IEA INTERNATIONAL ENERGY AGENCY

PHOTOVOLTAIC POWER SYSTEMS PROGRAMME

PVPS

annual report 2014

IMPLEMENTING AGREEMENT
ON PHOTOVOLTAIC POWER SYSTEMS

PHOTOVOLTAIC POWER SYSTEMS PROGRAMME

ANNUAL REPORT 2014

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CHAIRMAN'S MESSAGE

On behalf of the IEA Photovoltaic Power Systems Programme IEA PVPS, I am pleased to present our 2014 annual report. Electricity from solar photovoltaic (PV) power systems has continued to grow all around the globe achieving, for the first time in history, more than 1 % of the annual global electricity demand. Although this number may still appear as small, it represents a tremendous development of the past years, much faster than all predictions had forecasted, be it from the IEA all the way to Greenpeace. Along with this important market growth, PV has further gained in cost-competitiveness and has become one of the least cost options of renewable electricity, achieving remarkable levelized costs of electricity as low as below 6 USDcents/kWh in the best cases.

2014 has seen another roughly 40 GW of installed PV capacity worldwide, raising the cumulative installed capacity close to 180 GW. At the same time, the somewhat slower pace of the global growth observed in the past years has been confirmed and reflects important changes in the regional development of PV markets. Europe, the most important driver of the global PV market over the past ten years, has further slowed down whereas Asia and the USA have seen further market growth with China, Japan and the USA representing the largest markets in 2014. Most importantly, the PV markets have continued to expand to a broader range of countries with substantial market size. The important market growth and cost reductions observed over the past years have brought PV to the situation where it is affecting electricity markets, both technically as well as economically.

The recent PV technology, industry and market development and the future prospects of these are setting the scene for the activities within the IEA PVPS Programme. As a leading and unique network of expertise, IEA PVPS has the mission to cooperate on a global level in this rapidly evolving technology area. Working on both technical and non-technical issues, IEA PVPS undertakes key collaborative projects related to technology and performance assessment, cost reduction, best practice in various applications, rapid deployment of photovoltaics and key issues such as grid integration and environmental aspects. Furthermore, anticipating the future needs, IEA PVPS increasingly focuses on new business models, sustainable policy frameworks as well as technical and market related integration of photovoltaics in the electricity system. In 2014, under the leadership of the Netherlands, a new Task 15 on accelerating building integrated photovoltaics (BIPV) was decided by the Executive Committee.

Providing high-quality information about relevant developments in the photovoltaic sector as well as policy advice to our key stakeholders remain our highest priorities. Due to the increasing recognition of photovoltaics as an important future energy technology, the interest in the work performed within IEA PVPS is constantly expanding. Throughout 2014, IEA PVPS has been in close contact with the IEA Secretariat, there by contributing to the latest IEA publications, such as the new IEA PV roadmap.

Interest and outreach for new membership within IEA PVPS continued in 2014. Thailand has joined IEA PVPS as the 29th member. I welcome Thailand as the most recent IEA PVPS member and look forward to a long and fruitful cooperation. Contacts have continued with Chile, Finland, Greece, India, Morocco, New Zealand, Singapore and South Africa as well as with EPRI (Electric Power Research Institute USA) and ECREEE (ECOWAS Regional Centre for Renewable Energy and Energy Efficiency). IEA PVPS continues to cover the majority of countries active in development, production and installation of photovoltaic power systems.

The overall communication and dissemination efforts were continued through systematic distribution of PVPS products at conferences, workshops and by means of direct mailings. Communication was further supported by the PVPS website www.iea-pvps.org and targeted press work. Moreover, the IEA PVPS booth and the workshops at the 29th European Photovoltaic Solar Energy Conference in Amsterdam (The Netherlands) attracted a large number of visitors and provided an excellent forum for dissemination purposes. Thanks to our hosts from Japan, a special joint PVPS meeting and discussion opportunity was provided alongside the 6th World Conference on Photovoltaic Energy Conversion in Kyoto (Japan).

The detailed outcomes of the different PVPS projects are given in the Task reports of this annual report and all publications can be found at the PVPS website. Several of the more recent IEA PVPS Tasks have produced important new publications. The current status of photovoltaics in the PVPS member countries is described within the country section of this annual report.

With this, I take the opportunity to thank all Executive Committee members, Operating Agents and Task Experts, for their dedicated efforts and contributions to IEA PVPS.

Stefan Nowak
Chairman

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PHOTOVOLTAIC POWER SYSTEMS PROGRAMME

IEA

The International Energy Agency (IEA), founded in November 1974, is an autonomous body within the framework of the Organization for Economic Cooperation and Development (OECD), which carries out a comprehensive programme of energy cooperation among its member countries. The European Union also participates in the IEA's work. Collaboration in research, development and demonstration (RD&D) of energy technologies has been an important part of the Agency's Programme.

The IEA RD&D activities are headed by the Committee on Research and Technology (CERT), supported by the IEA secretariat staff, with headquarters in Paris. In addition, four Working Parties on End Use, Renewable Energy, Fossil Fuels and Fusion Power, are charged with monitoring the various collaborative energy agreements, identifying new areas of cooperation and advising the CERT on policy matters. The Renewable Energy Working Party (REWP) oversees the work of ten renewable energy agreements and is supported by a Renewable Energy Division 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 and organisation, while the management of individual research projects (Tasks) is the responsibility of Operating Agents. By late 2014, fifteen Tasks were established within the PVPS programme, of which six are currently operational.

The twenty-nine PVPS members are: Australia, Austria, Belgium, Canada, the Copper Alliance, China, Denmark, EPIA, European Union, France, Germany, Israel, Italy, Japan, Korea, Malaysia, Mexico, the Netherlands, Norway, Portugal, SEIA, SEPA, Spain, Sweden, Switzerland, Thailand, Turkey, the United Kingdom and the United States of America. Thailand joined PVPS in 2014.

IEA PVPS CURRENT TERM (2013 – 2017)

As one of the few truly global networks in the field of PV, IEA PVPS can take a high level, strategic view of the issues surrounding the continued development of PV technologies and markets, thus paving the way for appropriate government and industry activity. Within the last few years, photovoltaics has evolved from a niche technology to an energy technology with significant contributions to the electricity supply in several countries. IEA PVPS is using its current term to put particular emphasis on:

- Supporting the transition and market transformation towards self-sustained PV markets;
- Working with a broader set of stakeholders, especially from utilities, financiers and industry;
- Assessing and sharing experience on new business approaches and business models;
- Providing targeted and objective information on PV energy services for successful implementation and high penetration;
- Providing a recognised, high-quality reference network for the global development of PV and related matters;
- Attracting new participants from non-IEA countries where PV can play a key role in energy supply.
- Carrying out relevant activities of multinational interest;
- Specifically, IEA PVPS will carry out collaborative activities related to photovoltaics on the topics: Quality and reliability, environmental aspects, grid integration, urban, hybrid and very large-scale systems, off-grid energy services, policy and regulatory frameworks, as well as a broad set of information and communication efforts;
- Finally, where appropriate from an energy system point of view, IEA PVPS will increase the efforts to share its results and cooperate with stakeholders from other energy technologies and sectors.

The overall desired outcomes of the co-operation within IEA PVPS are:

- A global reference on PV for policy and industry decision makers from PVPS member countries and bodies, non-member countries and international organisations;
- A global network of expertise for information exchange and analysis concerning the most relevant technical and non-technical issues towards sustainable large-scale deployment of PV;
- An impartial and reliable source of information for PV experts and non-experts about worldwide trends, markets and costs;
- Meaningful guidelines and recommended practices for state-of-the-art PV applications to meet the needs of planners, installers and system owners. Data collected and the lessons learned are distributed widely via reports, internet, workshops and other means;
- Advancing the understanding and solutions for integration of PV power systems in utility distribution grids; in particular, peak power contribution, competition with retail electricity prices, high penetration of PV systems and smart grids. Monitoring these developments and giving advice from lessons learned will be increasingly useful for many parties involved.
- Establish a fruitful co-operation between expert groups on decentralised power supply in both developed and emerging countries;
- Overview of successful business models in various market segments;
- Definition of regulatory and policy parameters for long term sustainable and cost effective PV markets to operate.

IEA PVPS MISSION

The mission of the IEA PVPS programme is:

To enhance the international collaborative efforts which facilitate the role of photovoltaic solar energy as a cornerstone in the transition to sustainable energy systems.

The underlying assumption is that the market for PV systems is rapidly expanding to significant penetrations in grid-connected markets in an increasing number of countries, connected to both the distribution network and the central transmission network.

This strong market expansion requires the availability of and access to reliable information on the performance and sustainability of PV systems, technical and design guidelines, planning methods, financing, etc., to be shared with the various actors. In particular, the high penetration of PV into main grids requires the development of new grid and PV inverter management strategies, greater focus on solar forecasting and storage, as well as investigations of the economic and technological impact on the whole energy system. New PV business models need to be developed, as the decentralised character of photovoltaics shifts the responsibility for energy generation more into the hands of private owners, municipalities, cities and regions.

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, contributing to sustainability in the energy system and a growing contribution to CO2 mitigation:

1. PV Technology Development

Mainstream deployment of PV is in its infancy and will continue to need technology development at the PV module and system levels in order to integrate seamlessly with energy systems around the world. Performance improvements, specialised products and further cost reductions are still required. In addition, renewable energy based technologies, such as PV, by definition rely on the natural cycles of the earth's energy systems and their output therefore varies with the hourly, daily and seasonal cycles of sun, wind and water. This contrasts with energy supplies based on fossil fuels and nuclear, where the energy source is stored and thus available when required. As renewables contribute increasingly to mainstream electricity supply, the need to balance varying renewable energy inputs to meet demand also increases. For optimised PV deployment, this means that synergies with other renewables as well as storage, forecasting and demand-side related activities will become more important and suitable technology development will be required.

IEA PVPS shall:

- Evaluate and validate emerging PV technologies that are still at pre-commercial level and to provide guidelines for improvement of the design, construction and operation of photovoltaic power systems and subsystems to increase reliability and performance and to minimise cost;
- Contribute to the development of new standards, accreditation and approval processes, objective operational experience, grid interconnection-standards; investigation of barriers and communication of success stories;
- Assess the impact of PV on distribution networks, in mini- and micro-grids as well as in other applications and provide analysis of the issues and possible solutions;
- Examine the use of demand management and storage as elements in optimisation of renewable energy system deployment;
- Identify technical opportunities and provide best practice for emerging applications (non-domestic systems, community systems, hybrids, mini-grids, weak grids);
- Foster industry – academia interaction focusing on PV technology development.

2. Competitive PV Markets

Until recently, PV mainly relied on support schemes provided by governments or aid organisations. Within the next few years, the transition towards PV as a competitive energy source will need to take place in most of the energy markets. Therefore, this process needs to be accompanied by reliable information and credible recommendations.

IEA PVPS aims:

- To assess economic performance of PV across member countries and undertake collaborative research to overcome current issues;
- To develop material that will assist in the development of standardised contractual agreements between PV system owners and utilities;
- To encourage private and public sector investments that facilitate the sustainable deployment of PV in new markets and within mainstream energy markets;
- To investigate the synergies between PV and other renewables for optimum power supply in different regions;
- To stimulate the awareness and interest of national, multilateral and bilateral agencies and development and investment banks in the new market structures and financing requirements for economic deployment of PV systems;
- To collate information and prepare reports on market structures suitable for long term sustainable PV deployment;
- To identify economic opportunities as well as promising business models and provide best practice examples for emerging applications (non-domestic systems, community systems, hybrids, mini-grids, weak grids);
- To evaluate and promote "bankability" and innovative business models in PV projects namely:
  - Identifying criteria banks / financiers use in order to determine the terms of potential funding of projects (now and in the future, after the end of subsidized tariffs);
  - Identifying and evaluating insurance or innovative bridging products that would allow banks / financiers to fund more projects and apply better conditions;
  - Identifying, characterizing and potentially develop innovative business models in the PV sector aiming at the definition of clear market rules and legislation that potentiates such business models.

44th IEA PVPS ExCo meeting, Kyoto, Japan, 2014.

3. An Environmentally and Economically Sustainable PV Industry

The PV industry, even though with many years of experience, is still in its juvenile phase. The huge market growth in recent years needs to be followed by a phase of consolidation. IEA PVPS shall contribute to sustainable industry development around the globe. Development of human resources by adequate education and training, caring for quality in the products and services, aspects of environmental health and safety in the production (e.g. collection and recycling, as well as the whole life cycle of PV products) are essential to establish this new sector as a pillar in the new energy economy.

IEA PVPS shall:

- Investigate the environmental impact of PV products in their whole life cycle;
- Assist the development of collection infrastructure by examining and evaluating the collection infrastructure of other recyclables (e.g., electronics, liquid crystal displays);
- Enhance the interaction among industry players so that they share information and resources for collection and recycling;
- Show the technical and cost feasibility of collection and recycling to environmental-policy makers;
- Create a clear understanding of safety and provide recommendations on the use and handling of hazardous substances and materials during the manufacturing process;
- Foster industry – academia interaction focusing on PV's sustainability.

4. Policy Recommendations and Strategies

As PV moves into mainstream energy markets, standards, laws and regulatory arrangements made when fossil fuels dominated energy supply may no longer be suitable. Where PV is connected to distribution networks, market structures will need to be developed which accommodate on-site generation, two-way electricity flows, and associated energy efficiency and demand management opportunities, whilst also providing signals for ancillary services to enhance grid stability. Guidelines are needed for adapted innovation processes to achieve a sustainable PV industry, as well as best practice of the frame conditions in industry-policy for a competitive photovoltaic industry. For central PV-generation, new rules may be required to cater to variable generators, and market signals provided for accurate forecasting, synergies with other renewables and storage. In off-grid applications, cross subsidies currently provided across the world for diesel generation will need to be examined if PV is a more cost effective solution, while tax structures and other arrangements designed around annual fuel use may need to be changed to cater for the up-front capital investment required for PV.

IEA PVPS shall:

- Contribute to long term policy and financing schemes namely to facilitate implementation of innovative business models, national and international programmes and initiatives;
- Share the activities and results of national and regional technology development and deployment programmes;
- Provide objective policy advice to governments, utilities and international organisations;
- Identify successful policy mechanisms leading to self-sustained market growth;
- Examine and report on international examples of PV as a significant player in national and regional energy systems;
- Investigate the impact of the shift towards renewables on other - mainly fossil and nuclear – generation businesses in high PV scenarios.
- Develop strategies for markets where PV power is already economically competitive with end-user power prices.
- Develop long term scenarios and visionary papers and concepts namely developing a Multi – PV Technology Roadmap, by that contributing to new strategies and innovation.

5. Impartial and Reliable Information

PVPS is well established as a highly credible source of information around the PV sector. Even though many PV communities, agencies and other organisations exist, this role remains as one of the key IEA PVPS objectives. This role as a global reference for PV related issues will experience significant development within the upcoming period, including the impact of PV technology on the environment, existing energy systems and the society at large.

IEA PVPS shall:

- Collect and analyse information on key deployment issues, such as policies, installations, markets, applications and experiences;
- Present/publish the reliable and relevant parts of this information in appropriate forms (presentations, brochures, reports, books, internet, etc.);
- Increase awareness of the opportunities for PV systems amongst targeted groups via workshops, missions and publications;
- Respond to the IEA and other organizations' needs regarding the worldwide development of PV technology and markets;
- Identify the needs for PV specific training and education;
- Develop education and awareness materials which remove informational barriers among key target audiences, including consumers, developers, utilities and government agencies;
- Prepare material and tools for training and education in industry.

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. The following Tasks have been established within IEA PVPS:

- Task 1. Strategic PV Analysis and Outreach;
- Task 2. Performance, Reliability and Analysis of Photovoltaic Systems (concluded in 2007);
- 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. Study on Very Large Scale Photovoltaic Power Generation System;
- Task 9. Deploying PV Services for Regional Development;
- Task 10. Urban Scale PV Applications. Begun in 2004; follow-up of Task 7 (concluded in 2009);
- Task 11. PV Hybrid Systems within Mini-Grids. Begun in 2006; follow-up of Task 3 (concluded in 2011);
- Task 12. Environmental Health and Safety Issues of PV. Begun in 2007;
- Task 13. Performance and Reliability of PV Systems. Begun in 2010;
- Task 14. High Penetration PV in Electricity Grids. Begun in 2010;
- Task 15. BIPV in the Built Environment. Begun in late 2014.

The **Operating Agent** is the manager of his or her Task, and responsible for implementing, operating and managing the collaborative project. Depending on the topic and the Tasks, the internal organisation and responsibilities of the Operating Agent can vary, with more or less developed subtask structures and leadership. Operating Agents are responsible towards the PVPS ExCo and they generally represent their respective Tasks at meetings and conferences. The Operating Agent compiles a status report, with results achieved in the last six months, as well as a Workplan for the coming period. These are being discussed at the Executive Committee meeting, where all participating countries and organisations have a seat. Based on the Workplan, the Executive Committee decides to continue the activities within the Task, the participating countries and organisations in this Task commit their respective countries/organisations to an active involvement by their experts. In this way, a close cooperation can be achieved, whereas duplication of work is avoided.

TASK STATUS REPORTS

TASK 1 – STRATEGIC PV ANALYSIS & OUTREACH

Fig. 1 – Task 1 Experts, 42nd Task 1 Meeting in Kyoto, Japan, November 2014.

Fig. 2 – Task 1-Task 14 Workshop in collaboration with IEA SHC, IEA RETD & EPIA. "Self-Consumption Business-Models: Economic and technical Challenges," 29th EUPVSEC, Amsterdam, the Netherlands, September 2014.

TASK 1 – STRATEGIC PV ANALYSIS & OUTREACH

Task 1 shares a double role of expertise and outreach, which is reflecting in its updated name "Strategic PV Analysis & Outreach."

It aims at promoting and facilitating 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: To contribute to cost reduction of PV power applications, to increase awareness of the potential and value of PV power systems, to foster the removal of both technical and non-technical barriers and to enhance technology co-operation.

Expertise:

- Task 1 serves as the think tank of the PVPS programme, by identifying and clarifying the evolutions of the PV market, identifying issues and advance knowledge.
- Task 1 researches market and industry development, analyses support and R&D policies.

Outreach:

- Task 1 compiles the agreed PV information in the PVPS countries and more broadly, disseminates PVPS information and analyses to the target audiences and stakeholders.
- Task 1 contributes to the cooperation with other organizations and stakeholders.

Task 1 is organized into four Subtasks, covering all aspects, new and legacy activities.

SUBTASK 1.1: Market, Policies and Industrial Data and Analysis

Task 1 aims at following the evolution of the PV development, analyzing its drivers and supporting policies. It aims at advising the PVPS stakeholders about the most important developments in the programme countries. It focuses on facts, accurate numbers and verifiable information in order to give the best possible image of the diversity of PV support schemes in regulatory environments around the globe.

Fig. 3 - IEA PVPS "Challenges and Promises to Large Scale PV Development" Workshop, 6th WCPEC Kyoto, Japan.

National Survey Reports

National Survey Reports (NSRs) are produced annually by all countries participating in the IEA PVPS Programme. The NSRs are funded by the participating countries and provide a wealth of information. These reports are available on the PVPS public website www.iea-pvps.org and are a key component of the collaborative work carried out within the PVPS Programme. The responsibility for these national reports lies firmly with the national teams. 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 including financing, electricity utility interests, standards and codes, and an overview of R&D activities.

TRENDS in Photovoltaic Applications Report

Each year the printed 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 Trends report presents a broader view of the current status and trends relating to the development of PV globally. The report aims at

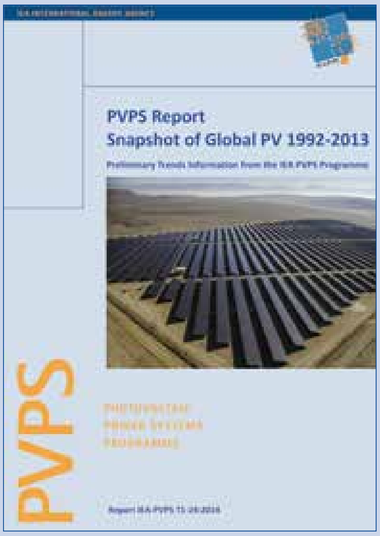

Fig. 4 – PVPS Report: A Snapshot of Global PV 1992-2013; Report IEA-PVPS T1-24:2014.

Fig. 5 – Trends in Photovoltaic Applications – Survey Report of Selected IEA countries between 1992 and 2013; Report IEA-PVPS T1-25:2014.

providing the most accurate information on the evolution of the PV market, the industry value chain, including research priorities, with a clear focus on support policies and the business environment. In recent years, the Trends report team has developed an in-depth analysis of the drivers and factors behind PV market development.

The report is prepared by a small editorial group within Task 1 and is funded by the IEA PVPS Programme. Copies are distributed by post by Task 1 participants to their identified national target audiences, are provided at selected conferences and meetings and can be downloaded from the website. From 1995 until the end of 2014, nineteen issues of Trends have been published.

A Snapshot of Global PV Report

Since 2013, a new report, *A Snapshot of Global PV*, is compiled from the preliminary market development information provided annually by all countries participating in the IEA PVPS Programme. The Snapshot report aims at presenting a first sound estimate of the prior year's PV market developments and is published in the first quarter of the new year. Task 1 aims at producing this report every year in order to communicate the PV market developments, including policy drivers' evolution early in the year.

SUBTASK 1.2: Think Tank Activities

Task 1 aims at serving as the PVPS programme's Think Tank, while providing the Executive Committee and dedicated PVPS Tasks with ideas and suggestions on how to improve the research content of the PVPS programme. In this respect, Task 1 has identified several subjects in 2013 that led to specific activities in 2014. In addition, the scope has been expanded in 2014 with some additional subjects.

- New Business Models for PV Development: With the emergence of a PV market driven in some countries by the sole competitiveness of PV, the question of new business models receives increasing interest. In 2014, Task 1's work on this focused on self-consumption and net-metering policies and will lead to the publication of a specific report in 2015. In addition, Task 1 and Task 9 have started to collaborate on these subjects in 2014, in order to enlarge the scope of analysis to emerging economies outside of the PVPS network.
- PV as Building Elements: While most of the PV market development concerned BAPV installations, the potential of BIPV remains largely untapped and requires additional research to become fully exploitable. Task 1 supported the Executive Committee with regard to the creation of the new Task 15. Further collaboration between Task 1 and Task 15 is foreseen in 2015 on market statistics, support policies and other points of interest.
- PV and Utilities: This subject has been identified as crucial for a large-scale PV development. It will lead to new PVPS activities in 2015, including possibly workshops and a dedicated task force where PV experts and utility experts could exchange information and experiences.
- Soft Costs: The continuous decline of the PV components' costs has put the emphasis on better understanding how soft costs could contribute to further system prices reduction in the coming years. This subject will be part of Task 1's 2015 activities.

SUBTASK 1.3: Communication Activities

Task 1 aims at communicating the main findings of the PVPS programme through the most adequate communication channels. In this respect, five main types of communication actions are conducted throughout the year.

- Events: Task 1 organizes or participates in events during energy or PV-related conferences and fairs. Workshops are organized on various subjects, sometimes in cooperation with other PVPS Tasks or external stakeholders. In 2014, the following workshops were organized in several locations around the world:
  - Tel Aviv, Israel – April 2014: In the framework of the 41st Task 1 meeting in Israel, a Task 1 workshop was organized in parallel with the Task 1 meeting. The meeting focused on the PV market development and its drivers together with specific business cases related to PV development in desert areas.
  - Amsterdam, The Netherlands - September 2014: EU-PVSEC Conference and Exhibition: A joint IEA PVPS, IEA RETD, IEA SHC and EPIA workshop on self-consumption driven business models and the concept of prosumers was organized.
  - Kyoto, Japan - November 2014: WCPEC-6 Scientific Conference: An IEA PVPS workshop has been organized in the official conference programme. This workshop focused on PV development trends globally with a specific focus on Japanese policies and trends.

Fig. 6 – The www.iea-pvps.org website has the latest information on IEA PVPS publications, databases, events and news.

    - Beijing, China – November 2014: A joint IEA PVPS workshop took place at the initiative of the China's IEA PVPS Executive Committee Delegate. This workshop surveyed the questions of market development including support policies, grid integration constraints and benefits, quality and reliability subjects, and introduced the new BIPV activities.
    - In addition, IEA PVPS partnered several events in 2014, including the ISES 2014 conference in Kuala Lumpur, Malaysia, and Turkey's event during Intersolar in Munich, Germany. Task 1 speakers represented the programme in several conferences in 2014, in Germany, France, Korea and Italy.
- Publications: Task 1 publications have been described in the previous paragraph. They aim at providing the most accurate level of information regarding PV development.
- Website and Social Networks: Task 1 manages the IEA PVPS website www.iea-pvps.org. The website has been updated throughout 2014. It has been partially revamped in order to be more accessible and will be completely reorganized in 2015, with new features and additional information, including an easily accessible information repository. IEA PVPS is present on Twitter and LinkedIn.

Press Releases

New publications are now followed by a press release to around 450 contacts. PVPS contacts have been expanded with more media from Asian, African and Latin American countries in a progressive way. Translation of press releases is done by some countries in order to expand PVPS visibility.

Four press releases have been issued in 2014, covering the two Task 1 reports (Snapshot and Trends), two Task 14 reports (*High Penetration of PV in Local Distribution Grids* and *Transition from Uni-directional to Bi-directional Distribution Grids*), and three Task 13 reports (*Analysis of Long-Term Performance of PV Systems, Review of Failure of PV Modules,* and *Analytical Monitoring of Grid-Connected PV Systems*).

SUBTASK 1.4: Cooperation Activities

In order to gather adequate information and to disseminate the results of research within Task 1, cooperation with external stakeholders remains a cornerstone of the PVPS programme.

This cooperation takes places with:

- Other IEA Implement Agreements (SHC, RETD, etc.)
- Stakeholders outside the IEA network: IRENA, REN21, etc.)

SUMMARY OF TASK 1 ACTIVITIES AND DELIVRABLES PLANNED FOR 2015

Task 1 activities will continue to focus on development of quality information products and effective communication mechanisms in support of the PVPS strategy. Furthermore, Task 1 will continue to analyse PV support policies and provide adequate and accurate information to policy makers and other stakeholders. In addition to business model analysis, Task 1 will engage in subjects related to soft costs analysis in 2015.

SUBTASK 1.1: Market, Policies and Industrial Data and Analysis

National Survey Reports will start to be published from Q2 2015 on the PVPS website.

The target date for publication of the 3rd issue of the *Snapshot of Global PV* report is the end of Q1 2015.

The target date for publication of the 20th issue of the *Trends in Photovoltaic Applications* report is the end of Q3 2015.

The report on self-consumption and net-metering will be published in 2015. A publication on soft-costs could be published in 2015 as well.

SUBTASK 1.2: Think Tank Activities

The main subjects to be developed in 2015 with regard to the Think Tank activities of PVPS can be described as follow:

- Expand the analysis on self-consumption based business models.
- The role of utilities with regard to PV development.
- Liaison with all PVPS Tasks in order to better exchange on the content and identify how Task 1 can bring in new ideas and especially:
    - Liaise with the revised Task 9 on business models, market statistics and support policies in emerging economies.
    - Liaise with the new Task 15 on BIPV market statistics and support policies.

SUBTASK 1.3: Communication Activities

Task 1 will continue its communication activities in 2015. First by communicating about the publications and events organized within Task 1 and second, by contributing to disseminating the information about publications and events of the entire PVPS program. The complete revamping of the website will be achieved in 2015.

SUBTASK 1.4: Cooperation Activities

Task 1 will continue to cooperate with adequate stakeholders in 2015. It will reinforce the link with IEA in particular and enhance its cooperation with IRENA and REN21. Regarding the cooperation between IEA Implementing Agreements, a special focus could be put on the cooperation with the IEA SHC Task 53 New Generation Solar Cooling and Heating Systems in heating & cooling systems (PV or Solar Thermally Driven Systems) and with IEA-RETD (PV prosumers in the commercial sector).

INDUSTRY INVOLVEMENT

Task 1 activities continue to rely on close cooperation 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.

MEETING SCHEDULE (2014 AND PLANNED 2015)

The 41st Task 1 meeting was held in Tel Aviv, Israel, April 2014.
The 42nd Task 1 meeting was held in Kyoto, Japan, November 2014.
The 43rd Task 1 meeting will be held in Golden, Colorado, USA in April 2015.
The 44th Task 1 meeting will be held in Europe, most probably in Turkey or Spain in November 2015.

TASK 1 PARTICIPANTS IN 2014 AND THEIR ORGANIZATIONS

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

COUNTRY	NAME	ORGANIZATION
Australia	Greg Watt	Australian PV Institute
	Warwick Johnston	SUNWIZ
Austria	Hubert Fechner	University of Applied Sciences Technikum Wien
Belgium	Grégory Neubourg	APERe
Canada	Patrick Bateman	CanSIA
China	Lv Fang	Electrical Engineering Institute, Chinese Academy of Science
Copper Alliance	Angelo Baggini	ECD
Denmark	Peter Ahm	PA Energy AS
EPIA	Ioannis Thomas-Theologitis	EPIA
European Commission	Arnulf Jaeger-Waldau	European Commission, Directorate General for Energy
France	Yvonnick Durand	ADEME
Germany	Dr Lothar Wissing	Forschungszentrum Jülich
	Klaus Prume	
Israel	Dr Yona Siderer	Ben-Gurion University
	Ms. Shoshana Dann	
Italy	Mr. Salvatore Guastella	RSE SpA
	Ms. Francesca Tilli	
Japan	Izumi Kaizuka	RTS Corporation
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TASK 8 – STUDY ON VERY LARGE SCALE PHOTOVOLTAIC POWER GENERATION SYSTEM

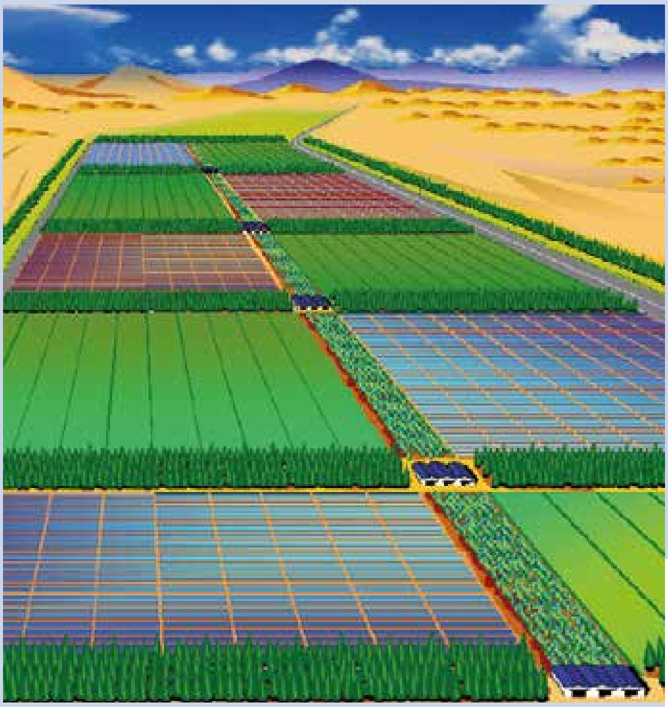

Fig.1 - Image of a VLS-PV System in a Desert Area.

Fig. 2 – 550 MW Topaz Solar Farm, San Luis Obispo County, CA, USA (Photo: First Solar, Inc.).

OVERALL OBJECTIVES

The objective of Task 8 is to examine and evaluate the potential and feasibility of Very Large Scale Photovoltaic Power Generation (VLS-PV) systems, which have a capacity ranging from over multi megawatt to gigawatt, and develop practical project proposals toward implementing VLS-PV projects in the future.

Throughout Task 8's work since 1999, large scale PV systems increasingly count as a realistic energy option and have started to appear around the world in the 2000s, and have been rising substantially year to year. Now 500 MW scale PV systems are becoming reality.

Task 8 has recognised that states/governments all over the world consider solar power plants as a viable option for their electrical energy supply. However, to accelerate and implement real VLS-PV projects, the feasibility of such projects should be provided as information to decision-makers in an appropriate manner, and Task 8 can/should contribute to achieving this vision.

Based on our previous results and changes in the market environment, Task 8 implemented its work under its Workplan during 2012-2014, which includes three Subtasks, as noted below:

Subtask 2: Case Studies for Selected Regions for Installation of VLS-PV System on Deserts
Subtask 6: Future Technical Options for Realizing VLS-PV Systems
Subtask 7: VLS-PV Vision, Strategy and Communication

SUMMARY OF TASK 8 ACCOMPLISHMENTS FOR 2014

Through Task 8 meetings and e-mail communications, Task 8 discussed working items described below. Based on the discussions, a draft manuscript of the Task 8 report has been developed and the report should be published in 2015.

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

Employing the concepts and the criteria of VLS-PV, as well as other results produced under other Subtasks, Task 8 participants have been undertaking case studies on VLS-PV systems for the selected regions and evaluating the resulting effects, benefits and environmental impacts. The feasibility and potential of VLS-PV on deserts will be evaluated from local, regional and global viewpoints.

The following items were carried out, and drafted as the report:

- Environmental issues in developing PV power plants;
- Socio-economic evaluation of localisation in photovoltaic value chains;
- Possible approaches for local assembly of CPV;
- International Tendering of PV Power Plants;
- China as a Role Model to the World for the Massive Introduction of PV Power Plants;
- Development of VLS-PV systems in West Africa.

As for the environmental aspects of VLS-PV systems, Task 8 carried out information exchange and collaborative work with Task 12.

SUBTASK 6: Future Technical Options for Realising VLS-PV Systems

Various technical options for implementing VLS-PV systems will be proposed and analysed. From the future electrical grid stability viewpoint, a global renewable energy system utilizing globally dispersed VLS-PV systems as the primary electrical energy source will also be analysed. To clarify requirements for VLS-PV system that integrates with energy network in the near-term and mid-&long-term, combination with other renewable energy technologies or energy sources will be discussed, as well.

