, H. Sorensen, Esbensen Consulting, 2002, To be ordered at Esbensen Consulting Engineers, DK, Fax: +45 33 26 73 01

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

## DELIVERABLES - Where to get them?

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

Task 7, Project Results and Documents.
To be ordered at:
Novem, Publication Centre
PO Box 8242
3503 RE Utrecht
The Netherlands
Tel.: +31 30 2393493
Email: publicatiecentrum@novem.nl.

Task 7 book: Designing With Solar Power"
To be ordered at:
The Images Publishing Group Pty Ltd
6 Bastow Place
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.

## CONTACT INFORMATION

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

Former Task 7 Operating Agent:
Mr van Schalkwijk
Ecofys, Utrecht, the Netherlands
Email: M.vanSchalkwijk@ecofys.nl

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

# ANNEX A

## IEA – PVPS EXECUTIVE COMMITTEE

### AUSTRALIA

Mrs Muriel WATT
Senior Lecturer
School of PV & Renewable Energy Engineering
University of NSW
AUS - Sydney NSW 2052
Tel: 61(0)2 9385 4257
Fax: 61(0)2 9385 5412
m.watt@unsw.edu.au

Mr Wolfgang MEIKE - Alternate
Managing Director
Novolta
GPO Box 2518
AUS - Darwin NT 0801
Tel: 61(0)8 8945 2958
Fax: 61(0)8 8945 0920
wolfgang.meike@novolta.com.au

### AUSTRIA

Mr Hubert FECHNER
arsenal research
Business Unit Renewable Energy
Giefinggasse 2
AUT - 1210 Vienna
Tel: 43(0)505 50 62 99
Fax: 43(0)505 50 63 90
hubert.fechner@arsenal.ac.at

Mr Heinrich WILK - Alternate
Energie AG
Böhmerwaldstrasse 3
AUT - 4020 Linz
Tel: 43(0)732 900 03514
Fax: 43(0)732 900 03309
heinrich.wilk@energieag.at

### CANADA

Mr Josef AYOUB
CANMET-Energy Technology Center
Natural Resources Canada
1615, Montée Lionel-Boulet
CAN-Varennes, Québec, J3X 1S6
Tel: 1(0)450 65 21 981
Fax: 1(0)450 65 25 177
jayoub@nrcan.gc.ca

Mrs Lisa DIGNARD-BAILEY- Alternate
CANMET-Energy Technology Center
Natural Resources Canada
1615, Montée Lionel-Boulet
CAN - Varennes, Québec, J3X 1S6
Tel: 1(0)450 65 25 161
Fax: 1(0)450 65 25 17 7
lisa.dignard@nrcan.gc.ca

### DENMARK

Mr Flemming KRISTENSEN
EnergiMidt A/S
Soendergade, 27
DK - 8740 Braedstrup
Tel: 45(0)7015 1560
Fax: 45(0)7658 1111
fvk@energimidt.dk

Mr Peter AHM - Alternate
Director, PA Energy A/S
Snovdrupvej 16
DK - 8340 Malling
Tel: 45(0)86 93 33 33
Fax: 45(0)86 93 36 05
ahm@paenergy.dk

### EUROPEAN UNION

Mr David ANDERSON
European Commission - DG Research
Unit K3: New & Renewable Energy Sources
Office: CDMA 0/171
Rue du Champ de Mars, 21
B-1049, Brussels, Belgium
Tel: +32 229 99959
Fax: +32 229 94991
David.ANDERSON@ec.europa.eu

Mr Pietro MENNA
European Commission
Office:DM24 3/116
B-1049 Brussels, Belgium
Tel: 32(0)2 295 45 12
Fax: 32(0)2 296 62 21
Pietro.MENNA@ec.europa.eu

## EPIA

Ms Eleni DESPOTOU
European Photovoltaic Industry Association
Rue d'Arlon 63-65
B-1040 Brussels
Tel: 32(0)2 465 38 84
Fax: 32(0)2 400 10 10
pol@epia.org

## FRANCE

Mr André CLAVERIE
ADEME
Renewable Energies Division
500, Route des Lucioles
FRA - 06560 Sophia Antipolis
Tel: 33(0)4 93 95 79 13
Fax: 33(0)4 93 65 31 96
andre.claverie@ademe.fr

## GERMANY

Mr Christoph HÜNNEKES- Deputy Chairman
Forschungszentrum Jülich GmbH
Projektträger Jülich - EEN
DEU - 52425 Jülich
Tel: 49(0)2461 61 22 27
Fax: 49(0)2461 61 28 40
ch.huennekes@fz-juelich.de

Mr Lothar WISSING - Alternate
Forschungszentrum Jülich GmbH
Projektträger Jülich - EEN
DEU - 52425 Jülich
Tel: 49(0)2461 61 48 43
Fax: 49(0)2461 61 28 40
l.wissing@fz-juelich.de