The following items were discussed, and drafted as the report:

- Technical Requirements for PV Power Plants;
- State-of-the-art of CPV technology;
- Geographic dispersion and curtailment of VLS-PV electricity;
- Concept of VLS-PV Supergrid in Northeast Asia;
- Renewable Energy Mix and Economics of Supergrid in the Northeast Asia.

SUBTASK 7: VLS-PV Vision, Strategy and Communication

Based on the previous results and changing market environment, Task 8 participants would perform active dissemination and communication with stakeholders to develop VLS-PV vision and strategy. The possible approach and enabler to achieve the vision and implement the strategy would be developed and identified, as well. Suggestions/ recommendations/drafts of how to overcome hurdles/ barriers, from technical and non-technical viewpoints would be proposed in order to accomplish this Task 8 activity.

The following items were discussed and drafted as the Task 8 activity's executive summary:

- Expectations and potential for PV power plants;
- Technical feasibility of PV power plants;
- Economic feasibility of PV power plants;
- Environmental benefits of PV power plants;
- Socio-Economic benefits of PV power plants;
- VLS-PV visions.

LIST OF TASK 8 PARTICIPANTS

COUNTRY	PARTICIPANT	ORGANISATION
Canada	John S MacDonald	Day4 Energy Group Inc.
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Fig. 3 - 520 MW Longyangxia Hydropower PV station, Gonghe, Qinghai, China (Photo: Yellow River Hydropower Company).

Fig. 4 - Shenguang high concentrating PV (HCPV) power station, Golmud, Qinghai, China.

DISSEMINATION ACTIVITIES

Task 8 made presentations at the following international events:

- A workshop on 'Large and Medium-sized Photovoltaic Power Station Construction and Operation Efficiency', in Xining, Qinghai, China (September 2014);
- 29th EU-PVSEC in Amsterdam, the Netherlands (September 2014);
- 6th WCPEC in Kyoto, Japan (November 2014);
- 2014 International Photovoltaic Technicians Forum and IEA PVPS Joint Tasks Workshop, in Beijing, China (November 2014).

SUMMARY OF TASK 8 ACTIVITIES PLANNED FOR 2015

Task 8 will publish a report entitled "Energy from the Desert: Very Large Scale PV Power Plants for Shifting to Renewable Energy Future," and successfully terminate its activity.

KEY DELIVERABLES

Internal Publications

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

External Publications

Book: "Energy from the Desert: Feasibility of Very Large Scale Photovoltaic Power Generation (VLS-PV) Systems," James and James, 2003 (ISBN 1 902916 417)
Report: "Summary – Energy from the Desert: Feasibility of Very Large Scale Photovoltaic Power Generation (VLS-PV) Systems," 2003
Report: "Summary – Energy from the Desert: Practical Proposals for Very Large Scale Photovoltaic Systems," 2006
Book: "Energy from the Desert: Practical Proposals for Very Large Scale Photovoltaic Systems," Earthscan, 2007 (ISBN 978-1-84407-363-4)
Book: "Energy from the Desert: Very Large Scale Photovoltaic Systems, Socio-Economic, Financial, Technical and Environmental Aspects," Earthscan, 2009 (ISBN 978-1-84407-794-6)
Report: "Summary - Energy from the desert: Very Large Scale Photovoltaic Power - State-of-the-Art and into the Future," 2013
Book: "Energy from the Desert: Very Large Scale Photovoltaic Power - State-of-the-Art and into the Future," Earthscan from Routledge, 2013 (ISBN 978-0-415-63982-8(hbk) /978-0-203-08140-2(cbk)))
Report: "Energy from the Desert: Very Large Scale PV Power Plants for Shifting to Renewable Energy Future," (ISBN 978-3-906042-29-9) (to be published in 2015).

MEETING SCHEDULE IN 2014

31st Task 8 meeting: was held in Morocco, 23-25 April 2014.
32nd Task 8 meeting: was held in Kyoto, Japan, 23 November 2014.

TASK 9 – DEPLOYING PV SERVICES FOR REGIONAL DEVELOPMENT

RATIONALE AND OBJECTIVES

Deploying PV Services for Regional Development

PV technology and its viable applications offer options to meet the Millennium Development Goals (MDGs) and now stretch far beyond services to remote communities.

With expected long term rising fossil fuel prices and declining prices of PV cells and modules, PV applications are competitive in a rising number of situations: Many initiatives in emerging regions are paving the way for broad PV deployment in non-OECD countries.

Beyond the more classical Solar Home Systems for individual (household and "pico" uses) and community uses, addressed during the first 10 years of Task 9, the challenge of the effective deployment of PV services for regional development now lay on a broader range of applications including village mini-grid power systems, in particular through hybrids, PV services for drinking water and health and also other social, productive, and professional applications, PV in the built and urban environment, and large scale PV.

The objective of Task 9 is twofold:

- In order to promote the implementation of appropriate and efficient technical solutions, Task 9 is developing partnerships with selected "megaphones" (financial institutions, regional / professional organizations) which offer dissemination opportunities for the outputs of other technology-focused PVPS Tasks addressing these challenges, adapting the messages and implementation frameworks in areas beyond the borders of OECD countries. These partnerships would enable the sharing of PVPS' knowledge in the area of rural electrification and beyond; e.g., highly relevant topics such as penetration of PV in the urban environment, PV hybrids, very large scale PV plants and high penetration in grids.
- Produce substantive work on applications meeting the needs of rural communities such as water pumping, health (refrigeration, lighting, etc.), "pico PV services" (highly efficient integrated appliances for lighting and ICT needs), and on relevant business models for deployment. The results of this work will be integrated in the dissemination process.

SUMMARY OF TASK 9 ACTIVITIES

SUBTASK 1: PV for Water Pumping

Water is an increasingly scarce commodity and harnessing and using it efficiently is of central importance. PV offers this possibility, and is often the least cost option on a life cycle basis, albeit burdened with high upfront costs. The scope of this Subtask is to initiate and maintain interdisciplinary expert dialog in the field of PV and water supply. The objective of this Subtask, led by Switzerland, is to provide guidelines to decision makers to ensure PV-powered drinking water supply systems are implemented where they are the most sustainable option, building on past experience.

This Subask was completed in 2012 with the publication of the Task 9 position paper on *"Policy Recommendations to Improve the Sustainability of Rural Water Supply Systems"* and the material is being used for dissemination activities.

WORKPLAN 2012-2014

MILLENIUM DEVELOPMENT GOALS RELATED	INTEGRATION OF PV IN ENERGY SYSTEMS
1 – PV for Drinking Water pumping (100%) 2 – PV and Health, community services (100%) 3 – Pico PV Services (100%)	4A – PV and hybrid mini grids for rural loads + French translation (100%) 5 – Monitoring of hybrid systems in rural areas: a simple guideline for rural operators (90%) 6 – Innovative business models – for urban and large scale applications – case studies (100%) 7 – Trends in the market for PV diesel mini grids (80%)
Deployment and outreach in Asia • Asian Development Bank (100%), Conferences in Myanmar, Thailand and Malaysia (100%), IOREC-Manila; Tokyo Deployment and outreach in Africa • Club ER (100%)	

Fig. 1 - IEA PVPS Task 9's Achievements

SUBTASK 2: PV and Health Centers

In the context of rapidly increasing price and the intermittent supply of fossil fuel, photovoltaic (PV) systems are an alternative energy supply option for rural health facilities in developing areas. Numerous PV system projects have been installed in health facilities in the past, and are mainly used to power vaccine refrigerators and lights. Nevertheless, the sustainability factors have not been considered sufficient in many cases, due to improper system design, battery misuse, and under-estimation of the daily load. The aim of this Subtask, led by Germany (Fraunhofer ISE), is to publish a compilation of good practice regarding PV for rural health facilities, and to facilitate the integration of the same into the work program of the relevant international institutions.

The Task 9 publication entitled, *"PV Systems for Rural Health Facilities in Developing Areas, A Completion of Lessons Learned"* was finalized in December 2014 and is available on the PVPS website.

SUBTASK 3: Pico PV Services

For households without any electricity service or with only limited service, very small amounts of power can meet some essential electricity needs, thanks to efficient devices: Basic (portable) telephone charging, radios, even small TVs). So far, as illustrated in the comprehensive technical overview and business model produced by GTZ, the literature has approached the deployment of Pico PV services in terms of "donor driven." Nowadays, devices of widely varying quality are already flooding the market and large companies, including multinationals, are disseminating Pico PV products on pure commercial bases.

Fig. 2 - Task 9 Meeting at Holland Solar, Utrecht, the Netherlands, September 2014.

Fig. 3 - Task 9 Meeting at Holland Solar, Utrecht, the Netherlands, September 2014

This Task was now completed in 2013 with the publication of the Task 9 report, *"Pico Solar PV Systems for Remote Homes - A New Generation of Small PV Systems for Lighting and Communication."* This publication was presented at the Rural Electrification Workshop organised by GIZ and ASEAN Center for Energy (ACE) in Rangoon, Myanmar in April 2013 and at the PVPS Task 9 open event in collaboration with DEDE Bangkok, Thailand, April 2013.

SUBTASK 4: PV and Mini-grids / Hybrids

After the publication of the Task 9 report, *"Rural Electrification with PV Hybrid Systems - Overview and Recommendations for Further Deployment,"* on the PVPS Website in April 2013 and in October 2013 for the French version, it was decided to carry out further work on this subject.

Feedback from the field tends to show that grid expansion is happening faster than expected; especially connecting load centres with "anchor loads" – so small scale (mini-grid) distributed generation (<1 MW) integration into the main grid may perhaps see a substantial growth in the future, as an interim solution to grid connection. Task 9 experts have decided to publish a report on the current *"Trends in PV Hybrid Systems for Mini-grids."* This publication also contains the results of a survey carried out among of 61 experts – 50 % European, 50 % African - coming from different horizons: Consultancies, Manufacturers, Academic, research, Utilities, NGO, Governmental (national/local) offices, International agency, donors, on *"The Future of PV Hybrid Systems within Mini-grids."*

SUBTASK 5: Innovative Business Models

The high upfront costs of PV technology remain one of the key challenges – although constantly diminishing - that need to be overcome to achieve a faster and greater deployment of PV technology. This problem is particularly pronounced in emerging regions where purchasing power is low and most people do not have access to commercial financing. Under such conditions, PV technology can only spread when innovative business models and financing mechanisms are available, which are adapted to the specific conditions in these regions.

Led by Switzerland, a Task 9 study on, *"Innovative Business Models and Financing Mechanisms for PV Deployment in Emerging Regions,"* was published in December 2014. The publication is a collection of case studies of business models and financing mechanisms which show possible patterns how such obstacles can be addressed and overcome in innovative ways.

SUBTASK 6: Deployment and Outreach

This Subtask is the operating arm of Task 9 to establish partnerships with regional organizations, countries, development bodies, etc. During 2014, the following dissemination activities have taken place:

- Participation of the Task OA, Anjali Shanker and Task 1/9 Expert Peter Ahm, Denmark, in the *"2nd International Sustainable Energy Summit (ISES) in Malaysia,"* March 2014.
- Participation in the IEA PVPS workshop within the 6th World Conference on Photovoltaic Energy Conversion (WCPEC), Kyoto, Japan 25 November 2014 where Anjali Shanker and Task 9 Expert Thomas Meier, Switzerland, have presented their work to the session on *"PV Market Development Trends: The Expected Rise of New Business Models."*
- PVPS Task 9 material and, in particular, the Innovative Business Model publication was used as support for the trainings organized in Sudan and Senegal by the CLUB-ER on Renewable Energy Financing.
- Participation of several IEA PVPS experts including Task 9 to the Chinese-IEA PVPS PV workshop in Beijing November 29-30, 2014.

THE FUTURE OF THE TASK 9

In 2013, about 99 % of the globally installed PV capacity of 135 GW were grid-connected systems. Off-grid systems which once dominated a small market, now account for 1 % at most. Nearly 1.3 billion people did not have access to electricity in 2011, mostly in sub-Saharan Africa and remote regions in Asia. Given the current speed of development and available financing, the IEA (2012) projects that close to 1 billion people will still be without electricity in 2030. The IEA further expects that several hundred million people will continue to live in sparsely populated rural areas where off-grid solar PV systems would likely be the most suitable solution for basic electrification.

Task 9 was the first initiative within an implementing agreement of the IEA PVPS which concentrated on energy related issues in non-member countries. The importance of these countries will increase, dramatically over the next 30 years. It is forecasted that to limit the global mean temperature increase to 2°C in the long run, 83 % of the required emission reductions by 2050 will have to be achieved outside the OECD in emerging regions.

The above two key aspects underline the importance and relevance of Task 9. The Task 9 has almost completed its four year program, the experts are currently elaborating a new Workplan for the next two years. Switzerland is evaluating a proposal to take over the function of Operating Agent (OA) for the new phase.

Given the speed of developments taking place, the new Task 9 will have to shift focus from doing its own independent research to transforming and adjusting the mass of experience and knowledge available within PVPS and present it to non-member countries. The following subjects have been selected as possible interest within the Task:

1. **Policy Issues, Regulatory Frameworks and Support Instruments:** This is a moving environment and lessons can be relevantly drawn from the experience of OECD countries for the benefit of emerging regions. Many of these countries have in many cases made a commitment to renewables and set targets, but they are currently faced with issues related to choosing their implementation framework and cost thereof. This work could relevantly be done in collaboration with IEA PVPS Task 1. Two themes have been identified:
   a. Net metering, which is already being implemented in a number of emerging regions
   b. integrating mini grids in the main grid: regulatory issues
2. **Deploying PV in Medium Scale Fast Growing Cities:** This work has started within the Task 9 from the angle of emerging business models for PV in urban environment. This could be relevantly pursued by working on the specific potential and issues as related to the integration of such applications in fast growing cities of emerging regions.
3. **Integration of Small Scale (Mini-grid) Distributed Generation (< 1MW) into the Main Grid:** This may be one of the trends of the future, as mini-grid may perhaps see a substantial growth, as an interim solution to access. Integration of mini-grids into the main grid will, in cases, have to be considered from the start – as it presents the advantage of contributing to grid quality but raises issues of grid management.
4. **Integration of PV in Grid Systems:** Many new and emerging PV markets have utilities facing the unknown technical/economic impact of an increasing penetration of PV in their grid systems as a consequence of political commitment to do so. IEA PVPS is accumulating a huge amount of experiences and data in this context, and Task 9 sees a challenge in adapting and disseminating this know how to regions and countries with fast growing PV deployment.

TASK 9 PARTICIPANTS

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France	Taric de Villers	IED
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Germany	Friedemar Schreiber	Fraunhofer ISE
Germany	Adnan Al-Akori	Fraunhofer ISE
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Sweden	Frank Fiedler	Dalarna University
Sweden	Caroline Nielsen	Dalarna University
Switzerland	Thomas Meier	ENTEC
Switzerland	Alex Arter	ENTEC

- *Although not officially, GIZ (Germany), Dalarna University (Sweden) and IRENA actively contribute to the work of this Task.*
- *Observers: Thailand, Ministry of Energy and EGAT, Malaysia, ECREEE.*

Fig. 4 - Task 9 Meeting dinner on the canal in Utrecht, the Netherlands, September 2014.

Fig. 5 - "2nd International Sustainable Energy Summit (ISES) in Malaysia," March 2014. Task 9 Expert Peter Ahm, Denmark, is second from the left.

KEY DELIVERABLES PUBLISHED IN 2014:

- December 2014: "Innovative Business Models and Financing Mechanisms for PV Deployment in Emerging Regions."
- December 2014: "PV Systems for Rural Health Facilities in Developing Areas,"

KEY DELIVERABLES FOR 2015:

"Trends in PV Hybrid Systems for Mini-grids" (Expected March 2015)

TASK 9 MEETING SCHEDULE

2014

30th Experts' Meeting, 2 April 2014, Lyon, France
31st Experts' Meeting, November 23, 2014, Kyoto, Japan
Task 9 Working Meeting, 22 September, 2014 – Holland Solar, Utrecht, the Netherlands

2015

To be determined.

TASK 12 - PV ENVIRONMENTAL HEALTH & SAFETY ACTIVITIES

Fig. 1 - Task 12 experts at meeting in Beijing, China, March 2014.

INTRODUCTION

Renewable energy, with photovoltaics in a prominent role, will need to provide an increasing share of the world's energy demand in order to slow the ever mounting streams of greenhouse gases emitted by our global society. In operation, photovoltaics generate electricity without emissions of any kind, and the life-cycle emissions of a kWh of PV electricity are only a small fraction of those of fossil-fuel generated electricity. In the manufacturing and at end-of-life, however, the material flows for producing PV cells and modules must be managed sustainably and responsibly, in terms of environmental health and safety impacts. The photovoltaics industry, to date, has understood that the advantages of renewable energy should be emphasized by responsible management of environmental, health and safety aspects.

As the industry grows and the technology advances, material designs and industrial processes are continually evolving. Safety practices also evolve with the growth of a sector or industry. Continual diligence and communication on the sustainable management of material flows, industrial processes and safety practices is necessary to safeguard health and the environment, and takes on even greater importance as we progress towards larger scales of photovoltaic deployment. Research such as life cycle assessment can help to predict future environmental emissions and lead to research and development improvements that avoid those future impacts.

OVERALL OBJECTIVES

The main goals of Task 12 are to foster international collaboration in the area of photovoltaics and the environment and to compile and disseminate reliable environment, health, and safety (EH&S) information associated with the life-cycle of photovoltaic technology to the public and policy-makers. Whether part of due diligence to navigate the risks of large PV products, or to inform consumers and policy makers about the impacts of residential PV systems, accurate information regarding the environmental, health and safety impacts of photovoltaic technology is necessary for continued PV growth. It builds consumer confidence, as well as policy-maker support, thus improving demand. On the supply-side, environment, health, and safety initiatives set standards for environmental, economic and social responsibility for manufacturers and suppliers, thus improving the solar supply-chain with regard to all dimensions of sustainability.

The overall objectives of Task 12 are to:

1. Quantify the environmental profile of PV electricity, serving to improve the sustainability of the supply chain and to compare it with the environmental profile of electricity produced with other energy technologies.
2. Help improve waste management of PV in collection and recycling, including tracking legislative developments as well as supporting development of technical standards.
3. Distinguish and address actual and perceived issues associated with the EH&S aspects of PV technology that are important for market growth.
4. Disseminate the results of the EH&S analyses to stakeholders, policy-makers, and the general public.

The first objective is served with Life Cycle Assessment (LCA) that describes energy, material and emission flows in all stages of the life cycle of PV. The 2nd objective is accomplished by proactive research and support of industry-wide activities (e.g., input to Industry Associations, such as EPIA in Europe or the China Photovoltaic Society to develop and help implementing voluntary or binding policies – such as WEEE in Europe.). The 3rd objective is addressed by advocating best EH&S practices throughout the solar value chain, and assisting the collective action of PV companies in this area. The 4th objective (dissemination) is accomplished by presentations to broad audiences, peer review articles, reports and fact sheets, and assisting industry associations and the media in the dissemination of the information.

APPROACH

Task 12 is subdivided into three topical Subtasks reflecting the first three objectives stated above. The fourth objective, dissemination of information, is contained as an activity within each of the three Subtasks: recycling, life cycle assessment and safety in the PV industry.

Fig. 2 - Task 12 experts on tour of Yingli Solar, China, March 2014.

Fig. 3 - Workshop on PV environmental aspects organized by Chinese National Academy of Sciences, March, 2014.

ACCOMPLISHMENTS OF IEA PVPS TASK 12

SUBTASK 1: Recycling of Manufacturing Waste and Spent Modules

The Task 12 group has a long history of bringing the issue of PV module recycling to the fore by organizing workshops on PV recycling, such as during the 34th IEEE Photovoltaic Specialists Conference (PVSC) in Philadelphia in June 2009, and supporting the 1st and 2nd International Conference on PV Module Recycling, in 2012 and 2013, hosted by EPIA and PV CYCLE.

Carrying on this long history, Task 12 organized a workshop at the 2014 European PV Solar Energy Conference (EUPVSEC) entitled, "PV Life Cycle Management and Recycling," which gathered over 90 leaders on this topic who reviewed the status of regulations and recycling technologies.

Publications by Task 12 members include articles on the technical and cost feasibility, on a cost optimisation model for the collection and recycling of PV modules, as well as on the development of a method for recycling Cd and Te from CdTe photovoltaics.

SUBTASK 2: Life Cycle Assessment

Task 12 brings together an authoritative group of experts in the area of the life-cycle assessment (LCA) of photovoltaic systems, who have published a large number of articles in high-impact journals and presented at international conferences. In November, 2011, Task 12 published the expanded 2nd edition of the "Methodology Guidelines on Life Cycle Assessment of Photovoltaic Electricity," and the associated report on life-cycle inventories (LCI) with data on the photovoltaic life-cycle materials and processes, necessary for conducting LCA studies.

Task 12 members have contributed to the factsheets on photovoltaics produced by EPIA's Sustainability Working Group, and have contributed to the update of the LCI data on photovoltaics in the ecoinvent database. In addition, Task 12 members are contributing to synergistic activities such as the UNEP International Resources Panel report on Environmental Sustainability of Low Carbon Technologies which uses hybrid LCA to consider benefits, impacts and tradeoffs of PV and other low carbon technologies along many environmental impact categories.

SUBTASK 3: Safety in Facilities

Task 12 members have also brought attention to safety issues associated with various stages in the life-cycle of photovoltaics in various seminars (e.g. on Silane Safety, at the IEEE PVSC in San Diego, April 2008) and workshops (e.g. "PV Fire Safety," September 2010).

ACTIVITIES IN 2014

SUBTASK 1: Recycling of Manufacturing Waste and Spent Modules

Andreas Wade, who is the chairman of the EPIA's sustainability working group, and EPIA's representative to Task 12, is leading this group. With the adoption and implementation of the recast WEEE Directive - making collection and recycling of end-of-life PV modules a legal requirement in all European Union Member states - a multitude of existing producer compliance schemes will also look at the waste stream from PV modules. Going forward, industry coordination on technical standardization as well as best practices in implementation will become important. This task will support activities in CENELEC TC111X WG6 and the eStewards program on the development of recycling standards for PV technologies (e.g., through EPIA participation in the respective forums).

A workshop on recycling occurred as a half day parallel event at the EUPVSEC in Amsterdam in September, 2014. At its peak, approximately 90 people attended the workshop, literally packing the room, and overall Andreas Wade received excellent feedback from the audience and the conference organizers. Highlights of the session include:

- Insight into recent recycling technology developments in China;
- Update on the regulatory situation in Europe with regard to the WEEE transposition and the inclusion of photovoltaic panels in the scope;
- Announcement of the development of a minimum treatment standard for the recycling of PV modules through the CENELEC TC111X WG4;
- Announcement of a best practice policy paper of IRENA with a special focus on non-OECD countries – this paper will certainly take up a lot of the points which are being included in the upcoming IEA PVPS Task 12 report on Recycling;
- Update on expected recycling volumes on a European and Global Perspective;
- Presentation of new technology approaches to delamination of end-of-life PV modules which enable cost-effective high value glass recycling;
- Insights into the European Union CU-PV project, with focus on recycling friendly design of future PV modules.

Task 12 is currently developing a report on recycling. The report will provide a comprehensive overview on the national requirements in the EU Member States on collection and recycling of end-of-life photovoltaic panels under the transposed recast WEEE Directive, including producer requirements, collection targets, recycling and recovery targets and compare these to the available compliance mechanisms (individual or joint producer compliance) as well as with implemented recycling technologies for the various PV technologies. The lively discussion about the WEEE Directive at the EUPVSEC workshop is evidence that there is certainly interest for an in-depth report on recycling experiences and standards.

SUBTASK 2: Life Cycle Assessment

The life cycle assessment (LCA) expertise on photovoltaic systems is one of the prominent strengths of the Task 12 group.

Dr. Rolf Frischknecht, an established LCA consultant, is leading Subtask 2.1 on LCA Methodology.

Activity 2.1a.: Update and expansion of the LCA methodological guidelines is envisioned to contain additional topics (e.g. water use, recycling and externalities) and to be completed at the end of 2015.

Activity 2.1b.: Guidelines for net energy comparisons (i.e. using the EROI metric) will be produced in this activity, and Task members are currently collaborating on this topic. It is envisioned that it will be a separate document from, but referenced to, the LCA guidelines. The recent use of the EROI metric to show that PV is an uneconomic technology has re-awakened a dialogue in the energy community about the merits and shortcomings of EROI as a metric, which international guidelines for appropriate definition and use of this metric are necessary to ensure fair comparison. (http://www.springer.com/energy/renewable+and+green+energy/book/978-1-4419-9436-3)

Activity 2.1c.: Pilot phase product environmental footprint category rules. The DG Environment (Directorate A1. Eco-Innovation & Circular Economy) of the European Commission put out a tender for proposals to develop 'product category rules' to set the standards for the life cycle assessment of the environmental impact of 1 kWh of photovoltaic (PV) electricity. The rationale for this project is based upon the observation that there is a growing demand for LCA based product declarations. At the same time, the many methodologies are 'similar but different,' leading to difficulty in comparing products. This initiative for the development of Product Environmental Footprint Category Rules (PEFCR) will simplify and make consistent the environmental assessment of European products. The application was accepted as one of 7 pilot phase projects (out of tens of applications) in 2013. The partner organizations that submitted this application, also referred to as the 'Technical Secretariat' of the project are: This Task 12 group, EPIA, the Int'l Thin-Film Solar Industry Assoc. (PVthin), Yingli Solar, First Solar, Total, Calyxo, ECN and Treeze. The supporting organizations are: IEA PVPS, WWF International - Energy Policy Unit, REC and the Bulgarian Photovoltaic Association. This is a three year project, ending in 2017.

The pilot on developing the rules for environmental footprinting of PV systems is underway in step with the timeline laid out by the European Commission. As of mid-April, 2014, an assessment of relevant environmental assessment guidelines have been compared to the EC's guidance document for the pilots on environmental footprinting (PEF). The first 'physical stakeholder consultation' meeting took place in Brussels, in which stakeholders who had registered on the PEF website were present to discuss the scope and representative product envisioned in our pilot for PV electricity.

As a result of this meeting, the functional unit for the pilot phase assessment and product category rule will be a kWh of DC electricity from a PV module, without the balance of system components for power conditioning.

Dr. Parikhit Sinha, Director of EH&S at First Solar, leads the Subtask 2.2 on Life Cycle Inventories.

Activity 2.2: Life Cycle Inventories (LCI). This activity concerns the updating and expanding of LCI data which Task 12 makes publicly available in IEA reports. A key improvement we are embarking on now is to make our LCIs publically available not only in reports, but in LCA-software readable formats to facilitate their use by LCA professionals. Task 12's original LCI report was updated and expanded in 2014 and is currently under review by the PVPS Executive Committee for publication, including electronic data files. The updated report encompasses sub-activities 2.2a and 2.2b though activities continue in both throughout the Workplan period.

Sub-activities 2.2a - 2.2c reflect the various types of data that will be included:

Activity 2.2a.: Global Supply-Chain. The aim is to find ways to gather LCI data for PV manufacturing, and other stages of the life-cycle, in the various regions of the globe. Due to fruitful discussions at Task 12's March 2014 meeting in Beijing, followed by further interaction during the Task 12 meeting in Beijing, data on the national and regional Chinese electricity mixes, and on the energy use in the Chinese PV supply chain is being gathered with the help of Chinese Task 12 members and their colleagues.

Activity 2.2b.: LCI Balance of System. The aim is to highlight the data which actually represents the average of the most prevalently installed systems, so that the average really reflects the installed systems.

Activity 2.2c.: Water use in PV life cycle (manufacturing, panel washing). The issue of water footprint of electricity generating technologies is emerging as a significant issue with significant data gaps. Task 12 will quantify the water use by electricity generation technologies, with a focus on the manufacturing and construction phases and publish a report in 2015.

Activity 2.2d.: Changes in life cycle impacts of PV to 2050. Rolf Frischknecht has delivered a forecast of the life cycle impacts of various scenarios of PV deployment and supply chains to 2050 to the Swiss government. This report has been transformed to an IEA PVPS Task 12 report suitable for a broader audience. This report is under review by the PVPS Executive Committee for publication.

Activity 2.2e.: LCI of module recycling. This group seeks to provide data, as well as methodological recommendations (in Activity 2.1a) to fill the void on recycling data for PV systems and how LCA practitioners can employ it. This activity will be tackled in 2015.

SUBTASK 3: Safety in PV Industry
This Subtask includes not only safety in facilities through the manufacturing process, but also safety throughout the life-cycle of a PV product, including the safety of solar installers and decommissioning agents.

This Subtask is led by Keiichi Komoto, from Mizuho Research Institute, Japan.

Activity 3.1: PV fire safety. The activity on PV Fire Safety includes surveying cases of fire where PV was present, reviewing current practices, codes and standards for dealing with these situations, and identifying recommendations for firefighters, the PV industry, and PV users in operation and maintenance to prevent fires. Workshops (2 or 3, in China, Europe and maybe the US) to communicate with stakeholders will be an important activity and are expected to occur in the future. All Task 12 members are asked to survey cases of fires at buildings equipped with PV systems, and to review the current practices, codes and/or standards in their respective countries. Japan will lead, supported by the Netherlands, the activity of drafting the Task 12 guidelines and recommendations for fire safety. Workshops will be organized in the future.

GOVERNANCE, DISSEMINATION AND NEXT MEETINGS

Membership: After recently welcoming two new member countries to Task 12 in 2013 (Austria and France), two new members of Task 12 have confirmed in 2014: EPIA and Korea. Total membership stands now at 11 countries and 1 industry association, with ~16 active experts.

PLANS FOR 2015

2015 will be a year of emerging Task 12 publications. As mentioned above, two are under review by the PVPS Executive Committee currently (the updated "Life Cycle Inventories and Life Cycle Assessments of PV Systems" and the new "Life Cycle Assessment of Future Photovoltaic Electricity Production from Residential-scale Systems Operated in Europe"). Members are working to finalize reports reviewing European recycling requirements and water use in the life cycle of PV. Activity will continue in developing methodological guidelines for net energy analysis of PV (new) and life cycle assessment (update), as well as a review of international fire safety guidelines. Finally, Task 12 will continue its leadership role of the European Pilot phase product environmental footprint category rules for PV.

PUBLICATIONS

Methodology Guidelines on Life Cycle Assessment of Photovoltaic Electricity, 2nd edition, IEA PVPS Task 12, International Energy Agency Photovoltaic Power Systems Programme. Report T12-03:2011. ISBN: 978-3-90642-01-5
Life Cycle Inventories and Life Cycle Assessment of Photovoltaic Systems, International Energy Agency Photovoltaic Power Systems Programme. Task 12, Report T12-02:2011. ISBN: 978-3-906042-00-8.
Methodology Guidelines on Life Cycle Assessment of Photovoltaic Electricity,1st edition, IEA PVPS Task 12, International Energy Agency Photovoltaic Power Systems Programme. Report T12-01:2009.

TABLE 1 - TASK 12 PARTICIPANTS

COUNTRY/ ASSOCIATION	PARTICIPANT	ORGANISATION
Austria	Susanne Schidler	University of Applied Science, Fachhochschule Technikum Wien, Department of Renewable Energy
China	Lu Fang	Institute of Electrical Engineering, Chinese Academy of Sciences
	Zhang Jia	Institute of Electrical Engineering, Chinese Academy of Sciences
EPIA	Andreas Wade	European Photovoltaic Industry Association
France	Isabelle Blanc	MINES ParisTech
Japan	Junichi Hozumi	NEDO (Technology Development Organisation)
	Keiichi Komoto	Mizuho Japan
Korea	Jin-Seok Lee	Korea Institute of Energy Research (KIER)
Norway	Ronny Glöckner	ELKEM Solar
Spain	Marco Raugei	ESCi (Escola Superior de Comerc Internacional) and Oxford Brookes University
Switzerland	Rolf Frischknecht	treeze Ltd., fair life cycle thinking
The Netherlands	Mariska de Wild-Scholten	SmartGreenScans
	Carol Olson	Energy Research Center of the Netherlands (ECN)
USA	Garvin Heath	National Renewable Energy Laboratory (NREL)
	Parikit Sinha	First Solar

In addition to the collectively published IEA reports, Task 12 members published extensively in peer-reviewed journals and presented at international conferences.

For more information, contact the Task 12 Operating Agent:
Garvin Heath, National Renewable Energy Laboratory (NREL), USA

MEETING SCHEDULE (2014 AND PLANNED 2015)

In 2014, **the Task 12 Experts meet** in Beijing, China on 17-18 March, and in Kyoto, Japan on 23-24 November.
In 2015, **Task 12 will meet** March 11-12 in Vienna, Austria and September 10-11 in Switzerland.

TASK 13 – PERFORMANCE AND RELIABILITY OF PV SYSTEMS

Fig. 1 - Task 13 Expert Meeting in Freiburg, Germany, 01-03 April 2014 (Photo: Thomas Nordmann).

INTRODUCTION

The industry has a continued high interest in information on performance and reliability of PV modules and systems. In addition, financial models and their underlying technical assumptions have gained increased interest in the PV industry, with reliability and performance being key parameters used as input in such models.

Most accurate energy yield predictions in different climates as well as information on operational availability of PV systems are vital for investment decisions and, thus, for further market growth. In this context, performance and yield data, reliability statistics and empirical values concerning quality of PV systems are far more relevant today than they used to be in the past. The availability of such information is, however, rather poor.

Within the framework of PVPS, Task 13 aims at supporting market actors to improve the operation, the reliability and the quality of PV components and systems. Operational data of PV systems in different climate zones compiled within the project will allow conclusions on the reliability and on yield estimations. Furthermore, the qualification and lifetime characteristics of PV components and systems shall be analysed, and technological trends identified.

Presently, there are 60 members from 35 institutions in 18 countries collaborating in this Task, which had started its activities in May 2010. The extended Task work is expected to be undertaken over a period of 36 months (September 2014 to September 2017).

OVERALL OBJECTIVES

Task 13 engages in focusing the international collaboration in improving the reliability of photovoltaic systems and subsystems by collecting, analyzing and disseminating information on their technical performance and failures, providing a basis for their technical assessment, and developing practical recommendations for improving their electrical and economic output.

The overall objectives of Task 13 are to:

1. Address the economic aspects of PV system performance and reliability and to review the current practices for financial modelling of PV investments from the perspectives of technical risks during PV module production, PV system operation and the remaining uncertainties over the system's service life time.
2. Provide available performance data for any kind of decision maker for different PV applications and system locations (e.g. different countries, regions, climates). This data is evaluated for its applicability and quality in both a quantitative approach, using very large data sets and statistical methods, and a qualitative approach, where evaluations on individual component performances are conducted.
3. Perform activities on PV module characterization and failure issues in order to gain a comprehensive assessment of PV module conditions in the field. The comprehensive collection and analysis of field data of PV module defects will increasingly become important as a growing number of PV installations world-wide fail to fulfil quality and safety standards, which work of this Task will help to overcome.
4. Disseminate the results of the performance and reliability analyses to target groups in industry and research, financing sector, and the general public.

APPROACH

Various branches of the PV industry and the finance sector will be addressed by the national participants in their respective countries using existing business contacts. Given the broad, international project consortium, cooperation will include markets such as Asia-Pacific, Europe, and the USA.

Task 13 is subdivided into three topical Subtasks reflecting the first three objectives stated above. The fourth Subtask, dissemination of information, utilizes the output of the three Subtasks and disseminates the tailored deliverables produced in the three Subtasks.

ACCOMPLISHMENTS OF IEA PVPS TASK 13

SUBTASK 1: Economics of PV System Performance and Reliability

The newly defined Subtask 1 addresses the economic aspect of PV system performance and reliability. Here, previous and ongoing work within the IEA PVPS Task 13 and by others has proven the importance of quality assurance throughout the life cycle of a PV investment, i.e., during component manufacturing, system design, installation, commissioning and operation. Performance and reliability and, consequently, energy yield and return on investment strongly depend on these practices of quality assurance. Subtask 1 will inventory current practices for financial modelling of PV investments and review them in view of technical risks during PV module production, PV system operation and the remaining uncertainties over the system's service life.

The team of Subtask 1 is collecting examples of financial models for PV investments. This collection of models will serve as a reference base for the Subtask members. It is meant to illustrate the different ways how performance uncertainty and reliability are taken into account in the financial evaluation of a PV investment today. The Subtask is still looking for contributions in terms of financial model templates from commercial PV installations. Interested contributors may contact the Subtask leader. Notably, for respecting confidentiality, these contributions do not need to contain project-specific data. A reality check for this reference-base is foreseen for spring 2015 at the occasion of a working meeting with financial institutions.

SUBTASK 2: System Performance and Analysis

Subtask 2 aims at the observation and analytical assessment of PV system operation. Various methods and models for the analysis of PV system performance have been gathered, tested and further developed, leading to detailed guidelines on how-to perform state-of-the-art PV performance assessments and system failure analysis. Two technical reports related to this Subtask were finalized and published in 2014 [Report IEA-PVPS T13-03: 2014 and Report IEA-PVPS T13-05:2014]. For the next phase of Task 13, the scope of this Subtask is extended towards system modelling and related uncertainties.

The two technical reports may contribute to further increase the performance of PV power plants in the future. Firstly, they describe typical configurations of PV monitoring setups along with standard sets of PV performance indicators and their calculation routines. As monitoring hardware has a decisive influence on obtained data quality, an overview of different irradiation sensor equipment and their distinct applications are given.

The actual analysis of PV monitoring data is focused using a number of detailed and practical examples on how-to use the mathematical approach of periodic linear regression to perform actual data analysis. The approach of linear regression allows for analyzing the energy flow in a grid-connected photovoltaic system with a limited but selected collection of variables. This allows the main energy conversion steps taking place within the system to be analyzed such that performance variations and a number of distinct system failures may be detected numerically in an automatized fashion (Figure 2).

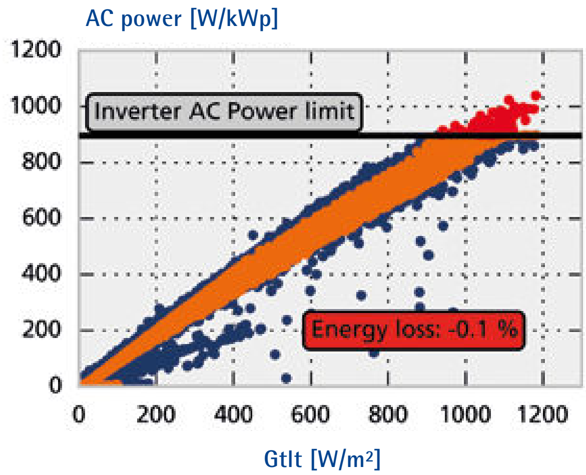

Fig. 2 - Specific AC output of a PV power plant vs. in-plane irradiance. Blue dots denote measured 5-min average values, orange and red dots show simulation results. Losses due to inverter power limitation cannot be measured in real life, but may be deducted from the fraction of red dots in this comparison.

Although the focus is on conventional PV power plant applications, also a number of detailed effects related to special PV module technologies have been considered. Effects related to special PV technologies, namely CIGS and amorphous silicon PV have been studied in particular. Based on data from different experimental installations in the field, their specific behaviour has been modeled and compared to classical crystalline silicon PV.

Finally, measures that can help to improve the performance of PV systems have been described, based on lessons learned from PV system design as well as operational monitoring using real time data acquisition. Regarding system design decisions, the main factors of influence are mounting angle and row distance (related to irradiance gains and shading losses), inverter to module power ratio and cabling optimizations. Several examples on both shading losses and inverter to module power ratio are given in the report [Report IEA-PVPS T13-03: 2014].

While the first phase of this Subtask dealt with essentials of monitoring and data analysis, our future work will consider also uncertainties related to data acquisition and subsequent modeling.

In a first step, realistic measurement uncertainties shall be determined, collected from different contributors and documented reports. Measurements of a number of important quantities (irradiances, temperatures, voltage, current, power, and energy values) shall be concerned. This includes both questions of sensor properties (spectral response, angular sensitivity) and sensor accuracies and questions of data acquisition system properties including sampling, averaging, data storage and data transfer. Best practice recommendations may be deducted from this collection.

Simulation models also show their uncertainties, both for intrinsic reasons (suitability of the model) and for reasons of parameterization. Uncertainties may be determined from theoretical considerations, from comparisons to observations or from Monte-Carlo-tests. The PV Performance Modelling Collaborative (https://pvpmc.sandia.gov) maintains a website with a collection of simulation models. One goal of this activity is to add uncertainty information to a number of these models. Also, for a number of "standard procedures" such as Performance Ratio (PR) assessments or yield estimations, methods for the determination of an overall uncertainty may be discussed among the participants.

SUBTASK 3: Module Characterisation and Reliability

Subtask 3 aims to provide recent scientific and technical findings and recommendations on suitable measurement, testing and characterisation methods for performance and reliability assessments of PV modules in the field. This work is based on close collaboration and exchange of results between international laboratories for PV module characterization and qualification in Europe, Asia and USA. Three technical reports related to this Subtask were finalized and published in 2014:

In March 2014 Task experts published the technical report on "Review on Failures of Photovoltaic Modules" [Report IEA-PVPS T13-01: 2014]. In the first part, this document reports on the measurement methods which allow the identification and analysis of PV module failures. In the second part, the most common failures of PV modules, their origin, statistics, relevance for module power and safety, are described in detail. The report mainly focuses on wafer-based PV modules. Thin-film PV modules are also covered, but due to the small market share of these types of PV modules reliable data is often missing. The author team focuses on types of PV module failures which are not specific for one special manufacturer and have a broader relevance. In the third part, new test methods are proposed to detect PV module failures in the field.

The target audience of this report is PV module designers, PV industry, engineering lines, test equipment developers, testing companies, technological research laboratories, standardization committees, as well as national and regional planning authorities.

In May 2014, Task 13 experts published the technical report entitled "Characterization of Performance of Thin-film PV Technologies" [Report IEA-PVPS T13-02: 2014] on how to measure the power of thin-film modules and evaluate these from an international perspective. Although thin-film PV modules have been in production for decades, the characterization of their performance, both outdoors and under artificial light, remains a topic of active research. This is because the field contains a diverse set of PV technologies, each of which has physical differences from conventional crystalline silicon PV. These differences range from different temperature coefficients to complex short-term or seasonal transients in performance. This report summarizes the nature of these special behaviours and demonstrates best practices for handling them in the context of several case studies.

TASK 13 PARTICIPANTS IN 2014 AND THEIR ORGANIZATIONS

COUNTRY	ORGANIZATION
Australia	CAT Projects, Desert Knowledge Precinct Murdoch University The University of New South Wales (UNSW)
Austria	Austrian Institute of Technology (AIT) Polymer Competence Center Leoben (PCCL) GmbH Institute of Polymeric Materials and Testing (IPMT), Johannes Kepler Universität Linz
Belgium	3E nv/sa, Brussels
China	Institute of Electrical Engineering, Chinese Academy of Sciences (CAS)
Denmark	Silicon & PV Consulting, Birkerød
EPIA	European Photovoltaic Industry Association (EPIA)
France	Commissariat à l'Énergie Atomique et Énergies Alternatives/ Institut National de l'Énergie Solaire (CEA / INES) Electricité de France (EDF R&D)
Germany	Fraunhofer-Institut für Solare Energiesysteme ISE Institute for Solar Energy Research Hamelin (ISFH) TÜV Rheinland Energie und Umwelt GmbH
Israel	M. G. Lightning Electrical Engineering
Italy	European Academy Bozen/Bolzano (EURAC) Gestore dei Servizi Energetici - GSE S.p.A. IMT Institute for Advanced Studies Lucca Ricerca sul Sistema Energetico – RSE S.p.A.
Japan	New Energy and Industrial Technology Development Organization (NEDO)
Malaysia	Universiti Teknologi Malaysia (UTM) Universiti Teknologi MARA (UiTM)
Netherlands	Utrecht University, Copernicus Institute
Norway	University of Agder
Spain	DNV GL - Energy - Renewables Advisory National Renewable Energy Centre (CENER)
Sweden	ABB AB, Corporate Research Paradisenergi AB SP Technical Research Institute of Sweden
Switzerland	Scuola Universitaria Professionale della Svizzera Italiana (SUPSI) TNC Consulting AG
USA	Case Western Reserve University National Renewable Energy Laboratory (NREL) Sandia National Laboratories (SNL)

Updated contact details for Task 13 participants (Figure 1) can be found on the IEA-PVPS website www.iea-pvps.org.

Fig. 3 - PV module reliability test site in Indonesia studying the stress factors of PV modules failures under real time outdoor testing compared to accelerated stress conditions (Photo: TÜV Rheinland).

The target audience of the report is scientists and engineers who participate in the collection, analysis and prediction of indoor and outdoor performance data. This includes planners, operators and manufacturers of PV power plants, participants in the standardization of methods for performance measurement and workers in academe or at national laboratories.

In November 2014, the technical report "Modelling Acceleration Based on Outdoor Stress Conditions for PV Module Testing" [Report IEA-PVPS T13-04: 2014] was finalized and published. Modelling of the service life of modules applied in different climatic regions requires knowledge about the transient temperature load. A model which allows calculating the module temperature as function of the ambient temperature, the global irradiation and the wind speed, facilitates the use of any time series of climatic data for a climatic region of interest, which could be provided by weather services, test reference years or via the internet. The microclimatic stress level of UV radiation and moisture on the PV modules is modelled as function of the module temperature and the important climatic parameters. Simple time transformation functions were used for the design of appropriate accelerated service life tests. The evaluated testing times differ up to an order of magnitude for different climatic locations, depending on the kinetics of the dominant degradation processes.

The target audience of this report is PV module designers, PV industry, engineering lines, test equipment developers, testing companies and technological research laboratories.

For the current phase of Task 13, the scope of this Subtask is extended towards PV module uncertainties and propagation into modelling as well as characterization of PV module conditions and PV module failures in the field:

Activity 3.1: Power Rating, Uncertainties and Propagation into Modelling will provide an analysis of typical contributions to uncertainty and comparability of laboratory power rating measurements and result in the possibility to analyse, explain and reduce deviations between indoor and outdoor power rating; and assess the influence of measurement uncertainty on modelling results.

Activity 3.2: Module Energy Yield Data from Test Fields in Different Climates aims to assess the today available approaches and to suggest how to harmonize the equipment requirements, measurements procedures and uncertainty determination and to apply it to a set of selected data which will be made available to team members and external partners working on modelling and energy rating. The data should cover the most important technologies and climatic zones and improve the comparability of data from different institutes and locations.

Activity 3.3: Characterization of PV Module Condition in the Field - Guidelines on IR and EL in the Field will provide an overview of different methods to collect IR and EL images in the field resulting in recommendations and guidelines for the standardized handling of IR and EL images to identify the most common failures in the field.

Activity 3.4: Assessment of PV Module Failures in the Field aims to provide status of the ability to predict the power loss of PV modules for specific failure modes. The team will describe interactions and incompatibilities of materials to better understand PV modules failures in various climatic zones. We will identify the most important stress factors for each PV module failure mode and assess its impact on the PV module power (Figure 3).

SUBTASK 4: Dissemination

This Subtask is focussed on the information dissemination of all deliverables produced in Task 13. The range of activities in this Task includes workshops, presentations, databases and technical reports.

The following five Task Reports were published and disseminated by websites, emails, press releases, newsletters and others in 2014 (Figure 4):

1. Review of Failures of Photovoltaic Modules, Report IEA-PVPS T13-01: 2014
2. Analytical Monitoring of Grid-connected Photovoltaic Systems - Good Practices for Monitoring and Performance Analysis, Report IEA-PVPS T13-03: 2014
3. Characterisation of Performance of Thin-film Photovoltaic Technologies, Report IEA-PVPS T13-02: 2014
4. Modelling Acceleration Based on Outdoor Stress Conditions for PV Modules Testing, Report IEA-PVPS T13-04: 2014
5. Analysis of Long-Term Performance of PV Systems, Report IEA-PVPS T13-05: 2014.

Fig. 4 – Task 13 Reports. Printed copies for the first two published reports are available for dissemination activities on national and international level.

Fig. 5 - The Task 13 workshop on PV system analysis and module reliability was held as a parallel event of the European PVSEC's programme in Amsterdam, the Netherlands in September 2014. The workshop entitled "PV Performance Analysis and Module Reliability', attracted more than 100 interested participants from industry and research.

All publications are available for download at the Published Documents section on the IEA PVPS website: http://www.iea-pvps.org/index.php?id=165

Task 13 hosted the Open Workshop "PV Performance Analysis & Module Reliability" at Fraunhofer ISE in Freiburg, Germany, on 2nd April 2014. Eight experts from Task 13 have presented the achievements of the common work for the period from May 2010 until April 2014.

As a parallel event and part of the EUPVSEC's programme, the "PV Performance Analysis and Module Reliability," Task 13 Workshop was held in Amsterdam on 23 September 2014. During this workshop, a number of international experts have presented and drawn on their experiences in different countries. First results of the extended Task were also included, particularly on the economics of PV system performance and reliability. The workshop attracted more than 100 participates from research, industry including module and inverter manufacturers, utilities, system operators, system owners, developers and construction companies, investors, banks and insurance companies (Figure 5).

Task 13 Workshop presentations from both workshops held in 2014 are publicly available for download at the Workshops section on the IEA PVPS website: http://www.iea-pvps.org/index.php?id=164

Furthermore, Task 13 experts were invited to present during the following international events and workshops in 2014:

- IEA PVPS Workshop at 6th WCPEC, "Challenges and Promises to Large Scale PV Development", Kyoto, Japan, 25th November, 2014
- IEA PVPS Workshop China, Beijing, China, 29-30th November, 2014
- Asia-Pacific Solar Research Conference, University of NSW, Sydney, Australia, 8-10th December 2014.

MEETING SCHEDULE (2014 AND PLANNED 2015)

The 9th Task 13 Meeting was held at Fraunhofer ISE in Freiburg, Germany, 01-03 April 2014.
The 10th Task 13 Meeting took place in Amsterdam, Netherlands, 22 September 2014.
The 11th Task 13 Meeting was held in Kyoto, Japan, 23 November 2014.
The 12th Task 13 Meeting will be held in Leoben and Vienna, Austria, 17-19 March, 2015
The 13th Task 13 Meeting will be held in Alice Springs / Melbourne, 6-8 October, 2015

TASK 14 – HIGH PENETRATION PV IN ELECTRICITY GRIDS

Fig. 1 - Task 14 Experts at Meeting in Geneva (Photo: IEA-PVPS Task 14).

INTRODUCTION

With PV becoming an increasingly visible part of the electricity mix in a number of countries, proper understanding of the key technical challenges facing high penetrations of PV is crucial to ensure further smooth deployment of PV. Key issues include the variable and somewhat unpredictable nature of PV generation, the power electronics interconnection to the grid and its location within distribution grids typically designed only for supplying loads. Power system protection, quality of supply, reliability and security may all be impacted.

Due to the different characteristics of PV compared to other renewable generation in all of these regards only limited lessons can be learned from more established intermittent renewable technologies such as wind generation.

Overcoming the technical challenges will be critical to placing PV on an even playing field with other energy sources in an integrated power system operation and augmentation planning process and will allow PV to be fully integrated into power system, from serving local loads to serving as grid resources for the interconnected transmission and generation system.

2014 marked a key milestone in the activities of Task 14 with the successful conclusion of its first term and the official endorsement of the second term by the IEA-PVPS Executive Committee in April 2014.

OVERALL OBJECTIVES

As part of the IEA-PVPS programme, Task 14 has been supporting different stake-holders from research, manufacturing as well as electricity industry and utilities by providing access to comprehensive international studies and experiences with high-penetration PV. This work will be continued in the second term, keeping the focus on technical issues related to high penetration PV.

Following the ongoing growth PV has today become a visible player in the electricity generation not only on a local, but country wide level. While during the initial phase of Task 14 in 2010, only a limited number of high penetration cases actually existed around the globe, mostly related to research or demonstration projects and field trials, the situation has changed fundamentally since then:

- High Penetration PV has become a truly global issue today in regions around the world.
- Massive technical developments are currently ongoing at the research as well as the industrial level following the increasing penetration of PV.
- New fundamental challenges arise with PV becoming a game changer on the bulk power system level in several markets.
- Without any other global initiative on PV grid integration, bringing together technical and non-technical expertise e.g. regarding market design with PV is strongly needed.

All these facts clearly highlight the strong need for continued international R&D collaboration to address various aspects related to PV grid integration and to collate and disseminate international knowledge of PV systems on a high penetration level.

Hence Task 14 will continue its work in order to reduce technical barriers to achieving high penetration levels of distributed renewable systems on the electric power system. However, as the recent work within Task 14 has shown that technical barriers are frequently a result of gaps or inadequacies in the regulatory and organisational framework, further aspects related to electricity markets and regulation will be a key part of the work programme for the second term.

SUBTASKS AND ACTIVITIES

The work programme for the second term addresses primarily technical issues to high penetration of PV in electricity networks, but also includes for the first time issues related to implications of high-penetration PV on the level of electricity markets.

Technical issues which are covered by the work programme for the proposed extension of Task 14 include energy management aspects,

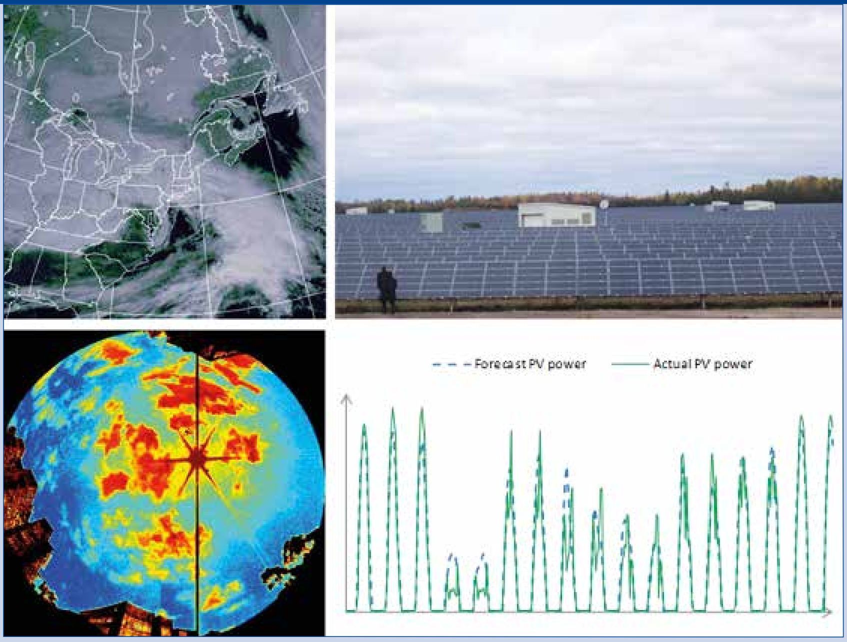

Fig. 2 - Photovoltaic and Solar Forecasting: State of the Art, (source: IEA-PVPS Task 14, Upper left image: Environment Canada, Data courtesy of NOAA (February 27, 2013) Upper right image: Dave Turcotte, CanmetENERGY, Natural Resources Canada

grid interaction and penetration related aspects related to local distribution grids and central PV generation scenarios. Besides these grid-focused aspects, requirements for components such as PV power converters acting as the smart interface between the PV generator and the electricity grid will be covered.

As the smart grid integration of decentralised solar PV is highly dynamic and strongly interlinked with the development of (future) smart grids, a new subtask has been set up which will particularly address the possible roles of PV in future Smart Grids scenarios.

The work programme is organized into five main technical Subtasks (1 to 5) and one cross-cutting subtask, which will be a hub to all other subtasks and will investigate the implications of the technical solutions on the electricity market:

- Cross-cutting subtask: Market implications with High PV Penetration
- Subtask 1 Energy management with high PV penetration
- Subtask 2 High penetration PV in local distribution grids
- Subtask 3 High penetration solutions for central PV generation scenarios
- Subtask 4 Smart power converters for high penetration PV and Smart Grids
- Subtask 5 (new): Communication and Control for high penetration of PV

CROSS-CUTTING SUBTASK: Market Implications with High PV Penetration

This Subtask introduces aspects related to market design with High PV Penetration into the scope of Task 14 and coordinate these activities with Task 1.

There shall be collaboration with other activities working on market issues (e.g. Task 1) and (external) stakeholders. It shall weave together technical information from other Subtasks, investigate with respect to their implications for the (existing) market and put them into a market context. This Subtask shall also undertake development of "building blocks" for market design and "PV Toolkits."

SUBTASK 1: Energy Management with High PV Penetration

PV is a key driver of new opportunities for local energy management. One of the main values of PV for grid in the association of a production source, with an existing consumption. Existing rules for the integration of PV into grid are generally missing this opportunity.

The Subtask 1 has already shown opportunities with very short term forecast (1.1), energy management opportunities in households (1.2) and management of the very short term variability (1.3). This Subtask is dedicated to focus on the technical and economic value of energy management in relation with local consumption in other configurations. Local energy management can facilitate the integration of measure to integrate PV as a major energy sources.

This Subtask is focusing on opportunities between the inverter and the point of connection, including virtual point of connection. These solutions can be valuable both for grid operators, for PV plant owners and if different building owners. Therefore, this task will include case studies and analysis of business model (self-consumption, pro-consumers).

SUBTASK 2: High Penetration PV in Local Distribution Grids

In high PV-penetration scenarios new challenges for the distribution system operator arise. These challenges include technical, as well as economic aspects of distribution system operation and planning. On a global scale, various research activities are currently being conducted in order to understand the distribution system operators' future needs for a secure and reliable grid operation in high PV-penetration scenarios. This Subtask brings together international expertise and experience in the field of distribution system operation and planning in the context of high PV-penetration scenarios.

Subtask 2 addresses grid planning as well as grid operation issues for distribution grids with high PV penetration. In this context, Subtask 2 collects best-practice examples from participating countries in order to present the state-of-the-art as well as future prospects in the field of a technically and economically improved PV grid integration

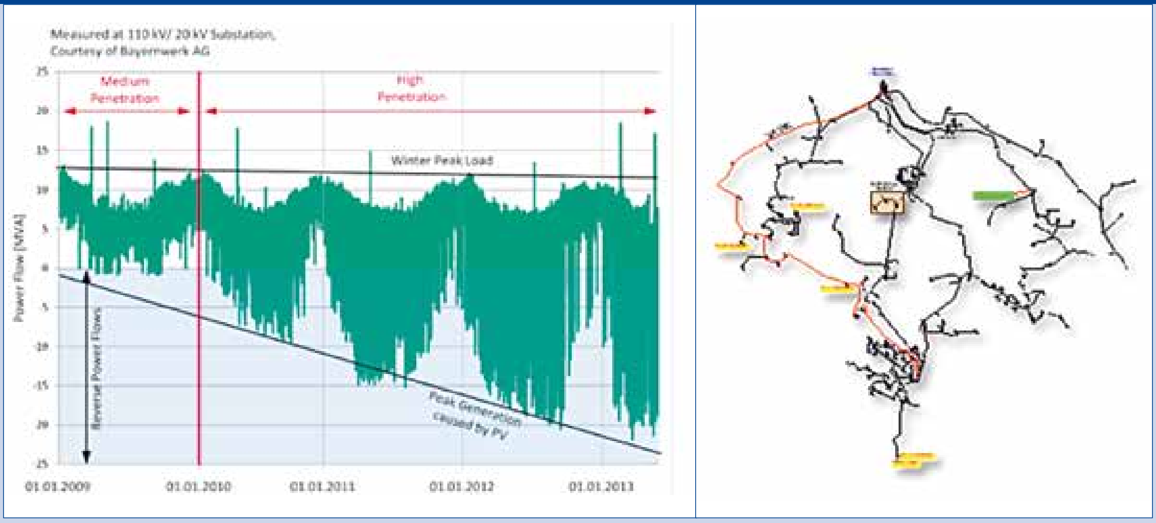

Fig. 3 - Example for the transition from consumption to supply grids. Bi-directional power flow at a 110kV/ 20 kV distribution substation. Courtesy of Bayernwerk AG, Germany.

and distribution grid operation. The collected bestpractice examples will be presented in activity reports together with recommendations for decision makers from the field of distribution grid operation and planning.

SUBTASK 3: High Penetration Solutions for Central PV Generation Scenarios

PV generation varies cyclically in a year and in a day, and irregularly due to climate. The large penetration of PV generation will cause the issues not only of voltage and power flow fluctuation in a local distribution system but also issues of the demand-supply balance of a power system, which will result in the problems including frequency fluctuation and difficulty of demand-supply management. Accordingly, in order to realize high PV penetration to a power system, it is crucial to evaluate the impact and envision the future power system.

This Subtask shall focus on grid interaction and penetration related aspects; identify gaps in current PV system technology and electric power systems; and analyze, how large numbers of PV installations can be successfully integrated in total power systems, including the technology of smart grids.

SUBTASK 4: Smart Power Converters for High Penetration PV and Smart Grids

This Subtask will discuss and investigate new requirements and new functionalities of power converters (inverters) which are needed for the full integration of PV generation systems into future Smart Grids. A particular focus will be laid on grids and power systems with a massive share of non-rotating variable generation (mainly PV and wind), where stability and control issues become vital for the extended deployment of RES.

Its scope includes power converter technology aspects; simulation and modelling of PV power converters; technical requirements arising from smart grid control schemes; addon functionalities of PV power converters; grid interconnection specifications and standards; and power converters for grid connected storage systems.

SUBTASK 5: Communication and Control for High Penetration of PV

The research field of smart grid integration of decentralised solar photovoltaics (PV) is highly dynamic and strongly interlinked with the development of (future) smart grids. Power system operators look at the PV grid integration as a "one of many" challenge, i.e. while the PV community is naturally focusing on the integration of PV, a utility has to balance the interests and technical solutions for a whole variety of new and future technologies. Those include renewable energy integration (not only focusing on solar, but especially also on wind, where applicable), and extend even more so into smart metering, demand-side management and/or direct load control. To ensure that PV grid integration solutions are well-aligned with such comprehensive requirements it is indispensable to analyze also in detail the challenges and solutions for the PV grid integration from a smart grid perspective and to suggest future-compliant solutions.

This Subtask shall analyse appropriate control strategies and communication technologies to integrate a high number of distributed PV in smart electricity networks.

PROGRESS AND ACHIEVEMENTS

Based on the analysis of the national regulatory framework for the interconnection of PV systems into distribution grids and the lessons learned from selected national high penetration PV case-studies, in Subtask 2 a report describing the "Transition from One-Directional to Bi-Directional Distribution Grids on from Consumption to Supply Grids – Recommendations based on Global experience" was produced. This work derives a roadmap with crucial technical milestones on the way to large scale high PV penetration scenarios and includes:

- Definition of PV penetration scenarios;
- Technical and regulatory barriers for high penetration PV in local distribution grids;
- Key findings from national high penetration PV case-studies aiming at in-creasing the hosting capacity of distribution grids including cost-benefit-analysis;
- Recommendations for the transition from consumption to supply grids;
- Future prospects regarding an improved distribution grid integration of PV.

In addition, the forecast expert group investigated the suitability of Forecast Tools with respect to high penetration PV, linking together weather forecasts, prediction and monitoring tools. This work item is jointly carried out with IEASHC Task 46 on solar resource characterisation.

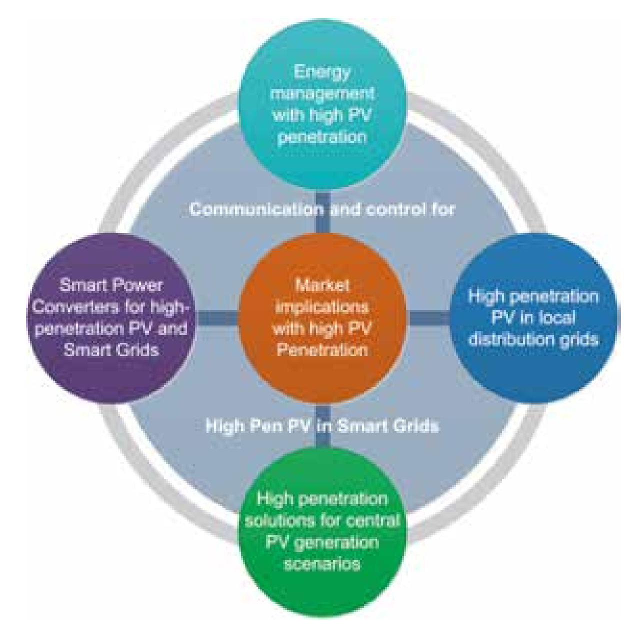

Fig. 4 - IEA PVPS Task 14 organization.

Complementing its technical work, Task 14 continued the successful series of high penetration workshops with several well received events:

- In March 2014 IEA PVPS Task 14 organized its 10th Utility Workshop in Geneva, Switzerland, at the premises of HEPIA. With almost 50 participants from Swiss utilities, manufacturers, research and agencies, the workshop was a great success and attracted broad interest from all stakeholders. The workshop program included presentations on specific case studies from Switzerland, as well as presentations on international experiences.
- In September 2014, the IEA PVPS Task 1 & 14 Workshop "Self-Consumption Business Models - Technical and Economic Challenges," as an official event of the 29th EU PVSEC, was jointly organised by the IEA - International Energy Agency, EPIA and the EU PVSEC. While the cost of PV electricity is going down, the question of how business models based on the self-consumption of PV electricity becomes more acute. This workshop explored the challenges associated with producing electricity with PV for local needs from a technical and economical point of view. An in-depth analysis of the potential and challenges of self-consumption based business models was discussed, with a focus on storage and "Demand Side Management." In addition, the need to integrate in the electricity system and especially the question of the integration into the distribution grids was linked to the question of self-consumption.

Task 14 Workshop presentations of both workshops held in 2014 as well as documents from previous events are publicly available for download at the Workshops section of the IEA-PVPS website: http://www.iea-pvps.org/index.php?id=212

SUMMARY OF TASK 14 ACTIVITIES PLANNED FOR 2015

Task 14 activities in 2015 will focus on the finalization of the new Workplan for the second term and the start of implementation of the subtasks.

In addition, further technical research will be made on the following issues:

- Emphasis will be given to the analysis of the impact of high PV penetration on higher voltage levels in electricity networks as a cross topic between subtask 2 and subtask 3 The mutual interaction between DSO and TSO will be elaborated in the planned joint workshop between IEA PVPS Task 14 and IEA-ISGAN Annex 6 to be held in Vienna in May 2015.
- Investigation of inverter related requirements for high penetration PV, including interface related issues and communication/control issues.
- Finalisation of the Subtask 1 activities and publication of the reports.

INDUSTRY INVOLVEMENT

As from the beginning, industry has been directly involved in the development of the concept and Workplan for Task 14. In addition, a number of PV industry and utility representatives also directly participate in the Task 14 group.

Besides the country participation, experts from EPIA, the European Photovoltaic Industry Association and CANSIA, The Canadian Solar Industry Association are also official members of Task 14 and actively contribute to its activities.

During its whole period, Task 14 actively integrates industry by organizing special workshops for knowledge exchange between experts from utilities and the Task 14 group.

PUBLICATIONS AND DELIVERABLES

The products of work performed in Task 14 are designed for use by experts from the electricity sector, specialists for photovoltaic systems and inverters, equipment manufacturers and other specialists concerned with interconnection of distributed energy resources.

In 2014 Task 14 published 2 official reports

- Part I: Report on state-of-the-art on active and reactive power management by PV systems under the regulatory framework of the participating countries including detailed information on national high penetration case studies: IEA–PVPS T14-02:2014 "High Penetration PV in local Distribution Grids: Case-Study Collection."
- Part II: Report on recommendations for the transition from distribution to supply grids and management summary: IEA PVPS T14-03:2014 "Transition from Uni-Directional to Bi-Directional Distribution Grids: Management Summary of IEA Task 14 Subtask 2 – Recommendations based on Global Experience."