## ISRAEL

Mr Avraham ARBIB
Deputy Chief Scientist and Director,
Division of R&D, Ministry of National
Infrastructures, Israel
P.O.Box 36148
ISR- 91360 Jerusalem
Tel: 972(0)2 53 16 12 7/8
Fax: 972(0)2 5316017
aarbib@mni.gov.il

## ITALY

Mr Saverio LI CAUSI
ENEA - Casaccia
Via Anguillarese, 301
ITA - 00060 S.Maria di Galeria - RM
Tel: 39(0)6 3048 4110
Fax: 39(0)6 3048 4346
licausi@casaccia.enea.it

Mr Fausto SANSON
CESI RICERCA S.p.A.
via Rubattino, 54
ITA 20134 Milano
Tel: 39(0)2 3992 5710
Fax: 39(0)2 3992 5626
fausto.sanson@cesiricerca.it

Mr S. GUASTELLA - Alternate
CESI RICERCA S.p.A.
via Rubattino, 54
ITA 20134 Milano
Tel: 39(0)2 3992 5691
Fax: 39(0)2 3992 5626
salvatore.guastella@cesiricerca.it

## JAPAN

Mr. Koji MATSUBARA
Koji Matsubara, Dr. Eng.
Director for Solar Cell and System Technology
New Energy Technology Development Department
New Energy and Industrial Technology Development Organization (NEDO)
18F Muza Kawasaki Building, 1310, Omiya-cho, Saiwai-ku,
Kawasaki City Kanagawa
JPN - 212-8554
Tel: +81-44 520 5277
Fax: +81-44 520 5276
matsubarakoj@nedo.go.jp

## KOREA

Mr Jinsoo SONG
KIER, Renewable Energy Research Dept.
71-2, Jang-Dong, Yusong-Gu
KOR - Taejon 350-343
Tel: 82(0)42 86 03 738
Fax: 82(0)42 86 03 739
jsong@kier.re.kr

## MEXICO

Mr Jaime AGREDANO DIAZ
Instituto de Investigaciones Electricas -
Energías no Convencionales
Avenida Reforma n 113
Colonia Palmira
MEX - 62490 Temixco, Morelos
Tel: 52(0)777 362 38 11 ext. 7771
Fax: 52(0)777 362 38 08
agredano@iie.org.mx

Mr Jorge M. HUACUZ VILLAMAR- Alternate
Instituto de Investigaciones Electricas -
Energías no convencionales
Avenida Reforma n 113
Colonia Palmira
MEX - 62490 Temixco, Morelos
Tel: 52(0)777 318 38 06
Fax: 52(0)777 318 38 08
jhuacuz@iie.org.mx

## NETHERLANDS

Mr Willem VAN DER HEUL
Ministry of Economic Affairs
P.O. Box 20101
NLD - 2500 EC Den Haag
Tel: 31(0)70 37 96 413
Fax: 31(0)70 37 96 872
w.vanderheul@minez.nl

Mr Job SWENS - Alternate
SenterNovem Utrecht
P.O. Box 8242
NLD - 3503 RE Utrecht
Tel: 31(0)30 239 3744
Fax: 31(0)30 2316491
j.swens@senternovem.nl

## NORWAY

Mr Harald RIKHEIM
The Research Council of Norway
P.O. Box 2700
St. Hanshaugen
N - 0131 Oslo
Tel: 47(0)22 03 74 96
Fax: 47(0)22 03 74 61
hri@forskningsradet.no

Mr Knut-Erik MADSEN- Alternate
E-CO Energi AS
P.O. Box 255- Sentrum
NOR - 0103 OSLO
Tel: 47(0)24 1169 05
Fax: 47(0)24 11 69 01
knuterik.madsen@e-co.no

## PORTUGAL

Mr Pedro SASSETTI-PAES
EDP - Energias de Portugal, S.A.
Praça Marquês de Pombal, 13
PRT - 1250-162 Lisboa
Tel: 351(0)21 002 11 73
Fax: 351(0)21 002 11 69
pedro.paes@edp.pt

## SPAIN

Mr Javier SANZ
CENER
Ciudad de la Innovación
ESP - 31621 Sarriguren-Navarra
Tel: 34(0)948252800
Fax: 34(0)948270774
jsanz@cener.com

## SWEDEN

Mrs Maria HALL
Ministry of Enterprise, Energy
and Communications
Division for Energy
SE -103 33 Stockholm
Tel: 46 (0)8-405 40 32
Fax: 46 (0)8-543 56 977
maria.i.hall@enterprise.ministry.se

Mrs Monika ADSTEN - Alternate
ELFORSK
Olof Palmes gata 31
SE - 10153 Stockholm
Tel: 46(0)8 677 27 35
Fax: 46(0)8 677 25 35
monika.adsten@elforsk.se

## SWITZERLAND

Mr Stefan NOWAK -Chairman
NET - Ltd.
Waldweg 8
CHE - 1717 St. Ursen
Tel: 41(0)26 49 40 03 0
Fax: 41(0)26 49 40 03 4
stefan.nowak@netenergy.ch