Besides PVPS related dissemination activities, Task 14 experts contributed to a number of national and international events and brought in the experience from the Task 14 work. Additionally, numerous presentations at various conferences and meetings, the main contributions to be noted during 2014 included the following:

- Invited presentations at the 2014 PV Distribution System Modelling Workshop, Santa Clara, CA, USA, on Task 14 activities in the field of Grid Codes and Interconnection Standards;
- Presentation at the Sustainable Energy Week, Brussels, on "How to match DSOs needs and PV capabilities?";

TABLE 1 – CURRENT LIST OF TASK 14 PARTICIPANTS (NOT INCLUDING OBSERVERS)

COUNTRY	PARTICIPANT	ORGANISATION
Australia	Iain McGill	University of NSW
Australia	Anna Bruce	University of NSW
Australia	Glen Platt	CSIRO Energy Technology
Austria	Roland Bründlinger	AIT Austrian Institute of Technology
Austria	Christoph Mayr	AIT Austrian Institute of Technology
Belgium	Pieter Vingerhoets	KUL
Canada	Sophie Pelland	Natural Resources Canada, canmetENERGY
Canada	Ravi Seethapathy	Consultant
Canada	Dhaval Shah	Schneider Electric
China	Wang Yibo	Chinese Academy of Science
Denmark	H. B. Frederiksen	EnergiMidt A/S
EC	Arnulf Jäger-Waldau	European Commission
EPIA	Ioannis-Thomas Theologitis	European Photovoltaic Industry Association
EPIA	Manoel Rekinger	European Photovoltaic Industry Association
Germany	Gunter Arnold	Fraunhofer IWES
Germany	Thomas Stetz	Fraunhofer IWES
Germany	Daniel Premm	SMA Solar Technology AG
Germany	Holger Ruf	Hochschule Ulm
Germany	Gerd Heilscher	Hochschule Ulm
Israel	Moshe Ohayon	Israel Electrical Company
Italy	Giorgio Graditi	ENEA
Italy	Adriano Iaria	RSE, Ricerca Sistema Eletrico
Japan	Kazuhiko Ogimoto	The University of Tokyo
Japan	Toshihiko Takai	NEDO
Japan	Yuzuru Ueda	Tokyo University of Science
Malaysia	Ali Askar Sher Mohamad	SEDA
Malaysia	Azah Ahmad	SEDA
Malaysia	Koh Keng Sen	SEDA
Netherlands	Arno Van Zwam	Mastervolt
Portugal	Catarina Calhau	EDP Inovacao, SA
Singapore (observer)	Thomas Reindl	SERIS
Singapore (observer)	André Nobre	SERIS
Spain	Vicente Salas	Universidad Carlos III de Madrid
Sweden	Antonis Marinopoulos	ABB Corporate Research
Switzerland	Christof Bucher	Basler & Hoffmann AG
Switzerland	Lionel Perret	Planair SA, Switzerland
Switzerland	Jan Remund	Meteotest
Switzerland	Pierre Renaud	Planair SA, Switzerland
Switzerland	Davy Marcel	Planair SA, Switzerland
United States	Barry Mather	National Renewable Energy Laboratory NREL
United States	Benjamin Kroposki	National Renewable Energy Laboratory NREL

Fig. 5 - Task 14 experts Kyoto, Japan (Photo: IEA PVPS Task 14).

- IEEE PES General Meeting, Washington D.C., "Local Voltage Control Strategies for PV Storage Systems in Distribution Grids";
- Keynote speech at the 2014 EUPVSEC in Amsterdam, "High Penetration PV in Local Distribution Grids - Outcomes of the IEA PVPS Task 14 Subtask 2" by T. Stetz et.al.;
- Invited talk at the 2014 International Conference on Integration of Renewable and Distributed Energy Resources (IRED) on "Grid Codes in Europe."

Presentations of all Task 14 events organised so far are publicly available for download at the Archive section of the IEA PVPS website: http://www.iea-pvps.org/index.php?id=9

The successful series of utility workshops related to high PV penetration scenarios in electricity grids will be continued in 2015, in order to involve industry, network utilities and other experts in the field of PV integration to the Task 14 work.

At the moment, 2 workshops are tentatively planned for 2015:
- Joint workshop between IEA-PVPS Task 14 and IEA-ISGAN Annex 6 planned in Vienna in May 2015 in the frame of the Austrian Smart Grids Week 2015
- Toronto, Canada, November 2015: Utility Workshop

Presentations of all Task 14 events organised so far are publicly available for download at the Workshops section of the IEA-PVPS website: http://www.iea-pvps.org/index.php?id=212

MEETING SCHEDULE

2014 Meetings:
- **The 9th Experts' Meeting** was held in Geneva, Switzerland, April 2014, supported by the Swiss Federal Office of Energy
- **The 10th Experts' Meeting** was held in Kyoto, Japan, November 2014, supported by NEDO 2015 Meetings (tentative)

2015 Meetings:
- **The 11th Experts' Meeting** is planned to be held in Vienna, Austria, May 2015, hosted by AIT, supported by FFG and BMVIT.
- **The 12th Experts' Meeting** is tentatively planned to be held in Toronto, Canada, November 2015, hosted by CANSIA

AUSTRALIA

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

RENATE EGAN, CHAIR, AUSTRALIAN PV INSTITUTE
WARWICK JOHNSTON, SUNWIZ

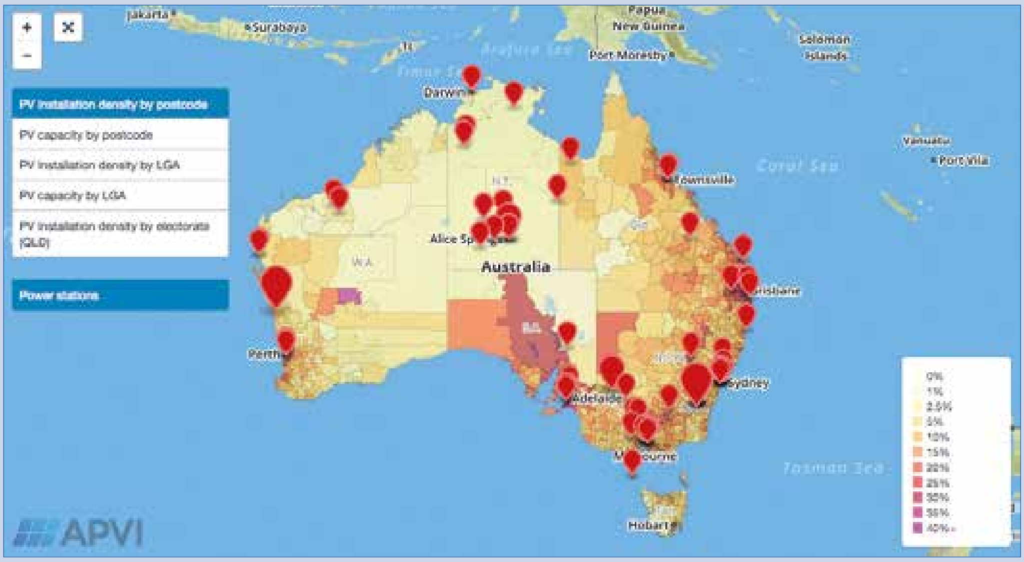

Fig. 1 – PV Density by Post Code in Australia. Image from the APVI Australian Solar Map http://pv-map.apvi.org.au/

GENERAL FRAMEWORK AND IMPLEMENTATION

Solar power is hugely popular in Australia. 1,4 million Australian homes now have a PV system. Residential penetration levels average 17 % of households and reach well over 40 % in some urban areas. Strong community support for solar energy has resulted in governments and utilities dropping proposed retrospective cuts in feed-in tariffs and charges for PV connections in three Australian states.

State incentives have been wound back to voluntary feed-in tariffs offered by electricity retailers. Where available, these are close to wholesale electricity prices and well below the retail cost of electricity in all but one Australian state. Australia's PV market is therefore increasingly focussed upon self-consumption. The main remaining incentive for PV is under review as the Federal Government negotiates proposed changes to the Renewable Energy Target.

Despite this, the Australian PV market expanded slightly in 2014, with installation levels increasing from 810 MW installed in 2013 to around 910 MWp. Installed capacity has reached 4,1 GWp, accounting for 7 % of electricity capacity and 2 % of electricity generation.

Installation restrictions are being imposed by electricity network operators in some areas to cope with potential issues arising from high penetration levels. The major issue arising, however, is economic, not technical. With revenue for electricity networks and retailers dependent largely on kWh sales, PV uptake has contributed to revenue reductions. Large central generators have also been impacted by the overall reductions in energy sales, with several plant closures. A debate about tariff reform has begun, but may take years to play out. Meanwhile many distribution network operators have singled out PV for punitive requirements such as export-limiting technologies, or otherwise restricted system sizes, particularly for non-residential systems.

Fig. 2 – IKEA's 3,6 MW Commercial PV Roll-out in Rhodes, NSW (Photo: Canadian Solar, Australia).

NATIONAL PROGRAMME

The Australian Government repealed the carbon price mechanism in 2014, so that the main support for PV at a national level remains the Renewable Energy Target (RET). Support for large systems is via the Large-scale RET (LRET) which at present increases each year to 41,000 GWh of renewable electricity by 2020, maintained to 2030. It operates via a market for Large-scale Generation Certificates (LGCs), with 1 LGC created for each MWh of electricity generated. Support for small-scale systems is via an uncapped Small-scale Renewable Energy Scheme (SRES), for which 1 MWh creates 1 Small-scale Technology Certificate (STC). All PV systems up to 100 kWp are also able to claim STCs up-front for up to 15 years of deemed generation, based on location. This means that the STCs for small systems act as an up-front capital cost reduction. The Government has proposed significant reductions to the RET and two separate reviews of the mechanism were completed in 2014. Combined with the Government's proposals to reduce the target, the reviews have created uncertainty that dampened investment in the Large-scale RET. The outcome of the reviews and the proposed reductions in the Target are no yet clear.

Fig. 3 - PV Outdoor Research Facility at the CSIRO Energy Centre in Newcastle Australia.

RESEARCH, DEVELOPMENT & DEMONSTRATION

PV research, development and demonstration are supported at the national, as well as the State and Territory level. In 2014, research grants were available through the Australian Research Council and the Australian Renewable Energy Agency (ARENA). 43 % of ARENA's funding has been directed towards PV projects, in which 64 PV projects have been supported to date, in addition to 75 scholarships and fellowships. Major projects supported included: Additional financial support for the 155 MW Solar Flagship, building Australia's first off-grid solar farm (6,7 MW) to power a Bauxite mine and nearby township. 2014 also saw 21 MAUD invested in 12 solar research excellence projects, complementing a portfolio of solar research projects with a combined value of 230 MAUD.

In 2014, the Clean Energy Finance Corporation has supported Innovative Solar Leasing Programs worth 120 MAUD for three PV companies, and 13 MAUD for a 3 MW expansion of Uterne solar power station in Alice Springs.

INDUSTRY AND MARKET DEVELOPMENT

After contracting in 2013, the solar industry stabilised in 2014 and even experienced modest growth. After years of instability caused by rapidly shifting government incentives, the market for sub-100 kW PV has stabilised. Australia's small-scale PV market has experienced a shift towards commercial systems, as many households already have a solar power system. The nascent commercial PV market has grown considerably to represent 20 % of the market by volume. Companies such as IKEA have installed PV on each of its stores. Hence, average system size has climbed to reach 4,7 kW/system by the end of 2014. Module prices stabilised at around 0,75 AUD/Wp in 2014 and installed prices for small residential systems also stabilised slightly below 2,50 AUD/Wp.

2014 saw the utility-scale market develop strongly in Australia. Driven by the government Solar Flagship program, that awarded funds some years ago, installation of several large-scale PV systems finally began. 31 MW was completed of a 100 MW solar farm in New South Wales, with another 3 MW project installed in Queensland as part of a related research program. Under a separate program which followed a reverse auction process, a 25 MW solar farm was completed in the Australian Capital Territory. The private sector also started to invest, though mostly foreign firms were involved: Belectric installed a 3 MW solar farm to test the waters in Australia.

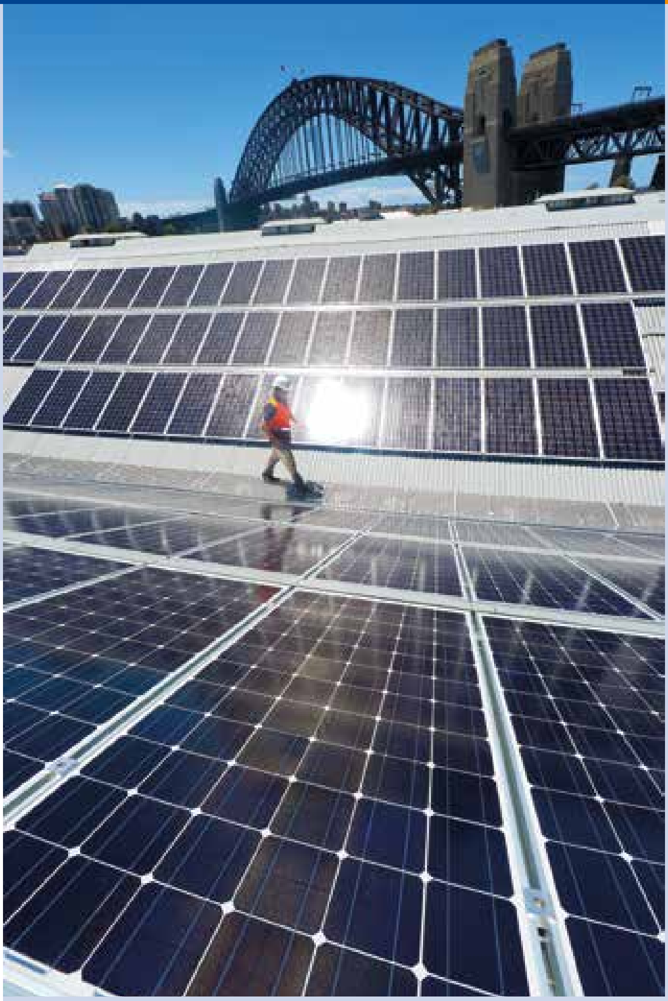

Fig. 4 - Sydney Theatre Company rooftop system (Photo: SF-Suntech).

The trends that commenced in 2014 are likely to continue into 2015. A gradually-declining residential PV sector continues to be offset by a rapidly growing commercial PV sector. Major utility-scale projects are also expected to continue in 2015, though this will represent the fruition of the government's historic one-off investment in utility-scale PV via the Solar Flagship program. A new Direct Action program has been introduced, whereby incentives will be provided for emissions reductions activities across the Australian economy – one such program that directly benefits PV is Solar Towns, a 2 MAUD program to support installation of PV in six electorates and two other areas of Australia.

Meanwhile there is ever increasing customer interest in on-site storage. Although not yet cost effective for most customers, a market for storage is already developing. This trend could exacerbate issues faced by incumbent electricity sector businesses, even if it offers a means to manage supply intermittency and peak demand, since it would facilitate the installation of larger PV systems and may also see a trend to self-sufficiency and disconnection of customers from main grids.

AUSTRIA

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

HUBERT FECHNER, UNIVERSITY OF APPLIED SCIENCES, TECHNIKUM VIENNA

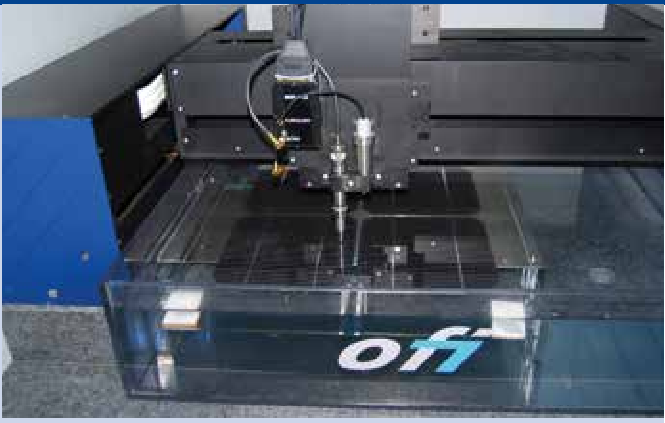

Fig. 1 - Non-destructive characterisation of a PV-test module by SAM (Scanning Acoustic Microscopy), Austrian Research Institute for Chemistry and Technology.

GENERAL FRAMEWORK AND NATIONAL PROGRAMME

Austria is amongst the countries with the highest share of renewably electricity in Europe. About 75 % of the electricity supply is based on renewable energy, predominated by mainly large hydro power with more than 65%, wind energy with about 7,5 %, some bio-electricity and since a few years ago, a significant rise in photovoltaics with about 1,3 % in 2014.

Austria's support schemes for photovoltaics are manifold. The support per unit was further reduced in 2014, while total financing remained more or less the same.

Two support schemes are dominating:

- The Feed-in-Tariff system is designed only for systems larger than 5 kWp; Feed-in Tariff is provided via the national green-electricity act; The "new *RES*" are supported by this act mainly via up to 13 years guaranteed feed-in-tariffs; an annual cap with an additional 50 MEUR for all "new renewables" limits the installation. The application had to be submitted via internet on January 2nd 2014. The available financial allocation was reached within some minutes. 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 traders. For 2014, the feed-in-tariff was set with 12,5 EURcent/kWh for PV at buildings (18,12 EURcent/kWh in 2013) and 10 EURcent/kWh for PV on open landscape (16,59 EURcent/kWh in 2013). As in 2013, an additional 200 EUR subsidy per kWp was offered.
- 26,8 MEUR were dedicated to PV investment support for small, private systems up to 5 kWp by the Austrian "Climate and Energy Fund." This additional support scheme exists since 2008, and is well-co-ordinated with the feed-in scheme. With 275 EUR per kWp for roof-top systems (300 EUR in 2013) and 375 EUR per kWp for building integrated systems (400 EUR in 2013), the support per kWp was again reduced in 2014. Only a minor part of the dedicated budget, about 10 MEUR was consumed in 2014, leading to about 7 800 new PV systems with a total capacity of 46,5 MWp.

Besides that, some provinces provide PV support budgets as well, amongst them very specific support, e.g., only for municipal buildings.

The target for the national PV market is laid down in the national green-electricity act (GEA), firstly issued in 2002, and meanwhile revised several times. The official market target is currently set with 1,2 GW in 2020. At the end of 2014 about 0,8 GW might have been already installed in Austria.

RESEARCH AND DEVELOPMENT

The National PV Technology Platform, founded in September 2008 and exclusively financed by the participating industry, research organisations and universities experienced a very good development again in 2014. Primarily supported by the Ministry of Transport, Innovation and Technology, this loose platform has been acting as a legal body since 2012. The PV Technology Platform brings together about 25 partners, active in the production of PV relevant components and sub-components, as well as the relevant research community in order to create more innovation in the Austrian PV sector. The transfer of the latest scientific results to the industry by innovation workshops, trainee programmes and conferences, joint national and international research projects, and other similar activities are part of the work programme; besides the needed increased awareness aimed at further improving the frame conditions for manufacturing and innovation in Austria for the relevant decision makers.

For many years, the Austrian PV research activities have been mostly focused on national and international projects. 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 Implementing Agreement and, concerning grid interconnection of renewables, in the IEA ISGAN Implementing Agreement.

Within IEA PVPS, Austria is leading the Task 14 on "High Penetration of Photovoltaics in Electricity Grids" as well as actively participating in Task 1, 12, 13 and actively involved in the definition phase of Task 15 on Building Integrated PV.

The national RTD is focusing on materials research, grid integration as well as more and more on building integration.

The national energy research programme *"Energieforschungs-programm 2014,"* from the Austrian Climate and Energy Fund, as well as the programme "City of Tomorrow," from the Ministry of Transport, Innovation and Technology cover quite broad research items on energy technologies, including PV. The research budget for PV related projects within the energy research programmes was rising substantially until 2013: Whereas in 2007 only 0,15 MEUR were dedicated to photovoltaic research, in 2013 more than 6 MEUR were spent for PV research. However, the data for 2014 shows a significant decline towards less than 1 MEUR. Further public research funding in the field of PV is given within the initiatives COMET or on individual project basis.

Fig. 2 - Simulation of solar cell stringing for development of new interconnect materials, Ulbrich Solar Technologies.

On the European level, the on-going initiative to increase the coherence of European PV RTD programming (SOLAR-ERA-NET) is actively supported by the Austrian Ministry of Transport, Innovation and Technology.

PV and the high penetration in some parts of the low voltage network become more and more drivers of the comprehensive and internationally oriented "Smart Grid" activities in Austria. Beside the demo-sites in Vorarlberg, Salzburg and Upper Austria, which are aiming at effective integration of high shares of PV into the distribution networks, an initiative of the Austrian Utility Association is remarkable for the process of PV-grid interconnection: The "Expert Pool Photovoltaic" developed new national guidelines for optimizing the PV-grid interconnection jointly with all relevant stakeholders - including the regulator.

IMPLEMENTATION AND MARKET DEVELOPMENT

Approximately 626 MW of PV power were installed in Austria by the end of 2013. There are no final figures for 2014 available yet, but it is expected that the growth in 2014 declined and approximately 800 MW have been totally installed in Austria by the end of 2014.

The annual growth rate in 2013, with a total of 263 MW, was by far the largest rate ever, but 2014 numbers might be lower.

One main reason for that might have been a public discussion about a self-consumption tax, to be introduced for photovoltaics. After a wide public campaign led by the Austria PV association, PV Austria, the decision was taken by the Parliament in June 2014 to introduce such a tax only for annual production which exceeds 25.000 kWh. This is far beyond the typical production by private PV systems, which are dominating the Austrian market traditionally. However, industry as well as small and medium enterprises are affected by this new taxation; self-consumption is mainly seen as the decisive factor for amortisation of larger PV systems in Austria; as mentioned before, the support scheme is only sufficiently endowed for small systems, but for the larger ones, which are supported by feed-in-tariffs, the annual funds of 8 MEUR for new systems are still very limited.

The main applications for PV in Austria are grid connected distributed systems, representing much more than 99 % of the total capacity. Grid-connected centralised systems in form of PV-Power plants play a minor role. Building integration is an important issue and a cornerstone of the public implementation strategy.

In 2014, some provinces introduced support schemes for storage systems in order to increase the self-consumption of the private photovoltaic systems. These initiatives led to a total of a few hundred storage systems.

Beside on-grid applications mainly small off-grid systems are traditionally widely used to provide electricity to technical systems or for domestic use in Alpine shelters or houses lying far away from the grid.

MARKET DEVELOPMENT

The Federal Association Photovoltaic Austria (PV-Austria) is a non-governmental interest group of the solar energy industry. The association acts as an informant and intermediary between business and the political and public sectors. The focus of the work is to improve the general conditions for photovoltaics in Austria, secure a suitable policy framework for stable growth, and thus ensure investment security throughout the solar industry. PV-Austria is very active in public relations, in creating a national network to distribute information on PV and in initiating various workshops and press conferences. By fostering the political contacts, intensive political lobbying work and a broad series of articles in newspapers on PV, the association is aiming at changing the legislative frame conditions for PV by introducing stable and supportive PV market incentives. By the end of 2014, more than 140 companies and persons involved in the PV business were Association members.

The 12th Annual National Photovoltaic Conference took place in Linz in 2014. For the first time it was a three day event, organised by the Austrian Technology-Platform Photovoltaic and supported by the Ministry of Transport, Innovation and Technology. This strategic conference is well established as THE annual come together of the Austrian PV community; bringing together about 250 PV stakeholders in industry, research and administration.

Many specific conferences and workshops were organised by the association "PV-Austria." Renewable energy fairs and congresses are focussing more and more on PV.

The "Certified PV Training" for planners and craftsmen, offered by the Austrian Institute of Technology, has increased their PV program significantly by performing 8 day-training courses all over the country with a total of more than 70 participants in 2014. 11 further courses are planned for 2015.

FUTURE OUTLOOK

The Austrian PV industry is strengthening their efforts to compete on the global market, mainly through close collaboration with the research sector, in order to boost the innovation in specific niches of the PV market.

Strategic initiatives to strengthen the potential of the local PV Industry will be further increased. International collaboration is very important.

Grid integration is one major issue; the fruitful collaboration between research institutes and some national distribution network operators have already create significant results from their first demo-sites.

PV research and development will be further concentrating on international projects and networks, following the dynamic know-how and learning process of the worldwide PV development progress. Mainly through IEA PVPS Task 14 on "High Penetration Photovoltaic in Electricity Grids," commenced in 2010 and lead by Austria, this topic is just about to become a focal point of the international research activities. However, the national energy research programmes are also more and more dedicated to PV issues, with many projects just in operation.

Building integration is another main issue with some larger projects starting in 2014. However, the cooperation with the building industry is still in its early phase. The European building directive is moving the building sector towards "active buildings" with PV as a possible central element of generation, which might lead to new momentum in the building sector.

Smart city projects are well supported by the Austrian Climate and Energy Fund. Within the broad range of city relevant research, PV plays more and more a role as a significant and visible sign of a sustainable energy future in urban areas, frequently also in combination with the use of electric vehicles.

The level of the public know-how and interest about the potential and perspectives of PV is continuously growing. Several renewable energy education courses are already implemented, some new courses are currently under development. All of them include PV as essential part of the future energy strategy. The importance of proper education for installers and planners of PV systems will increase depending on the market situation; the training is already available and can be extended easily. Meanwhile, at the University of Applied Science Vienna (Technikum-Wien) about 250 students are studying at the Bachelor and Master courses in "Urban Renewable Energy Technologies" with solar and specifically PV systems as one core element of the education.

BELGIUM

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

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Fig. 1 - The new European Union council headquarters in Brussels. An umbrella of photovoltaic panels for the electricity production covers both the modern and the historical parts; symbolizing the link with the present, the past and the future.

GENERAL FRAMEWORK

With an installation level just over 75 MWp, 2014 was the darkest year since the development of the Belgian photovoltaic sector in 2008. Although there were no major changes in support schemes, the uncertainty generated by the federal and regional elections is one of the main reasons for this bad year. Debates on the cost of the support schemes were an important issue during the electoral campaign.

In Flanders, despite the decision of justice to cancel the specific network fee for PV owners (<10 kW) at the end of 2013, the government decided to reintroduce it starting from July 2015. It is a fixed "prosumer fee" of around 85 EUR/KW depending on the Distribution System Operator (DSO). This fixed fee enables DSOs to charge for the cost of grid use by PV owners, without changing the system of net metering. If the PV owner installs a bidirectional meter counting the electricity flowing from and to the grid, they will pay the real cost of grid use instead of the fixed fee. Apart from this prosumer fee and net-metering on a yearly basis, there is also a green certificate support scheme to ensure that investors have an IRR of 5 % after 15 years. The support is recalculated every 6 months.

In terms of installed capacity, Flanders installed 31 MWp in 2014 reaching 2,2 GWp. The installation of small systems (<10 kW) was slightly better than in 2013 but still far from the one during the years of 2009 to 2012. There was no big PV plant (>250 kW) installed in 2014.

In Wallonia, the new support plan (Qualiwatt) for small systems (≤10 kW) has not yet encountered the success that was foreseen (less than 1 500 installed/12 000 planned). It replaces the previous system by a premium spread over five years and calculated to obtain a simple payback time of 8 years (5 % IRR for a 3kWp installation after 20 years). The plan removes the mechanism of green certificates and keeps the yearly net-metering.

Besides the financial aspects, this new plan also introduces strong quality criteria on the equipment (European norms, factory inspection), the installer (RESCERT trainee) and the installation (standard conformity declaration, standard contract) to give trust back to the new investors.

In terms of installed capacity, Wallonia installed 43 MWp in 2014 reaching 800 MWp. There was a decrease of the installation for all segments.

Following an in-depth review of the Council of State, Brussels is the first Belgian region confronted with the (partial) removal of the yearly net-metering system (the so-called compensation principle) that has benefited small capacity installation of 5 kWe or less. The government will analyze the review and make a decision in Q2 and Q3 of 2015, possibly opting for a (full) self-consumption scheme in 2017. The green certificates support will remain operational.

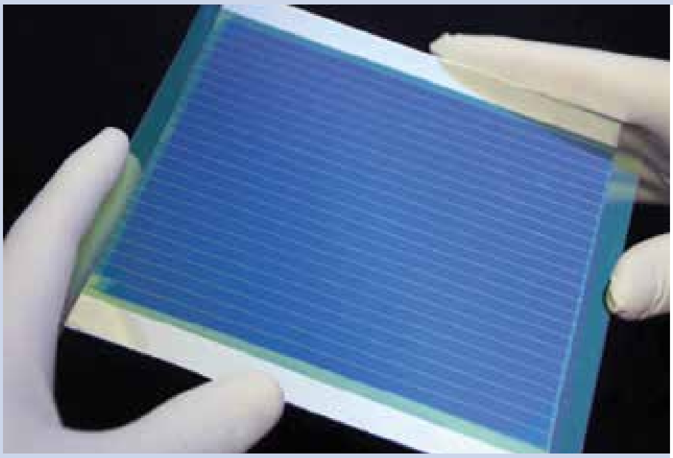


Fig. 2 - In September 2014 , Imec's novel fullerene-free Organic-PV cell concept was used to process an OPV module (156 cm²) with a conversion efficiency of 5,3 percent.

In terms of installed capacity, Brussels installed only 1,6 MWp in 2014 reaching almost 50 MWp. There was a strong decrease for all segments. The impact of the crisis in the two other regions cannot be neglected. A lot of potential investors do not know that support schemes are different in each region.

NATIONAL PROGRAM

In 2010, the 2009/28/EC European Directive to reach 20 % of renewable energy was translated in Belgium into a national renewable energy action plan with an objective of 20,9 % of renewable electricity. For PV, it foresaw an installed capacity of 542.1 MW for the end of 2013 and 1 340 MW for 2020. At the end of 2008, the total power of all photovoltaic systems installed in Belgium was about 100 MW. By the end of 2014, it reached more than 3 GW, which is already more than the double of the objective for 2020. This is another reason for the global reduction of the support.

RESEARCH AND DEVELOPMENT

R&D efforts are concentrated on highly efficient crystalline silicon solar-cells, thin film and organic solar-cells (for example by AGC). There is also some research on smart PV modules that would embed additional functionalities as micro-inverters (mainly Imec Research Center).

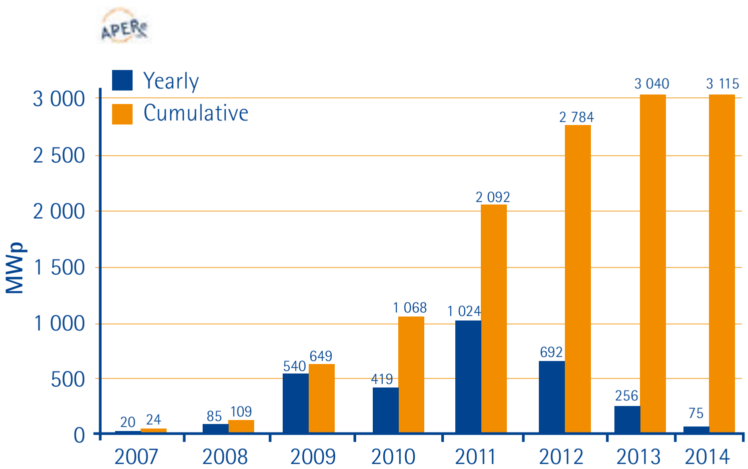
High penetration of PV in grid systems is being researched and demonstrated in Belgium, mainly in two projects: The European MetaPV project and the local project of Flobecq.

INDUSTRY

Issol is the last producer of classical modules, but it is not their main activity. With Soltech, they are the two main companies focusing on BIPV applications. Derbigum is specialized in amorphous silicon. Next to these three big companies, a lot of companies work in all parts of the value chain of PV, making the Belgian PV market a very dynamic sector. (www.pvmapping.be)

MARKET DEVELOPMENT

Photovoltaic: Installed capacity in Belgium



YEAR	YEARLY (MWp)	CUMULATIVE (MWp)
2007	19 643	23 937
2008	84 915	108 852
2009	539 895	648 747
2010	419 111	1 067 858
2011	1 024 246	2 092 104
2012	692 095	2 784 199
2013	255 791	3 039 990
2014	75 192	3 115 182

Small-scales projects (< 10 KW) represent 60 % of the installed capacity with more than 352 600 installations which represent approximately 1 household out of 13. The other 40 % include 6 800 large-scale projects.

CANADA

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

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GENERAL FRAMEWORK

Canada's Department of Natural Resources (NRCan) supports priorities to promote the sustainable and economic development of the country's natural resources, while improving the quality of life of Canadians. CanmetENERGY [1], reporting to the Innovation and Energy Technology Sector of NRCan, is the largest federal energy science and technology organization working on clean energy research, development, demonstration and deployment. Its goal is to ensure that Canada is at the leading edge of clean energy technologies to reduce air and greenhouse gas emissions and improve the health of Canadians.

The Canadian Solar Industry Association (CanSIA) is a member of the International Energy Energy PVPS implementing agreement and works with industry stakeholders and government decision makers to help develop effective solar policy and identify key market opportunities for the solar energy sector.

Provincial and Territorial government policies are now all supporting "net-metering" or "net-billing" of PV power in Canada. With the significant decline in the PV system costs and a recognition of opportunities to reduce "soft costs" (non-equipment, regulatory and administrative costs), PV generation is gradually approaching grid parity. These policies are aimed at simplifying the regulatory framework for customers that want to invest in their own renewable energy micro-generation as part of their overall energy conservation measures and to reduce their electricity bills.

The Province of Ontario, Canada's most populous and second largest province, leads the country in photovoltaic (PV) investments. As of September 2014, the cumulative PV installed capacity stood at 557 MW under the Renewable Energy Standard Offer Program (RESOP), 884 MW under the Feed-in Tariff Program (FIT) and 201 MWAC under the microFIT program for a total of 1 642 MW. The total amount of installed and under development PV capacity in Ontario is approximately 2 319 MW.

NATIONAL PROGRAMME

Research and Demonstration

NRCan's CanmetENERGY is responsible for conducting PV R&D activities in Canada that facilitate the deployment of PV energy technologies throughout the country. The PV program coordinates national research projects, contributes to international committees on the establishment of PV standards, produces information that will support domestic capacity-building and organizes technical meetings and workshops to provide stakeholders with the necessary information to make informed decisions.

A new Business-led Network of Centres of Excellence was established in 2014 [2]. The Refined Manufacturing Acceleration Process (ReMAP), headquartered at Toronto-based Celestica, is developing an ecosystem for commercialization that links academics, companies and customers. With access to 38 labs and manufacturing lines across the country, the ReMAP network will work with participating companies from the information and communications technologies, healthcare, aerospace, defence and renewable energy sectors to quickly identify innovations that are most likely to succeed, and then accelerate the product commercialization and global product launch.

The PV Innovation Research Network, funded by the Natural Sciences and Engineering Research Council (NSERC), brings together a core group of 32 academic researchers in Canada, as well as CanmetENERGY, the National Research Council, the Ontario Center of Excellence and 15 industrial partners. The network held its fifth national scientific conference in Montreal in May 2014. The PV Innovation Network is scheduled to end its research activities in the Fall of 2015.

The NSERC Smart Net-Zero Energy Buildings Strategic Network (SNEBRN) performs research that will facilitate widespread adoption in key regions of Canada of optimized net zero energy buildings design and operation concepts by 2030. CanmetENERGY is contributing to this research effort and has been leveraging its activities through its leadership of the recently completed Task 40/Annex 52, entitled "Towards Net Zero Energy Solar Buildings" - a large international collaboration jointly managed by the IEA SHC and EBC programs. To achieve this objective, some 75 T40/A52 experts from 19 countries, including Canada, have documented research results and promoted practical case studies that can be replicated worldwide [3].

IMPLEMENTATION

Ontario's Energy Plan and Procurement

In its 2013 Long Term Energy Plan (LTEP), Ontario highlighted that as PV system cost decreases and more PV systems are deployed at customer sites, the micoFIT program could gradually transition to a net metering program [4]. Net metering was also identified as supporting conservation objectives. In addition, the Ontario Power Authority has set aside some capacity at each transformer station for microFIT projects where there is already existing capacity. This prevents procurement of larger generation facilities from crowding out microFIT applications.

Jurisdictional Scan

In 2013, the Yukon Territory released its micro generation policy that will reimburse customers for the amount of electricity exported to the grid at a rate reflective of the avoided cost of new generation in the territory. This program will offer a tariff of 0,21 CAD for grid connected and 0,30 CAD generation micro grids up to 5 kW on shared transformer, 25 kW on a single transformer and up to 50 kW on a case by case approved by the local utility [5].

The Northwest Territories (NWT) has launched a Solar Energy Strategy to install solar systems with the capability to supply up to 20 percent of the average load in NWT diesel communities for 2012-2017 [6]. The province of Saskatchewan's net metering rebate provides up to 20 % of system costs for installations up to 100 kW for environmental preferred technologies including photovoltaics to a maximum of 20 000 CAD per eligible net metering project for a limited period ending on November 30, 2014.

Alberta's micro generation regulation was reviewed in 2013. This is a non-incentivized market where the recent increase in the price of electricity (30 % over the last 6 years) and the decreasing cost of solar PV makes solar electricity nearly competitive. Enmax, a utility, has initiated a Micro Renewable Energy Program to simplify the financing and installations of Solar PV residential rooftop systems [7].

British Columbia was the first province to adopt a net metering Policy in 2004. In 2013 a progress report was released that provided an update of the BC Hydro Net Metering program and a regulatory scan to benchmark /compare to similar programs across Canada and selected programs in the USA [8].

INDUSTRY STATUS

Canada's solar sector has experienced continued significant investments over the last 4 years. Employment in PV-related areas in Canada has grown with a 2013 labour force estimated at over 5 925 compared to 2 700 jobs in 2009. The Ontario government projects 6 000 jobs will be created from the four year FIT procurement targets. In 2013 the solar PV module manufacturing industry in Ontario accounted for over 1 900 full time direct jobs in the design, manufacturing and testing of modules, while the PV inverter industries in the Province provided an additional estimated 250 jobs. Racking, the other major segment of manufacturing accounts for approximately 700 jobs.

MARKET

PV power capacity in Canada grew at an annual rate of 25 % between 1994 and 2008. In recent years this growth was 98 % in 2011, 48 % in 2012 and 54 % in 2013 due to the Ontario incentive programs. Recent information from industry suggests module pricing to be approximately 0,95 CAD per watt. This can be compared to 6,18 CAD in 2004. This represents an average annual price reduction of 20 % over a 10-year period.

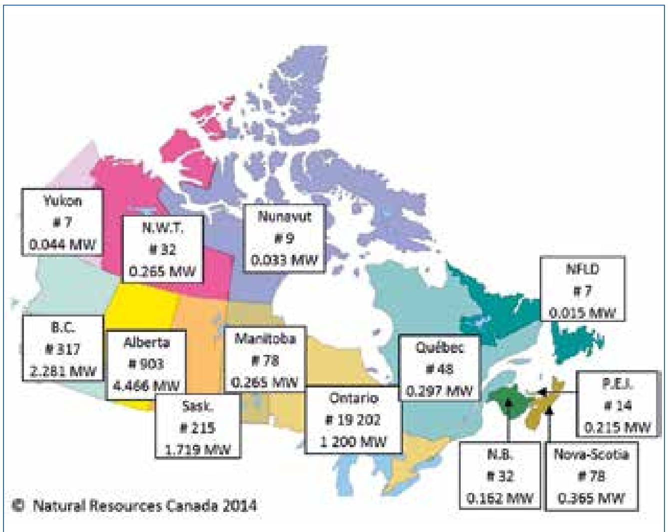

Fig. 1 - Map showing the Canadian provinces, the capacity (in megawatt) and the number of utility interconnected PV Systems in 2013.

FUTURE OUTLOOK

Ontario has set a "50 MW annual procurement target for microFIT starting in 2014 to encourage the development of a prosumer market" [9]. The contract prices paid by the microFIT program are reviewed annually to reflect the current costs. The Ontario government "is exploring the potential for the microFIT program to be transitioned to a net metering or self-consumption program in the future" [9].

In December 2014, the Canadian Solar Industry Association (CanSIA) released its solar industry roadmap 2020 that identified five key areas of focus [10].

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CHINA

PV TECHNOLOGY AND PROSPECTS

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GENERAL FRAMEWORK

In November 2014, China and the USA released the " U.S.-China Joint Announcement on Climate Change" and announced the target: By 2020, the share of non-fossil fuels energy in total energy consumption will reach 15 %; by the year of 2030, the target will be 20 % and CO_2 emissions will reach the peak by the year of 2030 or earlier. According to these targets, solar PV will provide significant contribution in the following years. Last year, the PV domestic installation was 10,64 GW (10,60 GW of grid-connected PV and 40 MW of off-grid PV); reaching the 10 GW target of average annual growth, as cited in "Opinions on Promoting the Healthy Development of Photovoltaic Industry" issued by the State Council. The details of last year's policy can be seen in Table 1 below:

TABLE 1 - THE FITS FOR PV POWER PLANTS AND THE SUBSIDY FOR DISTRIBUTED PV

SOLAR IRRADIATION ZONE	PV POWER PLANT	DISTRIBUTED PV	
	FIT	Subsidy for Self-Consumed PV Electricity	Subsidy for Surplus PV Electricity Feed-back to grid
	(CNY/kWh)	(CNY/kWh)	(CNY/kWh)
I:	0,90	Retail price of grid-electricity + 0,42	Wholesale Tariff of coal-fired power + 0,42
II	0,95		
III	1,00		

The 35 kV and lower projects that connected to the grid must follow the distributed PV policy. Even if distributed PV sells the total electricity to grid, the tariff is the wholesale tariff of coal-fired power plus 0,42 CNY/kWh (the wholesale tariff is less than 0,4 CNY/kWh) and doesn't allow for FIT to be obtained for PV plants. Thus, the total income for such distributed PV is only about 0,82 CNY/kWh (equal to 0,16 USD cents). Buildings with high tariff are very difficult to be found, so not many projects have been following the "self-consumption" model. To enlarge the market of distribution PV, the Chinese government (National Energy Administration-NEA) changed the policy for distributed PV in September 2014 and the incentive was too late to be effective in promoting the installation of distributed PV during the last 3 months in 2014. The key points for the new policy are: 1) PV projects can freely choose to either sell electricity to grid and obtain FIT (0,9 - 1,0 CNY/kWh) or with self-consumption, to have a subsidy of 0,42 CNY/kWh. 2) PV developers are allowed to build PV systems not only on building rooftops, but also on the rooftops of greenhouses, on discarded land, on the surface of water, lakes or fish pools. The sample projects are shown in Figure 1.

Fig. 1 - PV on greenhouses, on fish pools and on farmland.

Fig. 2 – Two views of a LS-PV Power Station in Qinghai, China (Photos: Lv Fang, IEA PVPS Task 1 Expert).

NATIONAL PROGRAM

On January 26, 2015, NEA issued the PV capacity quota for the year 2015. The total quota is 15 GW and 8 GW for PV power plants, which is for projects connected to the grid that are higher than 35 kV and with a capacity of > 20 MW and 7 GW for distributed PV, which is for projects connected to the grid ≤ 35 kV and with a capacity of ≤ 20MW.

The near term target: By the year 2015, cumulative PV installation in China will be 35 GW and by 2020, the target is 100 GW. The market development is as forecasted below:

TABLE 2 - PV MARKET DEVELOPMENT AND FUTURE FORECAST IN CHINA (2010-2020)

YEAR	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
ANNUAL INSTALLED (GW)	0,5	2,7	3,2	10,75	10,6	10	11	12	12	13	14
CUMULATIVE (GW)	0,8	3,5	6,7	17,45	28,05	38	49	61	73	86	100

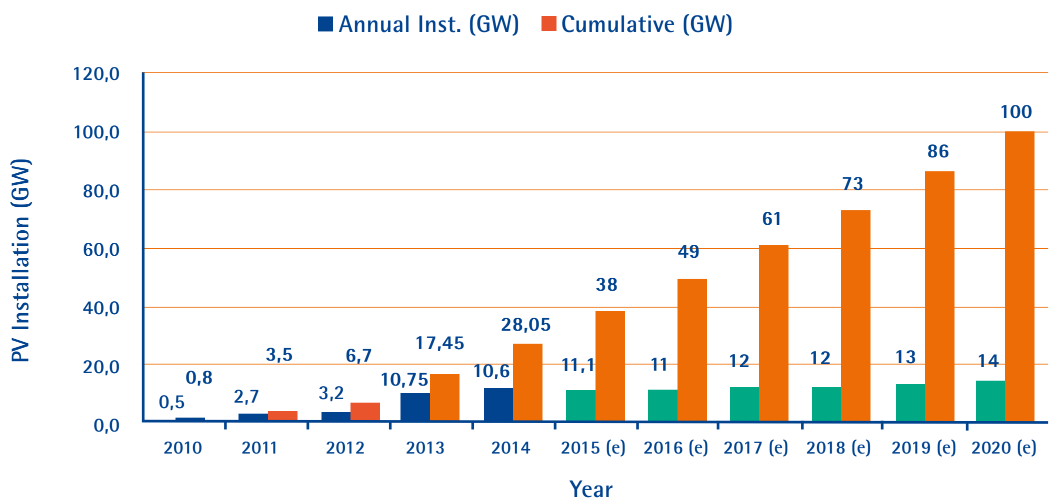

Fig. 3 - PV Market Development and Future Forecast.

RESEARCH AND DEVELOPMENT (R&D)

During the last 10 years, R&D of PV in China has made great progress in high efficiency PV cells, thin film and CPV technologies.

TABLE 3 – THE BEST RESULTS OF R&D OF PV CELLS AND MODULES IN CHINA

NO.	TYPE OF PV CELL	EFFICIENCY %	SIZE OF CELL OR MODULE	LEVEL	PROVIDER
1	N-type-mono HIT	22,00	156 mm×156 mm	Industry	Trina Solar/SIMIT
2	N-type-mono IBC	22,90	156 mm×156 mm	Industry	Trina Solar
3	N-type-mono MWT (Panda)	20,91	156 mm×156 mm	Industry	YGE, Baoding
4	P-type-mono MWT (ELPS)	21,10	157 mm×156 mm	Industry	Canadian Solar
5	P-type-mono PERC	20,44	156 mm×156 mm	Industry	CSUN, Nanjing
6	P-type-poly (Honey)	20,76	156 mm×156 mm	Industry	Trina Solar
7	a-Si single-junction	10,59	1 cm^2	Lab	Nankai University
8	a-Si/µc-Si	13,41	2 cm^2	Lab	
9	a-Si:H/a-SiGe:H/a-SiGe:H 3-junction	16,07	3 cm^2	Lab	
10	a-Si/µc-Si	10,00	600 mm×1200 mm	Industry	Hanergy
11	CIGS	15,50	650 mm×1650 mm	Industry	Hanergy
12	CdTe	15,30	1 cm 2	Lab	ASP
13	CdTe	13,00	0.72 m 2	Industry	ASP
14	GaInP/GaInAs/Ge 3-junction	1-Sun: 32,00 1000-Sun: 40,00	10mmx10mm	Industry	Suncore

Great progress has been made as well in advanced PV technologies such as dye-sensitized solar cells, organic solar cells and perovskite solar cells.

INDUSTRY AND MARKET DEVELOPMENT

China has been the largest producer of PV modules in the world since 2007.

The total PV grade poly-silicon produced in 2014 was about 132 000 Tons. Now, China is the largest producer of poly-Si in the world (with a 43 % share in total world production), but still needs to import about 100 000 Tons from other countries. The situation of the PV industry in China is shown below.

TABLE 4 – DOMESTIC DEMAND AND PRODUCTION OF POLY-SI (2008-2014)

YEAR	2008	2009	2010	2011	2012	2013	2014
Production (Ton)	4 685	20 071	45 000	84 000	71 000	84 000	132 000
Demand (Ton)	20 400	29 250	56 000	134 000	150 000	160 000	235 000
Imported (Ton)	15 715	9170	11 000	50 000	79 000	76 000	103 000
Share of Import (%)	77,03	31,35	19,64	37,31	52,67	47,50	43,83

TABLE 5 - ANNUAL PV MODULE PRODUCTION (2007-2014)

YEAR	2007	2008	2009	2010	2011	2012	2013	2014
PV Production (MW)	1 340	2 714	4 990	12 437	22 798	25 214	25 610	35 000
Dem. PV Market (MW)	20	40	160	500	2 700	3 560	10 680	10 640
Share of Export (%)	98,51	98,53	96,79	95,98	88,16	85,88	58,30	69,60

In February 2015, NEA released the corrected data of PV installation in 2014 and 2013. The corrected data is shown in Table 6.

TABLE 6 – DOMESTIC PV INSTALLATION BY SECTORS IN 2013 AND 2014

2013 DOMESTIC PV MARKET BY SECTORS			
NO.	MARKET SECTOR	ANNUAL INSTALLED (MWp)	CUMULATIVE INSTALLED (MWp)
1	Rural Electrification	50	150
2	Communication & Industry	10	70
3	PV Products	20	70
4	Building PV	800	2 620
5	Ground Mounted LS-PV	9 800	14 830
	Total	**10 680**	**17 740**
2014 DOMESTIC PV MARKET BY SECTORS			
NO.	MARKET SECTOR	ANNUAL INSTALLED (MWp)	CUMULATIVE INSTALLED (MWp)
1	Rural Electrification	20	170
2	Communication & Industry	10	80
3	PV Products	10	80
4	Building PV	2 050	4 670
5	Ground Mounted LS-PV	8 550	23 380
	Total	**10 640**	**28 380**

During 2007-2014, the cost of PV has been reduced sharply. It is estimated that PV price will reach grid-parity with traditional coal-fire power by the year of 2025.

TABLE 7 – PRICE REDUCTION OF PV DURING THE LAST 8 YEARS

YEAR	2007	2008	2009	2010	2011	2012	2013	2014
Cumulative (GWp)	0,10	0,14	0,30	0,80	3,50	6,70	16,28	26,84
Module Price (USD/Wp)	5,81	4,84	3,06	2,10	1,45	0,73	0,65	0,61
System Price (USD/Wp)	9,68	8,06	5,65	4,03	2,82	1,61	1,45	1,29
PV Tariff (USD/kWh)	0,65	set by bidding			0,19	0,16	0,16	0,15

COPPER ALLIANCE

THE COPPER ALLIANCE'S ACTIVITIES
FERNANDO NUNO, PROJECT MANAGER, EUROPEAN COPPER INSTITUTE

Fig. 1 – Copper granulate (Photo: Copper Alliance).

Fig. 2 - Copper magnet wire (Photo: Copper Alliance).

Fig. 3 – Copper cable (Photo: Copper Alliance).

The Copper Alliance develops and defends copper markets. Its policy, advocacy, education and partnership initiatives are based on copper's superior technical properties and its potential to accelerate the energy transition. It is supported by 43 industry members who are active in various areas of the copper production chain.

Headquartered in New York, NY, USA, the organization has divisions in Asia, Europe and Africa, Latin America, and North America. It contains a network of regional offices and copper promotion centers in nearly 60 countries, which propagate the Copper Alliance™ brand and are responsible for program development and implementation, in close cooperation with their partners. Through this international network, the International Copper Association Ltd. (ICA) has built a group of approximately 500 program partners from all over the world.

SUSTAINABLE ENERGY

Energy and copper need each other. Indeed, electrical applications are the largest market for copper, and there is a growing understanding that copper is essential in achieving sustainability for the energy system. Its high electrical conductivity is a favourable attribute for the construction of renewable energy systems and the manufacturing of energy efficient motors, transformers, and cables. One of the main aims of the Copper Alliance is to accelerate the transition to a sustainable energy economy. For this reason, it created Leonardo ENERGY (www.leonardo-energy.org), which is the Copper Alliance brand for advocacy and education in sustainable energy.

Leonardo ENERGY (LE) actively supports a low carbon economy by facilitating information exchange, promoting good practices, engaging professionals, stimulating market development, and managing policy initiatives. Furthermore, LE runs information campaigns on the importance of copper in sustainable energy systems.

The following are a few LE initiatives in the field of renewable energy:

- Analysis of how to make the electricity system more flexible and able to cope with variable electricity production;
- Promotion of industrial demand side management (facilitating the integration of renewables on the grid);
- Dissemination of best practices on renewables through application notes, webinars and e-learning programs.
- Literature review of scenarios for near 100 % renewable electricity systems

PV RELATED ACTIVITIES

Copper Alliance supports PV development through various streams:

- Market intelligence reports;
- Involvement in standardization activities at IEC level;
- Advocacy on new business models for PV (e.g. the promotion and support of the Grid Parity Monitor: http://www.leonardo-energy.org/photovoltaic-grid-parity-monitor);
- E-learning courses on designing, installing and operating PV systems.

COPPER ALLIANCE INVOLVEMENT IN IEA PVPS ACTIVITIES

The Copper Alliance actively participates in the IEA PVPS ExCo meetings. Moreover, it contributes in disseminating IEA PVPS messages and educational material. For example, the IEA PVPS Task reports and summaries are published on the Leonardo ENERGY website, which attracts a substantial number of visits. Finally, the Copper Alliance contributes to the work of IEA PVPS Task 1, particularly in the analysis of self-consumption business models.

DENMARK

PV TECHNOLOGY STATUS AND PROSPECTS

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Fig. 1 - The United Nations City Building, situated in the Port of Copenhagen, is one of the most prestigious new buildings in the Danish capital. It is not only an architectural star, but also an environmental one. One of the installations is a special designed 348 kWp PV-plant on the white rooftop. The special design, using a PV-plant as an architectural finesse, won the PV-company, SolarElements, a prize at the Intersolar in Munich 2014.

GENERAL FRAMEWORK

The Danish government launched its energy plan known as "Our Energy" in November 2011, with the vision of a fossil free energy supply by 2050 and interim targets for energy efficiency and renewable energy by 2020 and 2035, e.g. by 2020 50 % of the electricity shall come from wind turbines. The energy plan was finally agreed upon by a broad coalition of parties in- and outside the government in March 2012. The plan, which reaches up to 2020, was further detailed in the government's energy statements of May 2012 and April 2013.

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 following or surpassing the national targets as defined in the EU RE Directive, but sets only technology specific targets for wind energy and biomass.

Renewable energy is not only a future option, but very much a present and considerable element in the energy supply: By end 2014, more than 40 % of the national electricity consumption was generated by renewable energy sources including incineration of waste. Ongoing research, development and demonstration of new energy solutions including renewable energy sources have high priority in the proposed energy plan, the main objectives being the development of a future environmental benign energy system completely free of fossil fuels. Renewable energy technologies, in particular wind, thus play an important role with PV still seen as a minor but potentially fast growing RE technology to be prioritized when found more competitive. During 2014, PV proved periodically capable of providing about 14 % of the electricity demand.

Regions and municipalities are playing an increasingly more active role in the deployment of PV as an integral element in their respective climate and energy goals and plans, and these organisations are expected to play a key role in the future deployment of PV in the country. However, existing regulations for municipal activities have been found to present serious barriers for PV deployment.

NATIONAL PROGRAM AND IMPLEMENTATION

Denmark has no unified national PV programme, but does have a number of projects supported mainly by the Danish Energy Authority's EUDP programme including a special multiannual facility in support of BIPV, and via the Public Service Obligation (PSO) of Danish transmission system operator, Energinet.dk, a fully government owned body. Energinet.dk administers two programs of relevance for PV, e.g. ForskVE (mainly demonstration) and ForskEL (mainly R&D). The ForskVE programme will be discontinued by end of 2014. A couple of public funds also support PV related projects, mainly supporting market entrance.

Net-metering for privately owned and institutional PV systems was established mid-1998 for a pilot-period of four years. 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 relatively short time window of the arrangement was found to prevent it from reaching its full potential. During the political negotiations in the fall of 2005, net-metering for privately owned PV systems was consequently made permanent, and net-metering - during 2012 at a level of approximately EURcents 0,30/kWh primarily because of various taxes – combined with dropping PV system prices, proved to be able to stimulate PV deployment seriously in 2012, as the installed grid connected capacity during 2012 grew from about 13 MW to approximately 380 MW; a growth rate of about 30 times. For PV systems qualifying for the net-metering scheme, grid-parity was reached in 2012.

This dramatic growth gave rise to political debate towards the end of 2012, and the government announced a revision of the net-metering scheme inter alia reducing the net-metering time window from one year to one hour. During the first half of 2013, a series of new regulations were agreed upon politically; this because the consequences of the new regulations were not fully clear at time of decision and follow up measures were found to be necessary. By June 2013, the new regulations were finally in place including transitory regulations, effectively putting a cap on future PV installations under the net-metering scheme in terms of an overall maximum installed capacity of 800 MW by 2020; for municipal PV installations the cap was set at an additional 20 MW by 2020.

The above mentioned uncertainties as to net-metering regulations in the first half of 2013 and the general reduction in benefits of the revised net-metering scheme put a damper on the market. Furthermore, a dispute during 2014 between the European Commission and the government about the compliance of the

Fig. 2 - Aarhus City Tower. The system is produced by the Danish company, Racell SAPHIRE, and integrated as a 1 800 m² BIPV with a maximum power of 250 kWp. The building is fulfilling the energy performance building directive 2015. In the design phase, the focus was on architectural design, façade integration and energy production.

aforementioned PSO scheme with the Lisbon Treaty – the PSO constituting the very base for renewable energy development and deployment in the country – put effectively the PV market on hold. In 2014, only about 40 MW installed capacity was added leading to a total installed capacity of around 600 MW by end of 2014. The amount of PV installations not applying for the net-metering scheme but operating in the economic attractive "self consumption mode" appears to be growing, but no firm data is available yet.

The potential for large scale deployment of PVs in Denmark has been identified as building integrated systems in the national PV strategy. However, a couple of ground based centralised PV systems totalling about 5 MW have materialized.

The PVIB project on the island of Bornholm has contributed to a total installed capacity of more than 5,5 MW mostly in the form of roof-tops and municipal installations by end 2014. The BIPV project originally targeting 5 MW or a PV penetration of 10 % in the local grid system is integrated into the EU EcoGrid project investigating the future Smart Grid of Europe. The last phase of the PVIB project launched in the second half of 2013 targets an additional 1,5 to 3 MW, potentially reaching a PV penetration on Bornholm of about 17 %, but the aforementioned regulatory uncertainties for PV have mandated an extension of the PVIB project.

RESEARCH AND DEVELOPMENT

R&D efforts are concentrated on Silicon processing, crystalline Si cells and modules, polymer cells and modules and power electronics. R&D efforts exhibit commercial results in terms of export in particular for inverters but also for custom made components.

Penetration and high penetration of PV in grid systems are being researched and demonstrated. Network codes are under revision to accommodate a high penetration of inverter-based decentralized generation and to conform to the EU wide harmonisation under development in Entso-E/EC.

During 2014 Denmark has provided support to the development of a Solar Energy Roadmap for China.

INDUSTRY AND MARKET DEVELOPMENT

A Danish PV industrial association (Dansk Solcelle Forening) was established, late 2008. With about 75 members, the association has provided the emerging PV industry with a single voice and is introducing ethical guidelines for its members. The association has formulated a strategy aiming at 5 % of the electricity coming from PV by 2020, but is now revising this target, although being hampered in the process by the regulatory uncertainties.

A couple of Danish module manufacturers each with an annual capacity of 5-25 MW per shift are on the market. A few other companies producing tailor-made modules such as window-integrated PV cells can be found.

There is no PV relevant battery manufacturing in Denmark at present. A few companies develop and produce power electronics for PV, 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 home market. With the rapidly expanding market in 2012, the number of market actors increased fast, but many upstarts have disappeared again since 2013. Danish investors have entered the PV scene acting as holding companies, e.g. for cell/ module manufacturing in China.

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

Total PV business volume in 2014 is very difficult to estimate with any degree of accuracy due to the commercial secrecy surrounding the above mentioned business developments. However, the business volume of about 40 MW on the domestic market is estimated at around 60 MEUR and combined with exports the estimate is around 90 MEUR.

The cumulative installed PV capacity in Denmark (including Greenland) has been estimated at a bit more than 600 MW by end of 2014.

FUTURE OUTLOOK

The expected ongoing annual government funds at 135 MEUR allocated to R&D into energy and renewables are expected to give an ongoing boost also to the PV sector in terms of an increasing share of Danish products and know-how.

The future market development for PV in Denmark will strongly depend on the impact of the revised net-metering scheme incl. caps mentioned above following the settlement between the European Commission and the government. The emerging market sector of PV installations for own consumption is growing and is so far not burdened by taxes; there is little firm data on this new sub-market.

EUROPEAN COMMISSION

SUPPORT TO RESEARCH, DEVELOPMENT AND DEMONSTRATION ACTIVITIES ON PHOTOVOLTAICS AT EUROPEAN UNION LEVEL

PIETRO MENNA, EUROPEAN COMMISSION, DIRECTORATE-GENERAL FOR ENERGY
FABIO BELLONI, EUROPEAN COMMISSION, DIRECTORATE-GENERAL FOR RESEARCH AND INNOVATION

THE EUROPEAN ENERGY POLICY FRAMEWORK

A top priority of the European Commission is to set out "a resilient European Energy Union with a forward-looking climate change policy" [1]. The Energy Union is envisaged to consist of five interrelated pillars: Security of energy supply; internal energy markets; energy efficiency; decarbonisation of the energy mix; and research and innovation in the energy field. Major deliverables are needed under each of these pillars to make the Energy Union a tangible reality.

The first pillar is expected to be built around security of supply, solidarity and trust. The European Union is the largest energy customer in the world. Today the EU imports more than 50 % of its energy needs. Every year, the bill for energy imports amounts to about 400 BEUR. Obviously, EU Member States (MSs) stand a much better chance of striking a fair energy deal through collective bargaining, rather than going it alone. Speaking with one voice also implies that MSs must nurture relations with each other in a spirit of solidarity and trust. For instance, MSs should consult each other on the consequences of any change in their energy system potentially affecting the others (and neighbours).

The second pillar will address the completion of a competitive and well-functioning internal energy market. To boost the competitiveness of European industry and to secure affordable energy for all, all steps shall be taken to ensure that the EU's internal energy market is completed. In terms of investment, and particularly when it comes to increasing cross-border flows, more regional cooperation and better connected infrastructure is needed to bring real benefits to both households and industry.

The third pillar will deal with energy efficiency. Europe is the largest market in the world for energy-efficient products and services. However, only a small part of this economic potential is exploited. Effective measures in this direction will provide more affordable energy-efficient technologies, thereby reducing costs and allowing SMEs and more energy-intensive industries become more competitive. Action on demand side to improve the energy efficiency performance of the consumers is also included.

The fourth pillar will address the decarbonization of the EU energy mix. The EU 2030 energy and climate change framework calls for 40 % reduction in greenhouse gas emissions, at least a 27 % share of renewables at EU level, and an energy efficiency target of 27 %. Decarbonizing fossils fuels remains a major challenge. Investments in deployment of Carbon Capture and Storage (CCS) should be considered also in view of the current carbon prices. Effort to develop and deploy new technologies and associated business models should continue. Nuclear energy continues to play an important role as strategic fuel and power-generation capacity in half the MSs. Finally, decarbonization is accomplished by ambitious objectives for renewable energies, which also contribute significantly to green growth.
The fifth pillar is expected to focus on research and innovation in energy. The energy system of tomorrow will look very different from the one we have today. To bring new, innovative, high performance, low-cost, low-carbon energy technologies to the market it is necessary to mobilize investment in research and innovation. The SET Plan and Horizon 2020 are the current available tools. However additional investments (e.g. private, and from MSs) are necessary to develop innovative solutions to unlock the full potential of energy efficiency, reduce the energy demand and decrease the cost of energy technologies to make them more competitive and more affordable. Furthermore, new and competitive technological solutions are necessary to diversify the energy supply thereby reducing the EU's overall energy dependency.

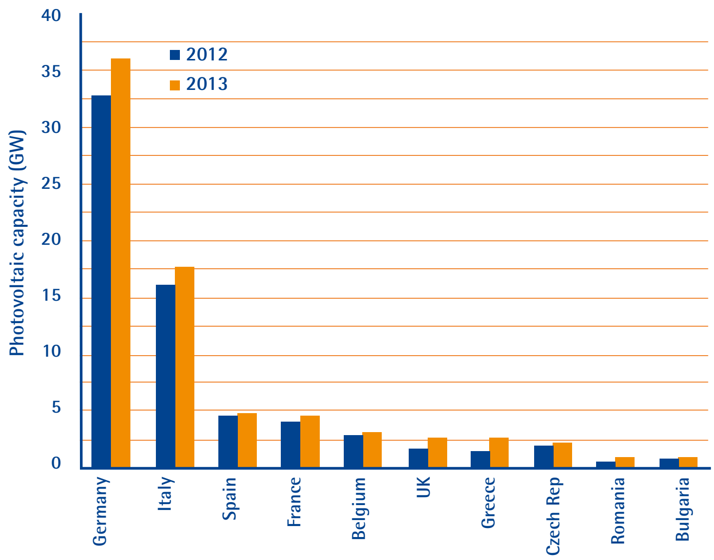

Fig. 1 - Cumulated PV capacity in some EU countries [2].

DEPLOYMENT

In the year 2013, 9,9 GW of new photovoltaic (PV) capacity was installed in the European Union (it was 16,7 GW in 2012), bringing the cumulative PV capacity to about 78,8 GW [2]. Figure 1 shows the most recent evolution of the installed, cumulated capacity in the EU countries recording more than 1 GW at the end of 2013. For different reasons (reductions of the support schemes, introduction of caps, and restricted access to credit), the European market is shrinking. The EU share of the new PV installations in the world was lower than 27 % in 2013, while it represented about 74 % in 2011. The solar electricity production is estimated at more than 80 TWh, with Germany (30 TWh) and Italy (22,2 TWh) accounting together for more than 65 % of the whole solar electricity production. On the average, solar power only accounts for about 2,4 % of the EU electricity output. However, the share is higher than 7 % in Italy and 5 % in Germany.

A further element of consideration is that the increasing deployment of variable renewables in the EU adds to the challenges for their integration and their balancing in the electricity system. The pioneering phase of "install and forget" was mostly focused on capacity growth and kWh-generation, with limited orientation to consumer demand.

During that phase, renewable electricity was easy to integrate because it was a minor share of total production. Today, economic efficiency is required to integrate the growing share of renewable electricity into the energy system. The situation is not homogeneous in Europe. There are countries which are already integrating and balancing well significant shares of variable electricity. Robust interconnections, both internal and with neighbouring countries, are a crucial enabler to deployment. But they might not be sufficient. Additional technical and regulatory solutions are to be implemented to effectively handle increasing shares of renewable electricity.

Another element to consider is the economic break-even point for residential PV installations, which impacts directly on current reflections concerning the support schemes. The price parity of solar with the retail price of electricity is diverse, in accordance with the heterogeneity of the European electricity market and the quality of the solar resource [3]. The grid parity for PV - defined as the moment when PV LCOE becomes competitive with retail electricity prices - has likely been reached in several regions of Europe. Nevertheless, policy measures are still needed to reduce administrative barriers and improve regulatory mechanisms in order to allow PV self-consumers to feed their excess generation into the grid in exchange for compensation (either monetary compensation or energy compensation).

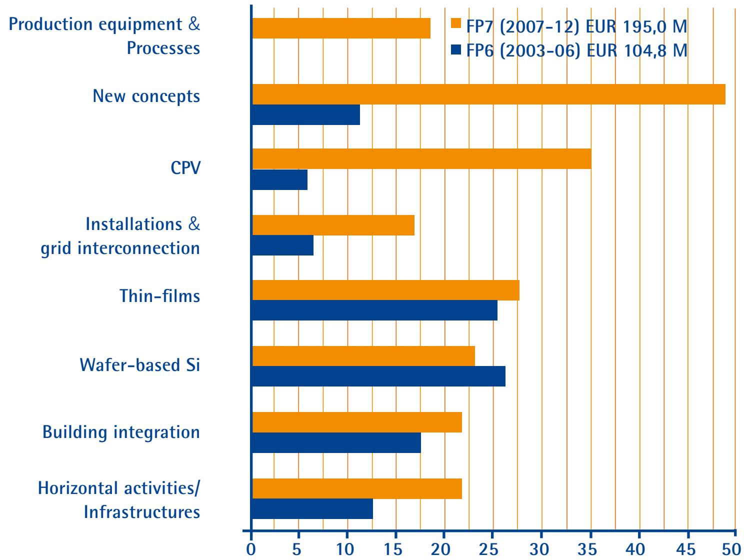

Fig. 2 - Comparison of the investments in PV made under FP6 and FP7 in the period 2003-2013 (Euro million).