## TURKEY

MR. Siddik ICLI
Solar Energy Institute
Ege University, Bornova
TUR- 35100 Bornova - Izmir
Tel: 90 (0)232-388 6025
Fax: 90 (0)232-388 6027
siddik.icli@ege.edu.tr

## UNITED KINGDOM

Mr Paul ROCHESTER
Assistant Director
Building and Community Renewables
Department of Trade and Industry
1 Victoria Street
UK - SW1H 0ET London, England
Tel: 02(0)7 215 6389
Fax: 02(0)7215 0139
paul.rochester@dti.gsi.gov.uk

## USA

Mr Robert HASSETT
U.S. Department of Energy
Office of Energy Efficiency
and Renewable Energy
Solar Technologies Program
1000 Independence Avenue S.W.
USA - Washington, DC 20585 -0121
Tel: 1(0)202 58 6816 3
Fax: 1(0)202 58 6814 8
robert.hassett@ee.doe.gov

Mr Ward BOWER – Alternate
Sandia National Laboratories
Solar Technologies
Dept. 6337 – MS1110
USA – Albuquerque, New Mexico 87185-1110
Tel: 1(0)505 844 5206
Fax: 1(0)505 284 2529
wibower@sandia.gov

## EXCO SECRETARY

Mrs Mary Jo BRUNISHOLZ
NET - Ltd.
Waldweg 8
CHE - 1717 St. Ursen
Tel: 41(0)26 49 40 03 0
Fax: 41(0)26 29 40 03 4
mary.brunisholz.@netenergy.ch

## WEBSITE

Mrs Irene DE JONG
OJA Services
Keizerstraat 121
NLD- 2584 BD DEN HAAG
Tel: 31(0)6 5314 32 69
irene@oja-services.nl

# ANNEX B

IEA - PVPS OPERATING AGENTS

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

Mr Greg WATT
Australian PVPS Consortium
P.O. Box 146
AUS - Wauchope NSW 2446
Tel: 61(0)2 6587 6116
gwatt@efa.com.au

## TASK 2 - PERFORMANCE, RELIABILITY AND ANALYSIS OF PHOTOVOLTAIC SYSTEMS

Mrs Ulrike JAHN
Bavarian Center for Applied Energy Research (ZAE Bayern)
Am Weichselgarten 7
DEU - 91058 Erlangen
Tel: 49(0)9131 691295
Fax: 49(0)9131 691181
Email: jahn@zae.uni-erlangen.de

## TASK 8 - STUDY ON VERY LARGE SCALE PV POWER GENERATION SYSTEMS

Prof Kosuke KUROKAWA
Tokyo University of Agriculture and Technology
2-24-16 Naka-cho, Koganei-shi, Tokyo
JPN - 184-8588
Tel & Fax: 81(0) 423 88 7132
kurochan@cc.tuat.ac.jp

Mr. Keiichi KOMOTO – Alternate
Mizuho Information & Research Institute Inc.
Environment, Natural Resources and Energy
3-1 Kanda-Nishiki-cho, Chiyoda-ku, Tokyo
JPN - 101-0054, Japan
Tel: 81(0)3 5281 5295
Fax: 81(0)3 5281 5466
keiichi.komoto@mizuho-ir.co.jp

### Task 8 Observer:

Mr Masanori ISHIMURA
Photovoltaic Power Generation Technology Research Association (PVTEC)
Nissay Takanawa Bldg. No.2
16-37 Takanawa 2-chome, Minato-ku, Tokyo
JPN - 108-0074
Tel: 81-3-5447-0460
Fax: 81-3-5447-0464
pvtec-ishimura@asahi.email.ne.jp

## TASK 9 - PHOTOVOLTAIC SERVICES FOR DEVELOPING COUNTRIES

Mr Bernard McNELIS
Managing Director
IT Power
Grove House
Lutyens Close
Chineham, Hampshire
UK - RG24 8AG
Tel: 44(0)12 56 39 27 00
Fax: 44(0)12 56 39 27 01
bernard.mcnelis@itpower.co.uk

## TASK 10 - URBAN SCALE PV APPLICATIONS

Ms Christy HERIG
Segue Energy Consulting, LLC
17609 First Street E.
USA - Redington Shores, FL 33708
Tel: 1(0)727 543 1285
Fax: 1(0)727 319 2405
cherig@tampabay.rr.com

## TASK 11 - PV HYBRID SYSTEMS WITHIN MINI-GRIDS

Mr Konrad MAUCH
KM Technical Services
1358 Sea Lovers Lane
CAN - Gabriola BC V0R 1X5
Tel: 1(0)250 247 9577
konrad.mauch@ieee.org

# COLOPHON

Cover Photograph
Josef Troxler
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 1200 copies by
Imprimerie St-Paul, Fribourg, Switzerland