RESEARCH AND DEMONSTRATION PROGRAMME

The 7th Framework Programme

The EU's 7th Framework Programme for Research, FP7 (2007-2013), has run for seven years and is now concluded. Calls for proposals based on topics identified in the work programme have been published on an annual basis. Seven calls for proposals have been published in the years from 2007 to 2013, including the last call in 2013. The PV projects granted under those calls have been described elsewhere [4]. Material development for wafer-based silicon devices, PV based on solar concentration, and manufacturing process development have attracted relevant European funding (Fig. 2). Significant funding has also been made available for thin-film technology and for the development and demonstration of new concepts and new approaches for building construction elements based on PV. The overall EC contribution granted in the FP7 PV projects accounts for more than 200 MEUR, an amount which is two times higher than the FP6 contribution.

Horizon 2020 - The Framework Programme for the 2014-2020 Period

Horizon 2020 is the new framework programme for research and innovation for the 2014-2020 period. The financial envelope for the implementation of Horizon 2020 has been set at about 77 BEUR in current prices [5]. Horizon 2020 is structured along three strategic objectives: "Excellent Science," "Industrial Leadership," and "Societal Challenges." With a budget of about 24 BEUR, the first objective, "Excellent Science," includes funding for the European Research Council (ERC) and the Marie Curie Actions, investments in Future and Emerging Technologies (FET), as well as support for the access to and networking of priority research infrastructures across Europe. With a budget of about 17 BEUR, the second objective, "Industrial Leadership," is intended to help make Europe a more attractive location to invest in research and innovation. It includes major investments in key industrial technologies such as Information and Communication Technologies (ICT), nanotechnologies, biotechnology, and space. This objective will also provide EU-wide support for innovation in SMEs with high growth potential. Finally, with a budget of about 30 BEUR, the third objective, "Societal Challenges," focuses on six key areas for the lives of European citizens: Health, demographic change and well-being; food security, sustainable agriculture, marine and maritime research, and the bio-based economy; secure, clean and efficient energy; smart, green and integrated transport; climate action, resource efficiency and raw materials; inclusive, innovative and secure societies. The specific objective of the "Secure, Clean and Efficient Energy" challenge, with an allocation of about 5,9 BEUR, is to make the transition to a reliable, affordable, publicly accepted, sustainable and competitive energy system, aiming at reducing fossil fuel dependency in the face of increasingly scarce resources, increasing energy need and climate change.

The Call "Competitive Low-carbon Energy" of the Energy Challenge has been published on 13 December 2013. Its work programme covers the period 2014-2015 and addresses four PV 'specific challenges', divided into two more general 'topics': LCE 2 (Developing the next generation technologies of renewable electricity and heating/cooling) and LCE 3 (Demonstration of renewable electricity and heating/cooling technologies). The LCE 2 topic addresses technology development, whereas technology demonstration and supply-side market readiness are addressed in LCE 3. The following PV specific challenges fall under LCE 2 (two-stage evaluation): 1. Developing next generation high performance PV cells and modules (for the year 2014; proposal submission deadline: 01/04/2014); and 2. Developing very low-cost PV cells and modules (for the year 2015; deadline: 03/09/2014). The PV specific challenges under LCE 3 (single-stage evaluation) concern: 1. Accelerating the development of the EU Inorganic Thin-Film (TF) industry (for the year 2014; deadline: 10/09/2014); and 2. PV integrated in the built environment (for the year 2015; deadline: 03/03/2015). Evaluations for the 2014 and 2015 LCE 2 specific challenges and for the 2014 LCE 3 ones have already taken place; the respective lists of successful proposals are expected to be published at the beginning of 2015 at the latest.

SOLAR EUROPEAN INDUSTRY INITIATIVE OF THE SET-PLAN

The Solar European Industry Initiative (SEII) of the Strategic Energy Technology Plan (SET-Plan) continues to work on the main priorities in the PV and concentrating solar power (CSP) fields. Current discussions are focused on seizing opportunities connected to the so-called "Juncker's Investment Plan" [6], with emphasis on the re-industrialisation of the PV sector in Europe.

Among the current initiatives promoted by the SEII, an ERA-NET action called SOLAR-ERA.NET (www.solar-era.net) is running. Three sets of joint calls for proposals have already been launched. The first set of joint calls has resulted in a total public funding of 12 MEUR and 47 PV proposals submitted. Among the successful proposals, 11 projects (including also those in the field of CSP) are about to start.
The Communication on Energy Technologies and Innovation [7] adopted on 2 May 2013 called for the development of an Integrated Roadmap under the guidance of the SET-Plan Steering Group.
The ultimate goal of the Integrated Roadmap is to prioritise the development of innovative solutions which will respond to the needs of the European energy system by 2020, 2030 and beyond. In particular, the Integrated Roadmap is intended to (1) address energy system and innovation chain integration, (2) consolidate the updated technology roadmaps of the SET-Plan, (3) cover the entire research and innovation chain from basic research to demonstration and support for market roll-out, and (4) identify clear roles and tasks for stakeholders such as EERA, the European Industrial Initiatives (EIIs), the European Institute of Technology (EIT) and other relevant actors such as universities, investors and financiers. The paper "Towards an Integrated Roadmap: Research & Innovation Challenges and Needs of the EU Energy System" [8], collecting the inputs of more than 150 relevant stakeholders under the guidance of the SET-Plan Steering Group, has been officially presented at the SET-Plan Conference of 10-11 December 2014, in Rome. Three kinds of actions (programmes) have been identified in view of accelerating the development of PV energy: 1. advanced research, 2. industrial research and demonstration, 3. innovation and market uptake. The implementation of the Integrated Roadmap is dealt with by an Action Plan. The Action Plan, to be finalised in early 2015, is intended to lay down coordinated and/or joint investments by individual EU Member States, and between Member States and the EU.

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EPIA

THE EUROPEAN PHOTOVOLTAIC INDUSTRY ASSOCIATION'S ACTIVITIES

FRAUKE THIES, POLICY DIRECTOR, EPIA
MANOËL REKINGER, SENIOR ADVISER, EPIA
IOANNIS-THOMAS THEOLOGITIS, TECHNOLOGY ADVISER, EPIA

Fig. 1 - EPIA president delivering a key note speech on global PV development at Intersolar Europe 2014.

Fig. 2 - EPIA booth during Intersolar Europe 2014.

EPIA – the European Photovoltaic Industry Association – represents the interests of the photovoltaic industry in Europe, with Members active along the whole solar PV value chain. EPIA's mission is to shape the regulatory environment to promote the growing market opportunity for solar in Europe.

To ensure its mission, in 2014, EPIA pursued its objective of successfully positioning solar-based energy solutions with policymakers at the European and national level.

EPIA has been engaged in various debates during the last year, to achieve this objective. The EPIA team advocated the cause of solar power through regular meetings with Members of the European Parliament, the political and service levels of the European Commission, and of course national representatives both in Brussels and in cooperation with our members from national associations. To achieve its objectives and enhance its voice, EPIA has built coalitions with utilities, system operators, sectoral industry associations, NGOs and other relevant stakeholders. EPIA has also participated in key discussions on:

- The new European State Aid Guidelines on Energy, describing the framework for member states to design support policies, including support to renewable energy technologies;
- The debate on electricity prices and costs launched by the European Commission and the related official report on subsidies in the Electricity sector;
- The 2030 framework for the development of Renewable Energy Sources in Europe.

EPIA's members have actively participated in the definition of EPIA's position on these key subjects through involvement in our working groups and ad-hoc tasks forces.

EPIA has also been active outside Brussels and has created opportunities for its members through supporting or representing them at the best business development platforms in Europe and beyond. In 2014, EPIA successfully contributed to:

- Intersolar Europe and Worldwide, by presenting updated information about Global PV market developments and organizing an event on innovative financing in the US and the EU.
- EUPVSEC 2015, by presenting the results of EPIA activities in the field of advanced Business models for PV and research projects.
- The European Utility Week, by organizing a workshop on evolution of roles and responsibilities of actors in a decentralised power system.
- The Solar O&M workshop Europe, by introducing and moderating a session on the evolution of operation practices required for the provision of Grid Support Services by PV systems.

EPIA's policy and business objectives were again supported in 2014 by thought-leading research in fields such as PV market forecasts, industrial development, PV grid integration and electricity market design. Notably, the EPIA team published or contributed to:

- The Global Market Outlook 2014-2018, describing global PV market trends until 2018.
- The European PV Grid and REserviceS projects, analysing respectively PV grid connections barriers and solutions, and PV cost and capabilities to provide grid support services.
- The European Sophia and Cheetah projects, analysing the role of research development and infrastructures on PV development, which proposed recommendations on how to improve PV innovation in Europe.

As an active member of the IEA PVPS, EPIA also contributed to the work of the PVPS Tasks 1, 13 and 14. EPIA will continue to contribute to and also learn from the IEA PVPS activities in 2015.

FRANCE

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

YVONNICK DURAND AND PAUL KAAIJK, FRENCH AGENCY FOR ENVIRONMENT AND ENERGY MANAGEMENT (ADEME)

GENERAL FRAMEWORK AND IMPLEMENTATION

2014 has been marked by an increase in annual installed power capacity, the announcement of tender results, the launch of new national and regional calls and the French government's draft law on energy transition.

The market deployment of photovoltaic applications in France is based on the government's policy of guaranteed feed-in tariffs. In 2014, the cumulative capacity of grid-connected photovoltaic installations reached a power of 5,6 GW slightly above the government's objective initially set for 2020. The 'Energy Transition Law for Green Growth' was voted on at first reading by the French National Assembly in October 2014. The law underlines the need for France to diversify its energy supply sources and confirms the previous target of 23 % of renewables in final energy consumption for 2020, while adding another target of 32 % for 2030.

Chapter 5 of the law is entitled 'Promoting renewable energy to diversify our sources of energy and enhance the resources of our territories.' It plans new support mechanisms for renewables, offering power producers the opportunity to sell electricity directly to the market while receiving a 'feed-in premium' that should replace guaranteed feed-in tariffs. In the case of photovoltaics, the support mechanism should only apply to large PV installations while feed-in tariffs schemes should be maintained for smaller PV systems. The involvement of local authorities and private individuals in renewable energy projects should be encouraged. Final approval by Parliament was still pending at the time of this report's publication.

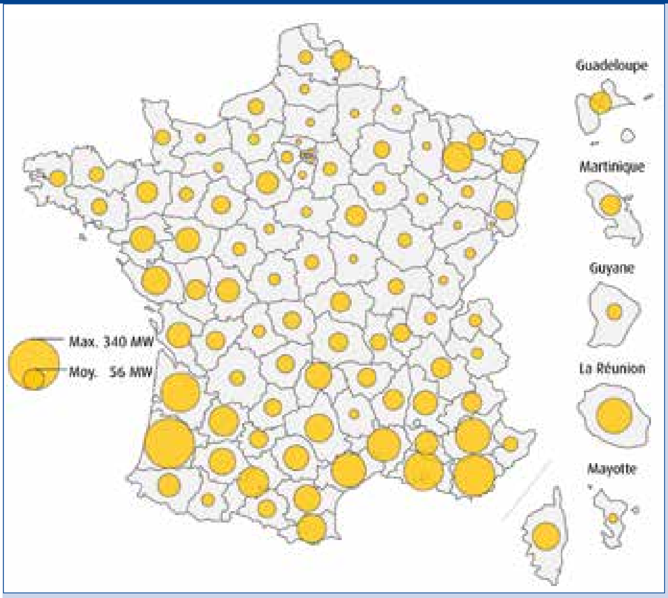

Fig. 1 – Grid-connected cumulative installed capacity in the French departments at the end of 2014: 5,63 GW and 346 200 PV systems (source: SOeS).

NATIONAL AND REGIONAL PROGRAMMES

Feed-in Tariffs

In 2014, the tax credit measure for individual PV roof owners was withdrawn so that the policy of guaranteed feed-in tariffs remained the only national financial support available. Feed-in tariffs aim to promote building-integrated photovoltaic systems (Table 1). A quarterly decrease in feed-in tariffs is applied: It is calculated on the basis of the number of grid-connection requests made in the previous quarter, even if professional associations advocate that the decrease should be based on the actual number of installed systems (according to grid operator ERDF, 47 % of projects over 36 kVA are abandoned before finalization). The Ministry has planned a reevaluation of the T4 tariff to boost the simplified building-integration (ISB) sector. Feed-in tariffs are guaranteed over a period of 20 years and annually adjusted to compensate for inflation. The cost of the feed-in tariffs measure is borne by electricity consumers via the CSPE fee (Contribution to Electricity Public Services).

Calls for Tenders for PV Systems over 100 kW

Table 2 provides a summary of all the national calls for tenders launched since 2011 by the organization in charge, the French Energy Regulatory Authority (CRE). There are two types of calls for tenders: The first type, called 'Simplified', relates to the construction and operation of photovoltaic installations between 100 kW and 250 kW. These installations have to comply with the rules governing simplified

TABLE 1 – PV FEED-IN TARIFFS FOR THE 4TH QUARTER OF 2014 (EUR/KWH)

TARIFF CATEGORY AND PY SYSTEM TYPE	POWER OF PV INSTALLATION (W)	TARIFF Q4 2014 (EUR/KWH)	2014 ANNUAL DECREASE (%) FROM Q1 TO Q4	DECREASE SINCE MARCH 2011 (%)
T1 - Building-integrated photovoltaic systems (IAB)	P ≤ 9 kW	0,2697	5,4 %	41,4 %
T4 - Simplified building-integrated systems (ISB)	P ≤ 36 kW 36 kW < P ≤ 100 kW	0,1374 0,1305	5,5 % 5,5 %	54,7 % 54,7 %
T5 - Other installations	P < 12 MW	0,0680	7,6 %	43,3 %

NOTE: In 2013, T2 and T3 tariffs were included into T1 and T4 categories.
Source: CRE, Ministry of Ecology, Sustainable development and Energy.

Fig. 2 – Photovoltaic power plant with horizontal single-axis tracker, 4,7 MW, Vallérargues (Gard Dpt), Urbasolar/Exosun (Photo: Christophe Ruiz).

building integration (ISB). In November 2014, the Ministry of Ecology announced the results of its second series of calls with a selection of 587 projects for 121,7 MW.

The second type of calls for tenders, called 'Ordinary', relates to the construction and operation of photovoltaic installations over 250 kW and up to 12 MW. Applications are PV on buildings, PV shelters for car parks, ground-mounted PV power plants on fixed structures or with solar trackers (Figure 2), and concentrator CPV power plants. For both types of calls, projects are selected on the electricity selling price proposed by the bidder over a period of 20 years, as well as on the carbon footprint assessment of the PV module manufacturing process. In the case of 'Ordinary' calls over 250 kW, tender specifications include the development of ground-mounted plants on brownfields, old quarries or waste dumps so as to avoid conflicts of use with farmland. The specifications also require that the environmental impact and industrial risks should be assessed and that applicants should submit RTD projects. PV plants set on brownfields are encouraged by municipalities even though such applications generally prove difficult to implement (Figure 3). In March 2014, the results of the second 'Ordinary' call (CRE2) were published with a selection of 121 projects totalling 380 MW of power. The weighted average electricity selling price of eligible projects was then estimated at 142 EUR/MWh.

Altogether the 'Simplified' and 'Ordinary' calls launched since 2011 allowed a selection of 1 569 PV systems with a total power of 1 178 MW.

A new 'Ordinary' call for tenders over 250 kW was launched by CRE in November 2014 with a target volume of 400 MW, the bid submission deadline being fixed for 1 June 2015. A new 'Simplified' call for tenders of 100 kW - 250 kW for a volume of 120 MW was to be issued in early 2015.

On a regional level, local authorities in partnership with ADEME have focused their support on the development of self-consumption projects and collaborative citizens' initiatives. In 2014, some regions such as Alsace, Aquitaine, Languedoc-Roussillon, Pays de la Loire and Poitou-Charentes launched calls for tenders with various approaches. One of the calls, for instance, planned to allocate a capped investment subsidy to systems below 250 kW, provided that 50 % of the PV production was self-consumed.

In 2014 the Ministry of Ecology, Sustainable development and Energy hosted a public consultation on the issues of self-consumption, one of the conclusions being that new support schemes and market segments should be defined at the end of an experimental period.

RESEARCH AND DEVELOPMENT

In France, research and technological development (RTD) activities cover the full spectrum of topics and involve most of the industrial and public research laboratories working in public-private partnerships. Research projects aim at increasing the conversion efficiency of PV materials, components and systems, as well as bringing down their manufacturing cost. ADEME manages a number of RTD projects as part of a major government initiative called 'Investment for the Future' (*Investissements d'avenir*). Nine projects of the 'AMI PV' RTD programme, in their final stage in 2014, should be assessed in 2015.

In 2013/2014, ADEME launched three calls for proposals on the following topics: 'Optimized Integration of Renewable Energies', 'Smart Electrical Systems' and 'Renewable Energy'. The third programme included innovative PV component processes as well as the experimentation and validation of original photovoltaic systems and building integration technologies. Six PV projects under private-public partnerships were selected.

In 2014, the French National Research Agency (ANR) was still in the process of assessing seventeen photovoltaic research projects selected under the 'PROGELEC 2011-2013' programme (Renewable electricity production and management). At the end of 2013, ANR launched a generic call for proposals. Photovoltaics was included in the research theme called 'Clean energy, safe and effective.' Three basic PV research projects were selected in 2014.

Fig. 3 – Photovoltaic power plant built on brownfields, 7 MW, Chateaurenard (Bouche-du-Rhône Dpt), La Compagnie du Vent/ Mydrone.fr (Photo: Lionel Barbe).

TABLE 2 – SUMMARY OF CALLS FOR TENDERS FOR PV SYSTEMS OVER 100 KW

CALL TYPE		TARGET VOLUME (MW)	ACHIEVED VOLUME (MW)	NUMBER OF INSTALLATIONS	AVERAGE SELLING PRICE* (EUR/MWH)
'Simplified' calls 100 kW to 250 kW Simplified building integration	**First series of calls 5 periods (2011-08)**	240	156,9	756	212*
	Second series of calls 3 periods (2013-03) Results published in 2014	120	121,7	587	162*
'Ordinary' calls 250 kW to 12 MW Large roofs, Large PV shelters, Ground-mounted plants, CPV...	**CRE1 (2011-09)**	450	520	105	213*
	CRE2 (2013-03) Results published in 2014	400	380	121	142*
Total		1 210 MW	1178,5 MW	1 569 installations	185* EUR/MWh

*NOTE: *Weighted average calculated on eligible projects corresponding to different types of systems. Provisional value.*

Source: CRE, Ministry of Ecology, Sustainable development and Energy.

In 2014, the 17th annual call for tenders of the French Single Interministerial Fund (FUI) led to the selection of two new projects aiming at improving PV/T hybrid modules as well as developing new printing processes for PV cells.

INES, the French National Solar Energy Institute, is the main organization in charge of RTD and training on solar energy. Its PV activity covers crystalline silicon (from feedstock to cells), organic materials, PV modules, PV components and systems, along with storage and building applications.

IPVF, the *Institut Photovoltaïque d'Île-de-France* (IPVF) associates several public research teams and industry laboratories so as to carry out further research into thin film materials, processes and machinery, and to develop advanced concepts for high efficiency cells and modules. The construction of a new building on the Research Campus of Paris-Saclay started in 2014.

Other public laboratories from the CNRS (National Organization for Scientific Research), universities together with engineering schools contribute to RTD programmes. RTD projects are funded by national public agencies such as ADEME, ANR and Bpifrance which is in charge of the Single Interministerial Fund. Regional councils can also provide financial support to collaborative projects. Projects are funded through subsidies and/or repayable advances.

Most PV research teams attended the 4th PV National days (JNPV) organized near Paris by the CNRS and the Federation of PV research labs (FedPV) from 2 to 5 December 2014.

INDUSTRY AND MARKET DEVELOPMENT

All professions are represented in the French photovoltaic value chain. Over the past two years, contraction of the market has had a serious impact on industry results as well as on the number of jobs. Cell and module production capacity expansion plans have been either put on hold or withdrawn.

TABLE 3 – GRID-CONNECTED PV CAPACITY AT THE END OF DECEMBER 2014 (PROVISIONAL)

POWER CAPACITY	CUMULATIVE NUMBER OF PV SYSTEMS AT THE END OF 2014	CUMULATIVE POWER AT THE END OF 2014 (%, MW)
Up to 9 kW	91,0 %	18 %
9 kW to 100 kW	7,2 %	19 %
Over 100 kW	1,8 %	63 %
Total (provisional)	**346 200 systems**	**5 630 MW**

Source: SOeS after ERDF, RTE, EDF-SEI, CRE and main ELD.

France boasts a long-standing vertically integrated manufacturer, Photowatt (EDF ENR PWT), producing multicrystalline silicon ingots, wafers and cells. The company restarted its module production in 2014 after years of outsourcing. Another long-established company, formerly Tenesol and now SunPower/Total Group, manufactures modules with monocrystalline silicon cells of high conversion efficiency. In recent years, around ten companies have engaged in the production of crystalline silicon modules with a wide range of applications including modules for building integration and hybrid PV/T. In early 2014, the activity of the French PV subsidiary of the German Bosch Group was taken over by silicon module manufacturer Sillia Énergie in partnership with project developer Urbasolar. Overall, the French annual production capacity of crystalline Si PV cells and modules has remained stable at around 100 MW and 800 MW respectively. In the area of thin film materials, Nexcis Company is developing a pilot line for CIGS PV modules prepared by electrodeposition and annealing processes.

According to provisional data from the French Observation and statistics office (SOeS), some 26 100 PV systems were grid-connected in 2014 with an estimated volume of 927 MW (643 MW in 2013). Of the power added in 2014, 12 % came from PV systems up to 9 kW and 20 % from systems between 9 kW and 100 kW. The calls for tenders for PV systems over 100 kW resulted in the installation of 68 % of annual power. At the end of 2014, the cumulative grid-connected PV power capacity was estimated at 5 630 MW with some 346 200 PV systems (Table 3). Distributed applications - mostly building-integrated systems - amounted to around 70 % of the installed capacity and ground-mounted PV plants to around 30 % (source: Observer and ADEME). Figure 1 shows the distribution of PV installations on French territory (metropolitan France and overseas departments).

As France will be the host country for the U.N. Climate Change Conference (COP 21) in 2015, the country wishes to adopt an exemplary environmental policy. This conference should lead to a universal binding agreement on climate, thus encouraging a global transition towards low-carbon societies. All PV stakeholders are ready to welcome new opportunities under such favourable conditions.

GERMANY

PHOTOVOLTAIC BUSINESS IN GERMANY – STATUS AND PROSPECTS
KLAUS PRUME, CHRISTOPH HÜNNEKES, PROJEKTTRÄGER JÜLICH (PTJ). FORSCHUNGSZENTRUM JÜLICH GMBH

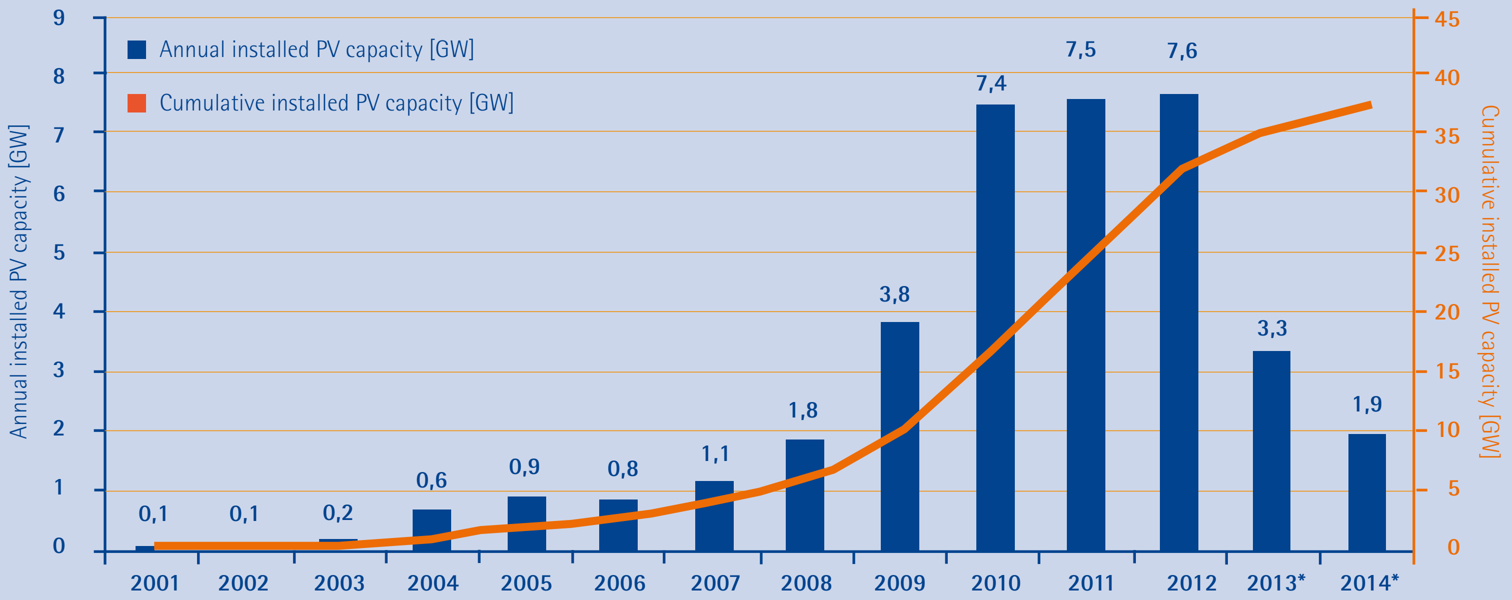

*Fig. 1 - Development of grid connected PV capacity in Germany, *first estimate as of January 2015.*

GENERAL FRAMEWORK AND IMPLEMENTATION

The transformation of the energy system is a core task for Germany's environmental and economic policy. The overall objective is an environmental friendly, reliable and economical feasible energy supply. Furthermore, it was decided in 2011 to terminate the production of nuclear power until 2022. The Federal Ministry for Economic Affairs and Energy (BMWi) recently defined an energy agenda comprising 10 key projects to approach this goal of the energy transition ("Energiewende") during the 18th legislative term [1].

The goals are to be reached firstly by efficient energy use and secondly by the use of renewable energies. The German Energy Concept states that renewable energies will contribute the major share to the energy mix of the future. With respect to the electricity supply, the share for renewable energies has reached approx. 27,3 % of the gross power consumption of Germany in 2014. The aim of the German Energy Concept is to reach 35 % in 2020 and 80 % in 2050.

Photovoltaic (PV) is a major part of this development driven by the Renewable Energy Sources Act (EEG) [2] on the one hand and a noticeable decrease of system prices on the other hand. A capacity of 1,9 GW PV power has been newly installed in Germany in 2014 (see Figure 1). This results in a total installed PV capacity of 38,2 GW connected to the electricity grid. Subsequently, PV contributed 35,2 TWh (approx. 6 %) to the annual gross power generation. This makes a 14 % rise in comparison to the previous year [3].

The EEG accelerated the installation of grid-connected PV-systems in Germany significantly. In addition, the decrease of system prices continues which makes PV systems economically more and more attractive. An analysis published by BSW-Solar, the German Solar Industry Association, shows that the average price for PV rooftop systems of less than 10 kW arrived at around 1 640 EUR/kW in 2014 [4]. This means, system prices are reduced by 68 % in the last eight years. The Levelized Costs of Energy (LCOE) for a small rooftop PV system in Germany are around 0,16 EUR / kWh whereas the electricity price for private households is around 0,25 EUR / kWh. Therefore, investments in PV installations are getting attractive even without financial support by a Feed-in-Tariff.

TABLE 1 – DEVELOPMENT OF THE FEED-IN TARIFF (FIT) FOR SMALL ROOFTOP SYSTEMS (< 10KW)

YEAR	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013*	2014*	2015*
EURcents/ kWh	50,6	48,1	45,7	57,4	54,5	51,8	49,2	46,75	43,01	39,14	28,74	24,43	17.02	13,68	12,56

** adjusted by a flexible monthly degression rate between 1 – 2,8 % throughout the year*

Fig. 2 - Ground mounted photovoltaic installation with 3,9 MW peak power on a former landfill site (Photo: Klaus Prume).

NATIONAL PROGRAMME

In order to streamline the German energy policies, the responsibility for all energy related activities are concentrated within the Federal Ministry for Economic Affairs and Energy (BMWi) since end of 2013. Up to now, the main driving force for the PV market in Germany is the Renewable Energy Sources Act (EEG 2014). In terms of achieving expansion targets for renewable energies in the electricity sector, the EEG is the most effective funding instrument at the German government's disposal. It determines the procedure of grid access for renewable energies and guarantees favourable Feed-in-Tariffs (FiT) for them. However, due to the successfully but very fast increase in PV and wind energy generation additional amendments to the EEG have been introduced on August 1st 2014. The most important change is that new PV installations > 500 kWp (from 2016 on PV installations > 100 kWp) are obliged to direct marketing of the generated electricity. A feed-in premium is paid on top of the electricity market price through the so-called "market integration model."

For PV, the FiT depends on the system size and whether the system is ground mounted or attached to a building. It includes a monthly adapted degression rate of the FiT, which depends on the previously installed PV capacity. This procedure tends to stimulate a yearly installation of 2,5 – 3,5 GW. Details on the development of the FiT can be found in [5]. Table 1 shows the development of the FiT for small rooftop systems (< 10 kW) since 2001 [6]. All rates are guaranteed for an operation period of 20 years. The FiT terminates at a total installed PV capacity of 52 GW. Meanwhile, the EEG contains measures for the integration of PV systems into the grid management.

In addition to the above mentioned support scheme for renewable energies, a new 25 MEUR market stimulation program has been introduced to boost the installation of local stationary storage systems in conjunction with small PV systems (< 30 kWp) [7].

RESEARCH AND DEVELOPMENT

Research and Development (R&D) is conducted under the 6th Programme on Energy Research "Research for an environmental friendly, reliable and economical feasible energy supply" [8] which came into force in August 2011. Within this framework, the BMWi as well as the BMBF (Federal Ministry of Education and Research) support R&D on different aspects of PV. The main parts of the programme are administrated by the Project Management Organisation (PtJ) in Jülich.

Funding Activities of the BMWi

In December 2014, the BMWi released a new call for tender which reflects the targets of the energy research program. Concerning PV, the call addresses six focal points which are all connected to applied research:

- Silicon wafer technology,
- Thin-film technologies, especially based on Silicon and Chalcopyrites (CIS/CIGS),
- Quality and reliability issues of PV-systems
- System technology for both, decentralised grid-connection and island systems,
- Alternative solar cell concepts, such as Concentrated Solar Power (CSP) and other alternative concepts and
- Cross-cutting issues, such as Building Integrated PV (BIPV), recycling or research on the ecological impact of PV systems.

In 2014, the BMWi support for R&D projects on PV amounted to about 43,34 MEUR shared by 260 projects in total. That year, 90 (2013: 53) new grants were contracted. The funding for these projects amounts to 66,9 (44,6) MEUR in total.

Details on running R&D projects can be found via a web-based database of the Federal Ministries [9]. The German contributions to the PVPS Tasks 1, 9, 11, 12, 13 and 14 are part of the programme.

Funding Activities of the BMBF

In 2013, the BMBF published a still open call for proposals "Material research for the energy transition" aiming for the support of long-term R&D on renewable energies which is complementary to the BMWi funding. Concerning PV, currently the focal point of engagement is the development of silicon and non-silicon materials for thin film solar cells.

Innovation Alliance PV – a Joint Initiative of BMWi and BMBF

In summer 2010, BMU (now under responsibility of BMWi) and BMBF initiated the Innovation Alliance PV. Under this scheme R&D projects are funded which support a significant reduction of PV production costs in order to enhance the competitiveness of Germany's industry. Therefore, projects under industrial leadership integrating different steps of the PV value chain were selected. In particular, cooperation between PV industry and PV equipment suppliers is of importance. Together, BMWi and BMBF allocated more than 100 MEUR to support this initiative. The German PV industry agreed to raise additional 500 MEUR to accompany the Innovation Alliance. A total of 25 R&D projects have been funded. The results of all projects have been presented at a final workshop held 6th of October 2014 [10].

FuE for Photovoltaic – a Joint Initiative of BMWi and BMBF

To support the momentum stimulated by the Innovation Alliance PV a new joint initiative of BMWi and BMBF has been launched in 2013. The aim of this program "FuE for Photovoltaic" is to support R&D activities especially with participation of the German PV industry in the fields of:

- economical operation of grid-connected and off-grid PV system solutions including energy management and storage systems,
- efficient and cost effective production concepts including the introduction of new materials and production monitoring systems, and
- introduction of new PV module concepts with a special focus on quality, reliability and life time.

The approval procedure resulted in 12 joint projects which are funded by the ministries (BMWi: 9 projects, 43 MEUR / BMBF: 3 projects, 6 MEUR). This sum will be increased by a sum of 58,2 MEUR as contribution from industry.

INDUSTRY AND MARKET DEVELOPMENT

The German PV industry manufacturers, as well as equipment suppliers, still face difficult situations. Today, burdens resulting from the world economic crisis and further falling prices result in a tough situation. Nevertheless, the Foreign Trade and Inward Investment Agency of the Federal Republic of Germany "Germany Trade & Invest" lists in the latest report (Issue 2014/2015 published April 2014) an impressive number of companies involved in PV:

- 40 manufacturers of silicon, ingots, wafer, cells, and modules,
- 100 PV material and equipment suppliers,
- more than 70 PV research institutes,
- and over a 100 additional manufacturers of balance-of-system component manufacturers.

This list shows that the German PV industry is positioned along the whole value chain. During the last years, equipment and production companies became the most experienced ones worldwide. A workforce of more than 100 000 people was employed in the PV industry [11].

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[2] Renewable Energy Sources Act (EEG 2014), see http://www.erneuerbare-energien.de/EE/Redaktion/DE/Downloads/EEG/eeg_2014.pdf?__blob=publicationFile&v=6

[3] Federal Statistical Office, see https://www.destatis.de/EN/FactsFigures/EconomicSectors/Energy/Production/Tables/GrossElectricityProduction.html

[4] BSW-Solar fact sheet (in German) "Statistische Zahlen der deutschen Solarstrombranche (Photovoltaik)", April 2014, see http://www.solarwirtschaft.de/fileadmin/media/pdf/2013_2_BSW_Solar_Faktenblatt_Photovoltaik.pdf

[5] Feed-in Tariffs for 2014 can be found at www.bundesnetzagentur.de

[6] The amended Feed-in Tariff (FiT) program went into effect on April 1, 2012. For PV system installations up to 10 kW capacity, the new FiT from January 1st, 2015 will be 12,56 EURcent / kWh. For roof top installations up to 40 kW capacity, the new FiT will be 12,22 EURcent / kWh, up to 500 kW the FiT is 10,92 EURcent / kWh (all without direct marketing of the electricity). Systems above 500 kW require direct marketing of electricity. For installations up to 10 MW at maximum on roof tops or ground installed systems the FiT amounts to 9,09 EURcent / kWh. No reimbursement is paid for installations greater than 10 MW. A monthly degression rate is fixed quarterly depending on the previous installation capacity. The FiT scheme will run up to 52 GW.

[7] Market stimulation program for local stationary storage systems in conjunction with small PV-systems: https://www.kfw.de/Download-Center/F%C3%B6rderprogramme-%28Inlandsf%C3%B6rderung%29/PDF-Dokumente/6000002700_M_275_Speicher.pdf

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ISRAEL

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS: AN UPDATE
GIDEON FRIEDMANN, TECHNOLOGIES & RENEWABLE ENERGY SECTION MANAGER,
MINISTRY OF NATIONAL INFRASTRUCTURE, ENERGY & WATER RESOURCES

GENERAL FRAMEWORK

In 2009, the Israeli government set a target of 10 % electricity generation from renewable sources by the year 2020 (of the actual supply). There is no potential for hydropower generation in Israel, whereas in most of Europe this is a significant part of the clean energy. Of this, 35 % was expected to come from PV systems. In light of the dramatic decrease in the cost of PV systems, it is now expected that a much higher percentage will come from the PV sector.

Approximately 580 MW of PV systems were installed by the end of 2014, of which 250 MW were connected in 2014. Most of these systems are small and medium size. In the next two years, additional PV power is expected to come mostly from large plants installation. The capacity factor in Israel for PV is considerably higher than in Europe and stands around 19 % for actual production on an annual average.

Government support is given in the form of guaranteed Feed in Tarrif (FiT) for 20 years. FiTs vary by project nature, size and other parameters. FiT have decreased considerably over the last few years, and are expected to continue their decline. Current FiT for PV systems range from 0,38 to 0,6 ILS (0,1 – 0,15 USDcents).

Because FiT includes a subsidy, there are quotas (Caps) for each renewable energy category. In 2014, an additional quota of 340 MW for PV was issued, to be evenly spread during 2015-2017. This quota comes mostly at the expense of Biomass electricity production, for which it was decided that the original targets were too high, due to lack of source material. In addition there is a quota of 180 MW, which is expected to be converted from CSP to PV. These steps are taken, in order to achieve the goal of 10 % RE production by 2020, and in consideration with the fact that PV is currently the most readily available RE in Israel.

It is now clear that PV systems are close to grid parity. In fact there is a tariff that is available to RE manufacturers, which PV entrepreneurs may start to consider soon. This tariff is the recognized conventional electricity generation tariff + a premium for emissions reduction (currently 0,30 + 0,08 ILS respectively). This tariff is not subject to the FiT quotas. The main issue for PV entrepreneurs now, is the fact that the rate fluctuates with conventional electricity generation rates, and is thus not guaranteed.

GOVERNMENT POLICY CONSIDERATIONS

A review of the current policies continues. Israel's view is that the main benefits of PV are:

- Energy Security by diversification – Israel is highly dependent on natural gas;
- Emissions Reduction;
- Guaranteed Prices over time.

Although PV systems in the summer produce electricity when it is needed the most, this is not the case in the winter. This, and the lack of guaranteed availability, will prevent PV systems from becoming a large source of Israel's electricity production, because their value decreases with increased penetration. Only when storage becomes a practical solution will this change.

In order to reduce the costs of RE installations, a system of tenders is currently being prepared, whereby the government will request bids for electricity generation by PV entrepreneurs, and the best offer will win the generation, with the price being a determinant factor in the choice of a winner.

Net Metering/Self Consumption

- In 2013, a net-metering scheme was implemented for all REs. It established a cap of 200 MW for 2013 and the same for 2014. This was extended to 2015, and is expected to be further extended. This quota is applicable to all renewable generation up to 5 MW.
- Real-time self-consumption simply reduces the electricity bill.
- Excess PV production can be fed into the grid in exchange for monetary credits, which can be used to offset electricity consumption from the grid during the following 24 months. The credit is time of day dependent. Thus a small overproduction at peak times, can offset a large consumption at low times.
- Credits can be transferred to any other consumer and, in particular, to other locations of the same entity.
- One has the option to sell a preset amount of the electricity to the grid for money (and not credit), but at a conventional manufacturing price (currently 0,30 ILS/KWh).
- All the electricity fed into the grid is subject to Grid and Services charges.
- A back-up fee that aims to cover the need to back-up PV systems with conventional power plants. This fee is technology dependent and will grow for solar from 0,03 ILS/kWh when the installed capacity will reach 1,8 GW and then 0,06 ILS/kWh when 2,4 GW will be installed.
- A balancing fee (0,015 ILS/kWh) for variable renewable sources has also been introduced.
- Finally, a grid fee that depends on the time of day and day of the week and connection type (to transmission, distribution, or supply grid) and ranges from 0,01 and 0,05 ILS/kWh has been introduced.

RESEARCH AND DEVELOPMENT

The Ministry of National Infrastructure, Energy and Water Resources supports R&D under 3 main programs:

- Direct support of academic research. Support is 100 % of research that won in the annual tender.
- Support of startup companies. Support is 62,5 % for projects with technology innovation.
- Support for Demonstration and Pilot programs. Support is 50 %. This is meant for field deployment of novel technologies. Demonstration can also be supported under a special dedicated cap for electricity production. In this case the payment is through the FiT over 20 years.

Among the current companies supported are:

- **M.G. Lightning** develops photovoltaic performance, fault and yield prediction tools based on machine learning algorithms. Having successfully developed algorithms for predicting next day's hourly production of even small residential systems, using only data from the inverter and simple local weather prediction servers. The company now applies these algorithms on yesterday's historical weather data to ascertain whether the system performed as expected in the weather conditions that prevailed over the system yesterday, thereby improving availability of small residential systems. The company is now working in collaboration with IEA PVPS Task 13 on predicting PV system faults before they occur, by developing a new set of machine learning algorithms that work on inverter data from sites in Israel and around the world.
- **PV Nano Cell** Ltd (PVN), is focused on the development and manufacture of materials and technologies that will enable substantial cost reduction in the manufacturing processes of solar cells and electronic devices, mainly through digital printing with inks based on single crystal nanometric materials - Sicrys™. PVN's Silver and Copper Sicrys™ inks are optimized for a wide range of applications in CleanTech (solar cells), Printed Electronics (flexible and customized devices), IoT (antennas), 2.5D and 3D Printed Electronics. Sicrys™ inks are the enablers for green and mass production commercially viable applications, bringing to customers a complete solution approach.
- **Solaris Synergy** develops FPV (Floating Photo-Voltaic) technology, which breaks the paradigm that mounting solar panels on water surfaces is an expensive and complicated process. Solaris Synergy provides solar electric generation on water surfaces at a cost equivalent to grid-parity, and competitive with ordinary land based systems, by leveraging the water surface to allow the use of simple and low-cost construction. The system enables owners of water surfaces to put their reservoirs, Hydro-electric dams, lakes and ponds to work, providing clean and efficient power. Solaris Synergy is one of a very few number of companies worldwide able to offer a commercial floating PV solution, and the only one to do so at a cost competitive with land based installations.

Fig. 1 - MG Lightning monitoring system at a solar PV installation.

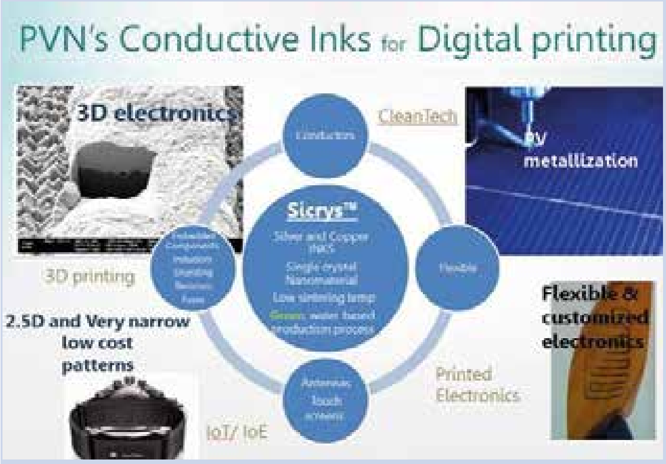

Fig. 2 - Physical Properties of PV Nano Cell's conductive inks for digital printing.

Fig. 3 - Solaris Synergy's solar PV field installation on a water reservoir.

ITALY

PV TECHNOLOGY STATUS AND PROSPECTS

SALVATORE CASTELLO, ENEA
SALVATORE GUASTELLA, FABRIZIO PALETTA, RSE
FRANCESCA TILLI, GSE

Fig. 1 - 16 kWp PV plant at Panicale (PG), "a-SI/µc-Si tandem / thin film" modules (Photo: GSE, Gestore dei Servizi Energetici).

GENERAL FRAMEWORK AND IMPLEMENTATION

In Italy, 2014 was the first year following the conclusion of the "Conto Energia" Programme incentive and the year where a relevant revision of the "Conto Energia"tariffs took place. Nevertheless, the regulatory framework for the installation of PV plants in Italy finally seems to have reached a stable condition. In fact:

- Small plants (peak power less than 20 kW) continue to grow thanks to the confirmation of the tax deductions for residential application;
- companies and public institution could benefit from white certificates but only for small size PV plants;
- the "Efficient Systems of Users" rules and self-consumption seem to be a good basis for medium size plant growth;
- rules and technical norms for the connection to the grid of systems with storage have been defined, allowing their use in photovoltaic plants connected to the electric grid.

A preliminary evaluation of the total PV power installed during 2014 amounts to about 385 MW:

- 85 MW plants realized still in the framework of the "Conto Energia" Programme (due to an additional period of nine months granted to install and put in operation some particular PV plants already admitted to incentive);
- 300 MW installed, benefitting from the fiscal bonus for PV investments, as well as measures concerning the sale or exchanging energy with the grid.

However, these results, even if lower than the expected value, confirm a mature market and a positive public perception towards photovoltaic technology. According to a preliminary evaluation, a total cumulative capacity of about **18,45 GW** has been installed and were operating in Italy at the end of 2014. In particular, the installations in the most significant sectors of PV power system applications are estimated cumulatively as follows:

- BIPV 2 650 MW
- BAPV 7 125 MW
- PV (other, on ground) 8 650 MW
- CPV 30 MW

Regarding BIPV plants, it must be noted that 280 MW plants are related to innovative BIPV plants (built under the third, fourth and fifth Conto Energia), while the remaining 2 370 MW of integrated plants include systems on pergolas, greenhouses and shelters (under the second Conto Energia).

A marginal sector that continues to grow slowly is represented by PV off-grid non-domestic applications that reached about 13 MW; while domestic applications, since they were built in the 1980s, result as almost completely decommissioned.

The cumulative installed capacity corresponds to an overall photovoltaic electricity production of 23 299 GWh, with a share of over 7,5 % of the national electricity consumption (309 006 GWh). Specifically, in August 2014 in Italy, also because of the reduction of electricity consumption, grid connected PV plants met 12 % of national demand, while for a few midday hours in June 2014, the power delivered by PV plants reached the value of the national electrical load.


Fig. 2 - 101 kWp PV plant at Fornace (TN), Monocristalline modules (Photo: GSE, Gestore dei Servizi Energetici).

Taking into account all renewables, the contribution of "new renewables" (solar, wind, geothermal) in the annual electric energy production reached 16,1 % (37,7 % including hydroelectric), while the decline of fossil fuel generation still continued.

Whereas photovoltaics in Italy has reached competitiveness due to good radiation values in southern regions and the high cost of electricity bills, some important factors currently hamper the further development of this technology.

On the contrary, as highlighted by several PV operators, the development of PV in Italy could continue to grow by initiatives at no cost to public finances, due to:

- Stable rules for the sale or the exchange of the produced electricity with the grid;
- simplified permitting process for PV installations (specially ground based);
- major focus on self-consumption of produced energy through electric storage;
- easier access to credit.

Regarding to the first point, the Italian Authority for Electricity and Gas has introduced new rules that could facilitate the installation of PV plants:

- Increase in the limit for exchanging energy with the grid from 200 kW to 500 kW;
- publication of specific rules for Electric Energy Storage System (EESS) installed in production plants (included PV plants) connected to the grid. Unfortunately, this publication happened only in December and the long expectation resulted in a standstill of the market of storage systems combined with PV plants, which has a very high interest in Italy, despite that storage is still expensive;
- the Efficient Systems of Users (SEU) rule definitions concerning the management (connection services, measurement, transmission, distribution, dispatching and sale aspects) of the private grid, both for single user and with more consumption units and industrial production unit of electrical energy functional for the production process. The SEU are systems in which one or more production plants, with a total power of not more than 20 MWe and totally installed on the same site, powered by renewable sources or in high efficiency cogeneration, operated by the same manufacturer, are directly connected, by means of a private link, to the unit of the final customer.

During 2014, the barrier to the diffusion of PV plants represented by the electric grid, inadequate in some regions of Italy, has been partly solved by the new version of Italian standards (CEI 0-16 and 0-21) which require that production plants connected to the grid (included PV plants) have to provide services to the LV and MV grids in order to improve their management.

NATIONAL PROGRAMME

Although the "Conto Energia" Programme was definitively concluded in May 2014, a decree was issued regulating the reshaping of the incentives provided by the Programme.

By 30 November 2014, it was necessary to choose one of the following options for PV plants with a nominal power greater than 200 kW, valid from January 2015:

- Extend the period of incentive reformulating the unit value of the incentive from 20 to 24 years;
- continue to benefit from the incentives for a period of 20 years, but with a reduction in a first period and with a corresponding increase in a second period;
- continue with incentives paid for 20 years but reduced by a percentage depending on plant size.

RESEARCH, DEVELOPMENT AND DEMONSTRATION

Research, development and demonstration activities on photovoltaic devices and systems are mainly conducted by ENEA (the Italian Agency for New Technology, Energy and the Environment) and RSE (a research company owned by GSE, the Italian publicly-owned company managing the renewable energy source incentives and regulations). Additional contributions have been supplied by some universities, CNR (the National Council for Scientific Research) and few private laboratories.

ENEA is the main PV Research organization operating in Italy. Its most significant fields of interest are: Crystalline silicon cells, amorphous-crystalline silicon heterojunction celsl, CZTS celsl and CZTS/silicon Tandem cells, Perovskite single junction cells, Perovskite-silicon tandem cells, microcrystalline Si devices, micromorph tandem solar cells, as well as concentrator technologies. In the field of PV systems, ENEA is developing devices, software, modeling, smart grid concepts and strategies for optimum plant integration in the electrical grid (for both existing and new plants) and added value services for producer/user and distributors.

RSE, in particular, is the main research organization carrying out activities on high efficiency solar cells in Italy, developing multi-junction solar cells based on III-V-IV elements and nano-structured coating for high concentration applications, in the framework of the Italian electric system research programme RdS (Ricerca di Sistema) and European projects. In this field, RSE is involved in the

Fig. 3 - 20 kWp PV plant at Badia (BZ), Monocristalline modules (Photo: GSE, Gestore dei Servizi Energetici).

design of new optics, in outdoor and indoor concentrating module characterization and in the development of advanced solar tracking control. Furthermore, RSE is engaged in the performance evaluation of innovative flat modules and plants, as well as in research and demonstration activities for electrification of remote communities.

INDUSTRY AND MARKET DEVELOPMENT

The production of photovoltaic cells has been drastically reduced in 2014 due to the stop in production of important national operators.

The production capacity of the modules has remained stable compared to 2013, thanks to the full operation of the 3Sun company in Sicily, a company of Enel Green Power. Moreover recently a new Italian company, MegaCell, is on market with a production capability of 80 MW/year of bifacial silicon solar cell. On the whole, a total module production capacity of about 800 MW has been estimated.

In the field of BOS components, in Italy, 8 companies manufacture inverters for on-grid and off-grid applications. During 2014 their production capacity has been around 7.000 MW.

Taking into account the Italian manufacturing assets and the size of the national market (expected around 0,5-1 GW/year), the road to internationalization is a necessity for the Italian photovoltaic industry.

However, while the business area of the inverter has recorded a higher degree of internationalization, the path for module manufacturers has been more difficult.

Regarding EPC contractors and system integrators, the reduction of the domestic market pushes them to move towards addressing international markets while relying on their own know-how.

Moreover, during 2014, the achievement of considerable stock of installed capacity has contributed to a significant change in business dynamics which are now related to operation and maintenance activities. In fact, the main Italian players previously acting as EPC and system integrators now appear to be more and more focussed on large size plant management and maintenance services.

Finally, a growing interest in the acquisition of large size existing plants (secondary market) in the Italian PV market has been recorded, mainly due to risk increase in the development of new large plants, accentuated by the effect of the tariff reshaping and the extremely limited installation permitting.

JAPAN

PV TECHNOLOGY STATUS AND PROSPECTS

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Fig. 1 - TETSUSO's Rental Storage Facilities (Koto Ward, Tokyo). Single-crystalline silicon PV module (by Mitsubishi Electric) 2,9 MW.

GENERAL FRAMEWORK

In Japan, the "Fourth Basic Energy Plan" was approved by the Cabinet in April 2014. The new basic energy plan takes into account Japan's mid- to long-term energy supply and demand structure for the next two decades. The Basic Energy Plan is designed to be a guideline for Japan's energy policy. The Fourth Basic Energy Plan covers the third revision from the original Basic Energy Plan which was formulated in October 2003. In the Fourth Basic Energy Plan, nuclear power generation is positioned as one of the key "base-load power sources," a term the government uses to describe types of power sources that can stably generate power at low cost 24 hours a day. Also, renewable energies such as PV and wind power generation are positioned as one of the key "low-carbon energy sources produced in Japan." Estimating the structural changes in energy supply advancing around the world, the plan positions the three years between 2018 and 2020 as a period to concentrate on the reform to establish a stable energy supply and demand structure, and defines the direction of various measures to take. Based on the Fourth Basic Energy Plan, the "Ministerial Council on Renewable Energy" was established in order to introduce renewable energy to a maximum extent.

The basic policy for formulating the Fourth Basic Energy Plan, positioned as a key guideline to define the future direction, is structured from six perspectives as follows: 1) To realize a multi-layered supply structure consisting of various energy sources; 2) To promote a tougher energy supply structure; 3) Participation of various entities in energy supply structure through promotion of structural reform; 4) To realize energy supply and demand structure led by the demand side by offering a variety of options; 5) To improve self-sufficiency rate with development and introduction of Japan-made energy to minimize impacts of circumstantial changes in other countries and 6) To contribute to addressing global warming to reduce greenhouse gas emissions across the world. "Participation of various entities in energy supply structure through promotion of structural reform" and "To realize energy supply and demand structure led by the demand side by offering a variety of options" are new perspectives in the Fourth Basic Energy Plan. They indicate a firm attitude to strongly promote advancement of institutional reform in Japan, including the electricity system reform.

In the plan, energy sources which Japan should depend on in the future are evaluated. Positioning of energy sources and the direction of policy are clearly described. Positioning of renewable energy is described as a "prospective, diverse and low-carbon key energy source domestically produced which can also contribute to energy security." As a policy direction, the following statements were made: "Introduction of renewable energy shall be promoted at a maximum extent for approximately three years from 2013. After the three-year period, renewable energy will continue to be actively promoted;" "Grids will be strengthened, regulations will be rationalized, and R&D on cost reduction, etc. will be steadily promoted;" "Ministerial council on renewable energy will be established and the government's function for leading introduction of renewable energy will be reinforced;" "Collaboration among concerned ministries and agencies will be facilitated;" and "Levels of introduction will be above the levels based on the preceding Basic Energy Plan."

Under the Fourth Basic Energy Plan, as to PV power generation, as part of "promoting utilization of renewable energy in distributed energy systems," community-level efforts on PV power generation will be supported since it is easy to install PV systems on a small and medium scale as distributed power source without much burden on the grid, PV systems can create opportunities for different levels of people in the nation to recognize energy issues as their own issues, and they can be used as emergency power source. PV systems are recognized as suitable for distributed power source supporting self-consumption, local production and consumption of energy. Moreover, in order to permit supplying surplus electricity from distributed energy systems to the grid as a flexible measure, a more flexible management of reverse power flow will be realized and technology innovation for grid stabilization will be promoted.

As to installation of PV systems, in the third year of the feed-in tariff (FIT) program which started in July 2012, Japan has grown in the market with 9 GW level of annual PV installed capacity. Meanwhile, the cumulative capacity of approved PV systems under the FIT program approached 70 GW as of the end of November 2014, causing some electric utilities to suspend responses to applications for grid connection contracts. The Ministry of Economy, Trade and Industry (METI) calculated the possible hosting capacity of these utilities for grid connection of renewable energy-based power generation systems and started working on a drastic revision of the implementation rules of the FIT program, taking into account of reducing the financial burden of the nation. Details of the revision of the FIT program are described in the "NATIONAL PROGRAM" section below.

NATIONAL PROGRAM

METI is taking initiative in supporting dissemination of PV systems by support measures including the following:

(1) Subsidy for supporting introduction of residential PV systems

(budget: 119,4 BJPY for multiple-years from FY 2011 to FY 2013)
METI ended acceptance of applications for the subsidy program for individuals and companies who install < 10 kW residential PV systems at the end of March 2014. In FY 2013 (from April 2013 to March 2014), the PV systems with the price between over 20 000 JPY/kW and 410 000 JPY/kW were eligible for 20 000 JPY/kW subsidy for the maximum output capacity of PV modules by kW and the PV systems with the price between over 410 000 JPY/kW and 500 000 JPY/kW were eligible for 15 000 JPY/kW subsidy for the maximum output capacity of PV modules by kW. Paperwork to grant subsidy continued in FY 2014 (from April 2014 to March 2015) and a total of 130 781 PV systems have been approved to receive the subsidy in the period between April and December 2014. The average installed capacity and the average price of these PV systems are 4,56 kW/system and 385 000 JPY/kW respectively. The average price decreased from the previous year. From FY 2014 onwards, support for introduction of residential PV systems is conducted through the FIT program.

(2) Feed-in Tariff (FIT) program for renewable energy power generation facilities

In FY 2014, the levels of the FIT for renewable energy power generation facilities were set lower than those of the previous year. The tariffs and periods of purchase are set as follows: 1) 32 JPY/kWh (excl. tax) for PV systems with the capacity of 10 kW or more for the period of 20 years; and 2) 37 JPY/kWh for PV systems with the capacity below 10 kW for the period of 10 years. Under the FIT program, as of September 30, 2014, total capacity of approved PV systems with the capacity below 10 kW, between 10 kW and below 1 MW and 1 MW or above are 3 140 MW, 29 056 MW and 36 788 MW, respectively, amounting to 68 984 MW in total. Since it takes time for large-scale PV projects to start operation after they received approval, only 12 958 MW of PV systems started operation under the FIT program and 6 113 MW of PV systems out of these started operation between January and September 2014, a 46 % increase compared to the same period of the previous year.

From FY 2014, it was decided that if land and facilities are not secured within 180 days after approval, the approval shall be cancelled for ≥ 50 kW PV systems and partitioning into small projects in one site is prohibited. METI also conducted collection of reports on PV systems with a capacity of 400 kW or more, which were approved for the FIT program but have not yet started operation, and canceled the approval after a hearing.

In the fall of 2014, METI started to discuss the revision of the FIT program following some electric utilities' suspension of responses to applications for grid connection contracts. Revision of the FIT program is conducted from several viewpoints including: 1) "maximum introduction of renewable energy under the new output curtailment rules;" 2) "response towards well-balanced introduction of renewable energy;" 3) "response towards the issue of suspension of grid connection contracts by each electric utility;" 4) "special treatments in Fukushima Prefecture;" 5) "dissemination policy in the future;" and 6) "revision of operation of the FIT program;" including the revision of output curtailment rules, obligation to install remote output controlling function for inverters, tightening of requirements for approval in case of change of facility and prevention of the gripping of the capacity without starting the operation. The new rules based on the revision, which will be stricter than the existing ones, aim at the maximum introduction of renewable energy without having an impact on the grid. The tariffs for FY 2015 (from April 2015 to March 2016) will be discussed from the beginning of 2015 and it is expected that the tariffs for PV systems will be lowered further.

(3) Subsidy for introducing renewable energy power generation systems as part of restoration measures (budget: 31,6 BJPY, multi-years from FY 2011 to FY 2015)

In order to create employment in the renewable energy industry and stimulate its related industries in the areas damaged by the Great East Japan Earthquake, subsidy has been provided for introducing renewable energy power generation facilities such as PV systems in the disaster-stricken areas. For PV systems, either 10 % or less of the eligible cost or 80 000 JPY/kW, whichever is lower, is subsidized. The upper limit of the subsidy is 500 MJPY per year or maximum 1 BJPY per system for multiple years. To be eligible for the subsidy, it is required that a system should have the output capacity of not less than 10 kW, or have the combined output capacity of not less than 10 kW of plural systems installed at more than one of the sites (the average output capacity per site must be 4 kW or larger). In FY 2011, 70 PV systems with a total output of approximately 140 MW were selected whereas 665 PV systems with a total output of 880 MW were selected in FY 2012 and 330 PV systems with a total output of approximately 600 MW were selected in FY 2014. Besides, "single-year subsidy reserved for quake-stricken three prefectures (budget: approximately 1,5 BJPY)" is implemented in Iwate, Miyagi and Fukushima Prefectures with the same support framework, under which 70 PV systems with a total output of approximately 45 MW were selected in FY 2014.

In FY 2014, with the "Green New Deal Fund," which was established in FY 2012 to promote introduction of renewable energy in local communities, the Ministry of the Environment (MoE) distributed 22 BJPY to 19 local governments and municipalities. Each local government introduces renewable energy facilities in public institutions and provides subsidy for homeowners and small to mid-size businesses based on this fund. Moreover, in FY 2014, MoE newly started various projects with the aim of realizing a low-carbon society. Under the "Green Plan Partnership Business (5,3 BJPY)," which supports implementation of renewable energy introduction plan led by communities and subsidizes introduction of renewable energy and energy-saving facilities, etc., MoE supported smart community improvement plans and low-carbon houses model town improvement projects led by local governments. Under the "project to promote introduction of PV systems at waste landfill sites, etc. (250 MJPY)," three projects conducted by private companies were selected. In addition, MoE has newly established the "Project to promote low-carbon communities in remote islands (2,8 BJPY)" and the "Project to accelerate renewable energy and energy saving in remote islands (400 MJPY)". As various measures taking advantage of the financial mechanism to attract private investment, "Eco lease business promotion project for households and businesses," which subsidizes leasing interest payments to low-carbon equipment, has also been continued as well as the "Project to create community low-carbon investment promotion fund," which invests in creation of funds to promote financing for community-level low-carbon projects and subsidizes interest payments. MoE, in addition to announcing investigation results regarding recycling of used PV facilities in cooperation with METI, decided to formulate a guideline for installation of MW-scale (large-scale) PV power plants inside natural parks.

The Ministry of Land, Infrastructure, Transport and Tourism (MLIT) has been promoting installation of PV systems in green government buildings for central ministries and agencies, as well as their related facilities in local areas equipped with PV systems and other new and renewable energy systems. In March 2014, MLIT developed a new environmental action plan for FY 2014 to FY 2020 and accordingly published "Environmental Load Reduction Program on Government Facilities 2014 (Government Buildings Green Program 2014)." Under this program, MLIT intends to promote the use of renewable energy such as PV on government buildings and reduce environmental load. For the private sector, MLIT invited proposals for projects which aim to reduce CO_2 emissions in houses and buildings; such as office buildings, in the urban environment and the transport sector, and also implemented a subsidy program to aid a fixed amount or a part of the maintenance cost. Furthermore, MLIT supports the efforts to realize zero-energy homes by upgrading the energy-saving performance of the building frame and equipment of the houses or by utilizing renewable energy systems.

The Ministry of Agriculture, Forestry and Fisheries (MAFF) implements a subsidy program to install PV systems at facilities for agriculture, forestry and fisheries, in order to promote the introduction of renewable energy into these industries. MAFF has implemented the "project to comprehensively promote renewable energy for revitalization of agricultural, forestry and fishing villages." Through this project, MAFF is supporting efforts to promote/ support commercialization of renewable energy by private organizations and local public organizations. In FY 2014, MAFF newly selected 24 projects to provide the subsidy. Besides, it cooperates for the implementation of MoE's "Green plan partnership business."

The Ministry of Education, Culture, Sports, Science and Technology (MEXT) continued the "Super eco school demonstration project" which was initiated in FY 2012 to promote the realization of zero energy at public school facilities. This demonstration project subsidizes 50 % of the renovation cost for introducing renewable energy power generation systems such as PV systems for the project period of three years. In FY 2014, a project aiming at zero energy of newly-built elementary schools through partnership between Kawasaki City of Kanagawa Prefecture and private companies was newly selected. MEXT also provides subsidy for installation of PV systems through the Eco School Pilot Model Project (63 schools were approved in FY 2014), improvement of functions of public school facilities as well as the renovation work in both interior and exterior of schools to build environmentally-friendly facilities in private schools. For public schools, MEXT provides subsidy (50 % subsidy) to install PV systems and storage batteries.

In addition to the national support measures, efforts by local governments and municipalities play an important role for supporting the dissemination of PV systems. Some local governments and municipalities which were offering subsidy programs for installation of residential PV systems ended these subsidy programs following the termination of the Subsidy for supporting introduction of residential PV systems by the national government. For the installation of industrial PV systems, some local governments offer subsidy programs or loan programs at preferential interest rates. In addition to various subsidy programs, some local governments and municipalities advanced their activities to promote installation of PV systems through deregulation by amendment of ordinances, while others provided roadmaps to support introduction of renewable energy using the Internet, "roof lease" models at public facilities, etc. and promoted introduction of PV systems such as MW-scale PV projects.

R&D, D

R&D

The New Energy and Industrial Technology Development Organization (NEDO) has been leading to conduct research and development of PV power generation in Japan. In 2014, NEDO formulated a new guidance for technology development "NEDO PV Challenge," based on the rapid changes in the circumstances for PV power generation over the past two to three years both home and abroad. The previous version of the guidance "PV Roadmap (PV 2030+)" was formulated in the spring of 2009, when the targeted PV installed capacities were 10 GW/year level globally and 0,5 GW/year level domestically. As for the environment for the deployment of PV power generation, the era of initial market cultivation has seen its end, shifting to the era of creating a market as a mainstream energy source. The annual PV market has grown to 40 GW globally and 7 GW domestically in 2013. Since the international trading price of PV modules decreased to around 0,7 USD/W, NEDO renewed its strategy on PV technology


Fig. 2 - AEON Mall Makuhari New City (Mihama Ward, Chiba City, Chiba Prefecture). 242-W multicrystalline silicon PV module (Kyocera). Total: 1,75 MW, of which, parking area: 1 MW.

development, by largely shifting its approach for technology development from "a strategy to promote dissemination of PV power generation" to "a strategy to support the society after the deployment of PV power generation." So far, NEDO focused on technology development by emphasizing improvement in conversion efficiency of PV cells/ modules as well as cost reduction. As a new perspective, the new strategy focuses on increasing utilization of PV power generation and enhancing infrastructure of Japan's PV industry, in order to smoothly realize a society with a large-scale PV installation. Specifically, the strategy has the following five pillars: 1) reduction of power generation cost; 2) improvement of reliability; 3) easing of restrictions on locations of PV system installation; 4) establishment of a recycling system of PV modules and 5) increasing added values of the PV industry. The strategy aims to achieve the PV power generation cost of 14 JPY/kWh by 2020 and 7 JPY/kWh by 2030 and to make Japan a global leader by creating new values through the enhancement of development on diversification of installation and development of systems for utilization, the areas where Japan can win the global competition.

NEDO continued R&D Projects titled "R&D for High Performance PV Generation System for the Future" and "R&D on Innovative Solar Cells" in FY 2014. Under "R&D for High Performance PV Generation System for the Future," research projects were conducted in the areas of crystalline silicon solar cells, thin-film silicon solar cells, CIS and other polycrystalline compound semiconductor solar cells, dye sensitized solar cells (DSCs) and organic solar cells (OPV) aiming at establishing technologies to reduce PV module cost.

Under the program of "R&D on Innovative Solar Cells," four projects continued; 1) post-silicon solar cells for ultra-high efficiencies; 2) thin film multi-junction novel solar cells with a highly-ordered structure; 3) thin-film full spectrum solar cells with low concentration ratios and 4) high-efficiency concentrating solar cells, a joint research of European Union (EU) and Japan as an exploratory research aiming at a cell conversion efficiency of 40 %. FY 2014 was the final year for these projects, and the results and achievements were reported in WCPEC-6, the 6th World Conference on Photovoltaic Energy Conversion held in November 2014 in Kyoto. It is expected that a number of research topics that have potential for further development will be included in the projects to be conducted under a new program, "Technological development for lowering PV power generation cost for high performance and high reliability photovoltaic power generation," starting from FY 2015.

The National Institute of Advanced Industrial Science and Technology (AIST) inaugurated "Fukushima Renewable Energy Institute (FREA)" in April 2014 in Koriyama City of Fukushima Prefecture as a part of reconstruction measures following the Great East Japan Earthquake. FREA introduced a commercial-scale pilot line of crystalline silicon solar cells and a field test site for PV and other sources of renewable energy. Technology development of PV and other sources of renewable energy including hydrogen energy and their application technology development will be promoted.

MEXT promotes "FUTURE PV Innovation Projects (FUTURE) (FY 2012 to FY 2016)," aiming at highly efficient silicon nano-wire solar cells with 30 % or higher conversion efficiency. Researchers moved the development site to FREA and started full-fledged research activities.

MEXT also conducts two basic R&D programs through the Japan Science and Technology Agency (JST): "Photoenergy Conversion Systems and Materials for the Next Generation Solar Cells" and "Creative Research for Clean Energy Generation using Solar Energy". Each program continued within twelve projects, mainly led by universities in order to achieve higher conversion efficiency and lower cost. Both programs are no longer accepting new projects.

Demonstration

NEDO conducted two demonstration projects: "Leading technological development for commercialization of organic PV (FY 2012 to FY 2014)," aiming at DSCs and OPVs in order to demonstrate those solar cells in the real environment and identify issues and "Demonstration project for diversifying PV applications (FY 2013 to FY 2016)" aiming at the extension of PV installation areas by examining installation technologies on agricultural land, slopes and water surfaces, etc. and by verifying power generation performance. NEDO additionally selected six projects for "Demonstration project for diversifying PV applications" in the area of high-value added technologies that utilize PV systems for additional functions or new application areas.

NEDO also started new 5-year programs following establishment of the "NEDO PV Challenge": "R&D to develop technology for operation and maintenance (O&M)" and "R&D to develop technology for recycling of PV systems" and solicited proposals.

Demonstration activities on practical applications of PV power generation are conducted in several demonstration projects aiming at realizing smart communities by METI or NEDO. A number of projects on smart communities are conducted home and abroad and a large number of PV systems are introduced in those demonstration projects. These projects are aiming at global market development by localization of technologies to meet the needs of different countries and regions. The following are major demonstration projects conducted in FY 2014:

- Demonstration of Next-generation Energy and Social Systems (FY 2010 to FY 2014): Yokohama City of Kanagawa Prefecture, Toyota City of Aichi Prefecture, Keihannna Science City of Kyoto Prefecture and Kitakyushu City of Fukuoka Prefecture;
- Demonstration Tests of Next-generation Energy Technologies (Project selected in FY 2014): Demonstration of power control system in Kashiwanoha Campus and surrounding areas, Kashiwa City, Chiba Prefecture, Technology demonstration on electricity supply system utilizing EVs and PHVs in Osaka Business Park, Osaka City, Osaka Prefecture, Demonstration of energy management for integrated fish processing site in Onagawa, Miyagi Prefecture, Technology demonstration aiming at establishing locally sharing system for thermal energy and electricity in an industrial park, Toyota City, Aichi Prefecture and Demand side PPS demonstration project for local production and consumption, Kazuno City, Akita Prefecture;
- Japan-U.S. Smart Grid Collaborative Demonstration Project (FY 2010 to FY 2014): New Mexico, USA;
- Demonstration Project for World-leading Remote Island Smart Grid (FY 2011 to FY 2015): Maui Island, Hawaii, USA;
- Smart Community Demonstration Project (FY 2011 to FY 2015): Lyon, France;
- Model Project for a Microgrid System Using Large-scale PV Power Generation and Related Technologies (FY 2012 to FY 2014): Neemrana, India;
- Smart Community Demonstration Project (FY 2011 to FY 2015): Gongqing City, Jiangxi Province, China;
- Smart Grid-related Technology Demonstration Project (FY 2011 to FY 2015): Malaga, Spain;
- Smart Community Demonstration Project in an industrial park (FY 2012 to FY 2017): Java Island, Indonesia;
- Smart Community Demonstration Project (FY 2013 to FY 2016): Manchester, UK.

INDUSTRY STATUS AND MARKET DEVELOPMENT

Japanese PV cell/ module manufacturers have been doing well in their business thanks to the rapid growth of the domestic PV market. Since the enhancement of production capacity by the Japanese PV manufacturers is limited and OEM supply agreements are a common practice for them, Chinese and other overseas PV manufacturers are increasing their shipment to the Japanese market. Meanwhile, some companies re-established their business toward enhancing their competitiveness. The manufacturers have been making efforts to increase their production capacity and supply volume while improving performance of their products. In the R&D activities, Panasonic and Sharp announced their achievement of over 25 % conversion efficiency of solar cells with back contact and hetero-junction technology. Some PV manufacturers are enhancing the downstream PV business such as EPC and power generation business in preparation for entering the O&M business and for the liberalization of electricity retailing in the future.

In the components and manufacturing equipment industry, pressures for lower prices are getting stronger against general-purpose components and manufacturing equipment, influenced by the continuously decreasing price of PV modules. As the profitability worsened due to intensifying price competitions, there is a stream of mergers and acquisitions (M&As) globally. Under such circumstances, some companies in Japan reconstructed their business, while others gained profits thanks to the increasing demand.

In the PV inverter industry, domestic demand has been significantly growing. In particular, manufacturers home and abroad have been increasing production volume or production capacity of medium- to large-capacity inverters. As the competitions over improvement of performance including both domestic and overseas manufacturers intensify, major inverter manufacturers started technology development to achieve higher conversion efficiency or launched new products using new power semiconductors such as SiC and GaN. At the same time, products with larger capacity are on the rise. Amid aggressive entries by Chinese and other overseas manufacturers into the Japanese market, Japanese manufacturers are also actively entering into overseas markets, resulting in the increase in M&As.

In the supporting structure industry, demand has been rapidly growing thanks to the increases in construction of non-residential PV systems. More overseas manufacturers are entering the Japanese market. Some Japanese manufacturers are enhancing their production capacity of supporting structures and brackets, while others established their overseas production bases in preparation for doing business in emerging markets in the future. Installation locations are getting more diverse, and development of new products and manufacturing processes has been advanced, including lightweight supporting structures with high corrosion resistance, as well as products for installation on soft ground.

In the industry of other BOS products, announcements on various large-capacity storage technologies are on the rise as part of technology development for grid stabilization, as the grid capacity issues have come to the surface. Some manufacturers released new products in compliance with the international standard, to achieve the compatibility of the products for overseas markets. On a product level, a large number of storage batteries for residential and commercial applications were announced, although they are installed mainly with the support of subsidy or other incentive programs. Under such circumstances, joint venture companies started a service to rent storage batteries at low cost. Equipment for the power generation monitoring service is also selling well, mainly for residential and other low-voltage PV systems.

In the housing industry, termination of the subsidy program for residential PV systems, reduction of FITs and an increase in consumption tax affected the residential PV market and the sale of

Fig. 3 - Shimizu Corporation headquarters building (Kyobashi, Chuo Ward, Tokyo). 150 kW Multicrystalline silicon PV module. 368 modules: 110 kW (by Sharp). Light-through thin-film silicon PV module 594 modules: 40 kW (by Sharp).

PV systems slowed down. Meanwhile, the sale of houses equipped with > 10 kW rooftop PV systems through efficient use of the roofs is strong. Manufacturers announced new products applicable to the gross FIT by the summer of 2014. In product proposals, combinations of a PV system as standard equipment with storage batteries and/or HEMS are actively proposed. The launch of smart houses by a major homebuilder was a major news item.

In the EPC business, demand for design and installation increased regardless of the scale. PV manufacturers are entering the EPC business. Established EPCs are actively starting the O&M business, aiming to provide one-stop services in the area of PV installation and utilization. Also, some companies are working on developing products to broaden the customer base with such products and services as delivery and installation of energy conservation equipment, sale of PV systems for farms and construction of floating PV power plants. Furthermore, other companies are making efforts to satisfy the customer needs by providing new added values through proposals for power generation business on leased roofs and paid maintenance service.

The power generation business has been going well with expanded investments in construction of PV power plants. A large number of PV projects eligible for 40 JPY/kWh approved before the emergence of grid connection issues or 36 JPY/kWh are under construction.

A number of MW-scale PV power plants as well as low-voltage and high-voltage PV systems started operation across Japan. A wide variety of companies from all different business sectors including domestic PV manufacturers, electric facility companies, electric utilities and related companies, construction companies, communications companies, gas companies, PV system installers and distributors, developers, funds, trading companies, as well as companies from overseas entered this business sector. Some companies conduct the power generation business through utilization of their own idle/unused land or leased land from public and private entities. Installation locations are increasingly varied. In addition to conventional PV systems on the ground, slopes or rooftops, some EPCs started installing floating PV systems on the water surface. As a new business model, "solar sharing" or PV power generation in farmland while continuing agricultural activities was introduced. Thanks partly to the enforcement of the Renewable Energy Act for agricultural, forestry and fishing villages, utilization of PV systems in agriculture is expanding.

In the finance industry, financing for renewable energy grew with the advancement of syndicate loans to finance MW-scale PV power plants. New loan programs for PV systems by reducing the screening period or improving the screening process were developed. Partnerships between local governments and financial institutions have been advanced. A local bank in Osaka Prefecture and Osaka City jointly established a fund (lending allocation) for the PV business.

REPUBLIC OF KOREA

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

DONGGUN LIM, KOREA NATIONAL UNIVERSITY OF TRANSPORTATION

Fig. 1 - PV test-bed (Chungcheong region), Jincheon-gun, Chungcheongbuk-do, Korea.

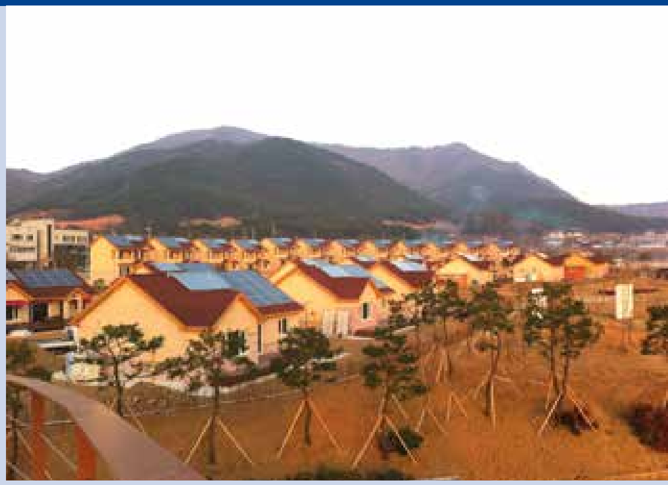

Fig. 2 - Wolgok renewable energy village, Gochang-gun, Jeollabuk-do, Korea.

GENERAL FRAMEWORK AND IMPLEMENTATION

On 14 January 2014, the Ministry of Trade, Industry and Energy (MOTIE) announced "The Second National Energy Basic Plan (2014-2035)." A 29 % reliance on nuclear power is lower than the target set by the previous government (41 %) but it is still 2,6 % higher than the current level (26,4 %). The government maintained the target for the supply of renewable energy at 11 % of the total primary energy supply (TPES), the same as the target in the first energy plan. They also decided to provide more than 15 % of the electricity generated through a dispersed type power source in 2035. Currently only 5 % of the electricity is generated through the dispersed power source.

On 19 September 2014, the MOTIE announced "The 4th basic plan for new and renewable energy (NRE)," which is the domestic/international resource development and the long-term (2014-2035) basic plan for the NRE. Visions and targets of the 4th basic plan for NRE are as follows. (1) By 2035, provide 11,0 % of the TPES with NRE, with a mean annual NRE growth rate of 6,2 % from 2014 to 2035 (mean annual growth rate of 0,7 % for TPES). (2) Reduce the relative importance of waste while developing PV and wind power as main energy resources, so that 13,4 % of total electric energy is supplied by NRE in 2035. In the target scenario, the PV energy share of NRE supply will account for 4,9 % in 2014, 12,9 % in 2025 and 14,1 % in 2035. (3) Focus on making NRE market base to shift from a government-led system to one that is driven by private partnerships. (4) Secure self-sustainability for sustainable growth through expansion into foreign markets.

The Korea's government has attempted to adopt two market-based regulations - the renewable portfolio standard (RPS) and the emission trading system (ETS). The RPS will require power producers with a capacity greater than 500 megawatts to generate 2 % of their total power from renewable energy sources and raise it to 10 % by 2022.

NATIONAL PROGRAMME

Korea has been making a strong effort to increase the renewable energy portion of the "national energy mix." The goal was announced in 2014. In the target scenario, the Korea's renewable energy share of primary energy supply will account for 5,0 % in 2020, 9,7 % in 2030, and 11 % in 2035. Currently the renewable energy is estimated to account for about 3,6 % of total primary energy consumption.

Korea's national PV programs are categorized into two major sub-programs; Infrastructure-building programs and PV deployment programs. Three main programs are operating under the infrastructure-building programs; certificate of PV system, solar energy test-bed, and overseas business supporting program. Additionally, five main programs are operating under the PV deployment programs; PV subsidy, home subsidy, regional dissemination, public building obligation, and RPS program.

(1) Certificate of PV System

The certification scheme for PV systems has been designed to guarantee the quality of systems manufactured or imported and enhance the reliability for users, thereby expanding the deployment of PV systems and helping create the foundation for growth. It focuses on promoting the commercialization of technologies that have already been developed and establishing the infrastructure for further deployment through performance evaluation and standardization.

(2) PV Test-bed

This program seeks to aid new companies struggling to commercialize their productions due to the lack of test-beds that are necessary for the production of the products (parts / materials) they have developed. To secure an advantageous position for these Korean companies in the rapidly expanding international market, it is mandatory to develop a systematic environment for testing.

(3) General Deployment Subsidy Program

The government provides subsidy for PV facility users to accelerate PV system deployment. The government supports up to 50 % of installation cost for PV systems with a capacity below 50 kW. In addition, the government supports 80 % of initial cost for special purpose demonstration and pre-planned systems in order to help the developed technologies and systems to advance into the market. In 2013, a total of 3,7 MW were installed by this program. Until the end of 2013, about 20 MW benefited from this program. Various grid-connected PV systems were installed in schools, public facilities, welfare facilities as well as universities.

(4) Home Subsidy Program

This program was launched in 2004 and the existing 100 000 solar-roof installations program was emerged into this project. The government will support a certain portion of total installation cost. Although 100 000 solar-roof deployment project was to install PV system in residential houses, the one million green homes plan focuses on a variety of resources such as PV, solar thermal, geo-thermal, and small wind. In addition, there are several types of homes which range from detached houses to apartment houses. Until the end of 2013, about 142 MW capacity and about 164 828 households were benefited from this program. In 2013, the number of households benefitting from the program was 25 409 and the installed capacity was about 20,6 MW.

(5) Regional Deployment Subsidy Program

In an effort to improve the energy supply & demand condition and to promote the development of regional economies by supplying region-specific PV systems that are friendly to the environment, the government has been promoting a regional deployment subsidy program designed to support various projects carried out by local government. The government supports up to 50 % of installation cost for PV systems owned and operated by local authorities. Until the end of 2013, about 71,3 MW benefited from this program. In 2013, the installed capacity was about 11,4 MW.

(6) Public Building Obligation Program

The new buildings of public institutions, the floor area of which exceeds 1 000 square meters, are obliged by law to use more than 12 % of their total expected energy use to install renewable energy resource system. Public institutions include state administrative bodies, local autonomous entities, and state-run companies. From 2015, the "Public Building Obligation Program" will be expanded, due to the recently amended act on NRE deployment promotion. The original 13 % by 2015, 14 % by 2016, 15 % by 2017, 16 % by 2018, 18 % by 2019, and 20 % by 2020 will be changed to 15 % by 2015, 18 % by 2016, 21 % by 2017, 24 % by 2018, 27 % by 2019, and 30 % by 2020.

(7) RPS Program

The RPS is a system that enforces power producers to supply a certain amount of the total power generation by new and renewable energy. The RPS replaced the FIT Scheme from 2012. Electricity utility business companies exceeding 500 MW are required to supply a total of 10 % of their electricity from NRE source by 2022, starting from 2 % in 2012. Total fourteen companies participated in RPS. PV has its own set-aside amount in the RPS, totalling 1,5 GW for the four years covering 2012~2015. The original plan was for five years, but the government decided to shorten the target year by one year, considering the difficult situation of Korean PV companies. In 2013, the record-breaking 409,4 MW was installed under this program.

Fig. 3 - 100 kW tracking-type PV power plant on the water surface at Hapcheon Dam, Hapcheon-gun, Gyunsangnam-do, Korea.

TABLE 1 – OBLIGATORILY ALLOCATED CAPACITY FOR PV (RPS PROGRAM IN KOREA)

YEAR	2012	2013	2014	2015
CAPACITY (MW)	220	330	470	480

A further amendment of the RPS scheme was made in 2014 to boost the small-scale installations and use of idle lands. The REC weighting factor scheme was changed from the originally region-dependent (5 different regions) scheme to the capacity-dependent scheme.

TABLE 2 – AMENDED REC WEIGHTING FACTOR SCHEME IN RPS

TYPE	SMALL SCALE (< 100 kW)	MEDIUM SCALE (100 kW ~ 3 MW)	LARGE SCALE (> 3 MW)
General	1,2	1,2+1,0	1,2+1,0+0,7
Building	1,5		1,5+1,0
On-water	1,5		

(8) Convergence and Integration Subsidy Program for NRE

This is a new NRE subsidy program started in 2013. A consortium led by either local authority or public enterprise with NRE manufacturing companies and private companies can apply for this subsidy program. This program is designed to help diffuse the NRE into socially disadvantaged and vulnerable regions and classes such as islands, remote areas (not connected to the grid), long-term rental housing district, etc. Local adaptability is one of the most important criteria, thus the convergence between various NRE resources (PV, wind, electricity and heat) and the complex between areas (home, business and public) are primarily considered to benefit from this program.

(9) Solar Lease Program

In 2013, MOTIE (through Korea Energy Management Corporation) introduced this new scheme to promote PV deployment and launched a few demo projects. The Solar Lease Program fully began in 2014. It is designed in such a way that the private companies take care of installations and after-services without government support, while consumers pay the PV rental fee. More than 2 000 households using 350 kWh or more electricity per month can benefit from this new program. Rental fee, rental period and Renewable Energy Point (REP) prices are properly set to motivate the participation of leasing companies and consumers.

TABLE 3 – SOLAR LEASE PROGRAM

	SUBSIDY PROGRAM	LEASE PROGRAM
Government Subsidy	Certain portion of the installation cost	No support
Consumer Expense	Certain portion of the installation cost	Rental fee
Leasing Company	Installation cost	Rental fee + REP sales income
Ownership	Household	Leasing company (Transfer of ownership to consumers after the contract) period)

R&D, D

The annual average growth of PV R&D budget for the period of 2009-2013 was 8,7 %, which was similar to that in other sectors of national R&D. However, after peaking in 2011, the PV R&D budget started to decrease slightly each year (annual average decrease of 2,7 %) due partly to the recession of the worldwide PV market. The government budget in 2013 for PV R&D was 213,1 BKRW. The program mostly consists of industry-oriented research works in PV area. For the short-term commercialization, many projects have been implemented with the subjects of polycrystalline Si, Si ingot, crystalline silicon solar cells, CIGS thin film solar cells, solar modules, and PV systems. For the long-term and innovative goal, many projects have been implemented in the area of quantum dot, organic, and dye-sensitized solar cells.

TABLE 4 – CAPACITY OF THE PV PRODUCTION CHAIN IN 2014

POLY-SI (TON)	INGOT (GW)	WAFERS (GW)	CELLS (GW)	MODULES (GW)
70 000	3,45	2,51	1,63	3,63

INDUSTRY AND MARKET DEVELOPMENT

The supply chain of crystalline silicon PV in Korea is complete, from feedstock materials to system installations.

Production of Feedstock and Wafer: OCI achieved its total production capacity of poly-silicon feedstock up to 42 000 tons. Woongjin Energy is operating a 1 GW silicon ingot capacity plant. Nexolon has a capacity of 1,35 GW in silicon wafers.

Production of Photovoltaic Cells and Modules: Hyundai Heavy Industry has a capacity of 600 MW and 600 MW in the c-Si solar cells and modules, respectively. LG Electronics has their own capacity of 500 MW and 5 030 MW in the c-Si solar cells and modules, respectively. Shinsung Solar Energy has a capacity of 350 MW and 150 MW in the c-Si solar cells and modules, respectively. Samsung SDI decided to stop the production of CIGS thin film PV modules.

Since the largest annual installation of 276 MW in 2008, the PV installation during the following three years became stagnant, with an installation of about 156 MW in 2011. This was mainly due to the limited FIT scheme which played an important role in the early stage Korean PV market expansion. However, a new installation of 230 MW was recorded in 2012 due mainly to the newly introduced RPS scheme with mandated PV requirement. The RPS scheme was again the main driver for PV installation in 2013, and a remarkable size of 531 MW installed was recorded. At the end of 2013, the total installed PV capacity was about 1 555,0 MW, among them the grid-connected centralized system accounted for 82 % of the total cumulative installed power. The grid-connected distributed system amounted to 18 % of the total cumulative installed PV power. On the other hand the share of off-grid non-domestic and domestic systems has continued to decrease to less than 1 percent of the total cumulative installed PV power. The total capacity of 1 555,0 MW corresponds to 1,79 % of total electricity generation capacity of about 86,969 GW, and the installed PV power of 531 MW in 2013 accounts for 10,3 % of total power generation capacity newly installed in 2013.

MALAYSIA

PV TECHNOLOGY STATUS AND PROSPECTS

DATO' DR NADZRI BIN YAHAYA, MINISTRY OF ENERGY, GREEN TECHNOLOGY AND WATER
CATHERINE RIDU, SUSTAINABLE ENERGY DEVELOPMENT AUTHORITY MALAYSIA

Fig. 1 - Lot E, KL Sentral (168kWp), Platinum rated "Green Building" (Photo: Pekat Teknologi Sdn Bhd).

GENERAL FRAMEWORK AND IMPLEMENTATION

The year 2014 marked the third anniversary of the feed-in tariff (FiT) programme in Malaysia. The FiT was implemented on 1 December 2011 and Sustainable Energy Development Authority (SEDA) Malaysia is the implementing agency for this programme. The FiT is framed under the Renewable Energy Act 2011 whilst the establishment of SEDA is under the SEDA Act 2011. Aside from SEDA, the main actors involved in the FiT framework are the Ministry of Energy, Green Technology and Water, the Energy Commission, the distribution licensees, RE developers, and the RE service providers.

FiT Programme: In Malaysia, the FiT programme is applicable for the entire country except for the state of Sarawak. The FiT portfolio covers five types of renewable resources; they are biomass, biogas, small hydro, PV, and geothermal. Of the four renewable resources (quota for Geothermal will only be available in 2017), PV has the fastest take up rate due to the ease of project implementation. As of end of December 2014, SEDA Malaysia approved a total of 4 498 applications (252,3 MW) for PV and these applications constituted 97 % of the total applications approved under the FiT programme. More importantly, in 2014 a new PV category was introduced, the new category was for community. The criteria for community included public and non-profit schools and kindergartens, not-for-profit welfare homes, and places of worship (such as temples, mosques, churches).

Degression rates: In Malaysia, the FiT has been designed with the incorporation of degression rates. On 12 March 2014, the degression rates were decreased from 20 % to 10 % for installed PV capacities greater than 24 kW. On 17 December 2014, the degression rates for PV were revised again; this time the degression rate for installed PV capacities above 24 kW to 1 MW was increased from 10 % to 15 % and above 1 MW and up to 30 MW, the degression rate was increased from 10 % to 20 %. Additionally, the degression rate for bonus criteria for use of PV as installation in building or building structures (i.e. retrofitted application) and use of PV as building materials (i.e. BIPV application) was increased from 10 % to 20 %.

FiT Funding: The programme is funded by electricity consumers via the 1,6 % contribution imposed on electricity bills (domestic consumers with usage not more than 300 kWh per month are exempted from the collection) and this amounts to approximately 633 MMYR per year. The fund is collected by three distribution licensees; two of them are located in Peninsular Malaysia and one in the state of Sabah. Due to the constrained RE fund, the FiT is designed with a cap for each renewable resource in order to manage the cashflow.

NATIONAL PROGRAMME & MARKET DEVELOPMENT

The market development for grid-connected PV systems hinges mainly on the FiT programme. In 2014 alone, a total of 1 798 applications for PV were approved with a total capacity of 43 MW. The breakdown of approved applications is as follows: individuals (1 617 applications 14 MW), community (91 applications 2 MW), and non-individuals (90 applications 28 MW). As at 31 December 2014, a cumulative total of 160 MW of PV projects were operational of which the 29 MW were for the individuals and 131 MW were for the non-individual PV projects. This translated to 2 773 individuals and 195 non-individuals feed-in approval holders. The installed PV capacity in 2014 alone was 86,73 MW; 13,46 MW from individuals and 73,27 MW from non-individuals. The market for off-grid PV systems is largely funded by the government to address rural electrification. Up-to-date information on PV quotas, FiT rates and operational capacity can be accessed via www.seda.gov.my.

INDUSTRY DEVELOPMENT

On the PV manufacturing front, Malaysia is a significant PV producer (after China and Taiwan). In 2014, the total metallurgical grade silicon (MGS) and polysilicon manufacturing nameplate capacity was estimated to be 53,4 tonnes with employment of 840. For wafer, solar cells and PV modules manufacturing, the total estimated nameplate capacity was 6 177 MW with employment of 10 969. Figure 2 shows the statistics on major PV manufacturing in Malaysia; the statistics are classified under 3 categories.

NO.	COMPANY NAME	CAPACITY	EMPLOYMENT
Metallurgical Grade Silicon / Polysilicon			
1	Elpion Silicon	33,4 kilo tonne	160
2	Tokuyama	20 kilo tonne	680
TOTAL		53,4 kilo tonne	840
Wafer & Solar Cells			
1	AUO-SunPower	700 MW	2 145
2	MEMC	1 000 MW	676
3	Panasonic Energy	300 MW	969
4	Hanwha Q-Cells	1 000 MW	860
5	TS Solartech	400 MW	123
6	Comtec Solar International	Under construction[1]	139
7	Tetrasun (First Solar)	Under construction[2]	135
TOTAL		**3 400 MW**	**5 047**
PV Modules			
1	First Solar	1 690	3 700
2	Flextronics	577	800
3	Panasonic Energy	300	1 207
4	Malaysian Solar Resource	200	120
5	SolarTIF	5	40
6	PV Hi-Tech Solar	5	15
7	Endau XT	Under construction[3]	40
TOTAL		**2 777**	**5 922**

Fig. 2 - Statistics on Major PV Manufacturing in Malaysia (Source: Malaysian Industry-Government Group for High Technology).

Within the PV industry, there were over 140 PV service providers active in the market in 2014. The list of these registered PV service providers for 2015 can be found in http://www.seda.gov.my/?omaneg=00010100000001010101000100001000000000000000000000&s=4392.

R&D, D

R&D activities in PV are largely under the purview of the Ministry of Science, Technology and Innovation. Figure 3 shows the list of universities and research institute and their research area involvement in solar PV.

UNIVERSITY/ RESEARCH INSTITUTE	AREAS OF R&D
UNIVERSITI TEKNOLOGI MARA	Performance of Selected Stand-Alone PV Systems
	Impact of Ambient Parameters on PV Systems Output in Equatorial Climate
	Stabilisation Period and Assessment of Design Techniques for Thin-Film PV modules under Malaysian Weather
	Sizing of Stand-Alone PV systems using ANN
	Development of SCADA for Application on PV Systems
	http://www.uitm.edu.my/index.php/en/

[1] 2015 Production capacity 1 000 MW, employment 1 300. *[2] 2015 Production capacity 100 MW* *[3] 2015 Production capacity 75 MW.*

UNIVERSITY OF MALAYA POWER ENERGY DEDICATED ADVANCED CENTRE	Design of Grid-connected PV inverter 3-10kW
	Inverter-performance testing
	PV integration and monitoring
	Photocells testing
	http://www.umpedac.um.edu.my/
SOLAR ENERGY RESEARCH INSTITUTE, UNIVERSITI KEBANGSAAN MALAYSIA	Advanced Solar Cell (Thin Film Silicon, CdTe, CIGS and organic solar cell including dye-sensitized solar cell)
	Solar Hydrogen Production System
	Grid Connected Photovoltaic
	Solar PV Hybrid Systems
	Solar Power Regenerative Electrolyzer/Fuel Cell System
	Charge controllers
	Inverters
	Power Quality
	Impact study on PV technology to the grid
	http://www.ukm.my/seri/?lang=en
TNB RESEARCH	PV system performance - impact from local weather (cloud effect)
	Solar PV resource assessment and forecasting
	PV performance and reliability
	http://www.tnbr.com.my/tnbr/
UNIVERSITI TEKNOLOGI PETRONAS	CPV
	PV performance
	http://www.utp.edu.my/
UNIVERSITI TEKNOLOGI MALAYSIA	Study of partial shading problem for PV in tropical countries
	Development of MPPT for PV inverters using soft computing methods
	Design and construction of PV charging station for Electric Vehicle
	Monitoring of performance of various PV technologies under tropical environment
	Development of new "inverter efficiency index" for PV inverters for tropical regions
	Partial shading solution based on hardware energy harvesting
	http://www.utm.my/
UNITEN POWER ENGINEERING CENTRE	Grid connection issues of PV plants
	http://www.uniten.edu.my/research/pec/Pages/Introduction.aspx
UNIVERSITI TUNKU ABDUL RAHMAN	CPV
	http://www.utar.edu.my/main.jsp
UNIVERSITI MALAYSIA PERLIS	PV application performance
	http://www.unimap.edu.my/
UNIVERSITI MALAYSIA TRENGGANU	organic solar cells
	solar thermal collector
	http://www.umt.edu.my/index.php?go=
UNIVERSITI SAINS MALAYSIA	PV cells
	http://www.usm.my/index.php/en/

Fig. 3 - Solar PV Researches by Local Universities and Research Institute.

MEXICO

PV TECHNOLOGY: STATUS AND PROSPECTS IN MEXICO

JAIME AGREDANO, JORGE M. HUACUZ
ELECTRICAL RESEARCH INSTITUTE

Fig. 1 - 324 kWp PV system installed in the parking lot of a snack factory in Merida Yucatan (Photo: CONERMEX).

GENERAL FRAMEWORK AND IMPLEMENTATION

The policy framework for PV in Mexico, as well as for other renewables, entered a process of transition after the Mexican Constitutional Energy Reform of 2013 was enacted. A number of new regulations expected to have impacts on the future development of the local PV market are already in the making; while already existing ones, such as Self Generation and Net Metering, have either been abolished or are being adapted to the new policy framework.

The Model Contract for the interconnection of medium voltage renewable generation of less than 500 kW in capacity for collective use, such as in condominiums or commercial malls, has already been enacted. However, the regulation establishing the technical requirements for grid interconnection of PV power plants, planned to be issued in September this year, was put on hold until the new rules for the operation of the national electricity system are approved. The issue of grid interconnection of intermittent energy sources, of high concern to the newly created System Operator, is currently been addressed in view of the growing number of permits approved by the Energy Regulatory Commission to private investors for the construction of PV power plants, now accounting to over 1,2 GW.

NATIONAL PROGRAMME

There is still no national program for the promotion of PV in Mexico. Nonetheless, the Planning Scenario of the 2014-2028 Renewable Energy Prospective of the Energy Secretariat, SENER, establishes a target of 1,9 GW of PV capacity installed by the year 2024 and 3,4 GW by the year 2028, as the contribution of PV generation to meet the country's clean energy goals. Current activities in this direction continue with the installation of PV-powered micro-grids in remote rural communities, the majority of 50 kWp capacity each, and some of them with capacity exceeding the 100 kWp, of which the national electric utility CFE installed 25 systems in 2014. CFE also carries out a pilot program to install 1 500 PV rooftops, 1 kWp each, for self-electricity supply at homes of the electric union workers. If successful in social and financial terms, this program may be extended to cover a high percentage of the union workers households in the whole country. In a similar fashion, CFE is active in promoting the installation of urban solar farms in the modality of collective use and other government agencies are promoting the installation of PV systems in the municipality setting. Such is the case of a 500 kWp system in the municipality of Juchitan in the state of Oaxaca, amidst of over 2 GW of wind farms.

R&D, D

In a move to speed up technology development and market penetration, the Government of Mexico instrumented a strategy this year based on the creation of virtual Centers of Innovation for renewable energy technologies. The Center of Innovation for solar energy (CEMIE-SOL) networks 57 universities/research institutions and 10 private firms, coordinated by the Renewable Energy Institute of the National Autonomous University UNAM. A number of PV projects have been approved for the CEMIE-SOL associates to carry out during its launching phase.

INDUSTRY AND MARKET DEVELOPMENT

The Mexican PV market is still small, but promising. It is reported that PV installed capacity in 2014 reached 64 MW, which brings the total cumulative capacity to 176 MW by the end of this year. The largest PV power plant in Mexico (39 MW) installed at the tip of the Baja California peninsula was inaugurated in early 2014, along with another 17 MW PV plant in the state of Durango. The state of Coahuila witnessed the beginning of construction of another 17 MW PV power plant at the end of 2014. In the area of small capacity roof tops for net metering, a total aggregate of over 4 100 systems were already connected to the grid by the end of 2014. According to a recent press release, the growth of the Mexican PV market has attracted a local investor to build a 500 MW per year PV module manufacturing plant to start production by the end of 2015. No further details on this project have been released.

THE NETHERLANDS

PV TECHNOLOGY STATUS AND PROSPECTS

OTTO BERNSEN, RVO, ENERGY INNOVATION

Fig. 1 - Crystalline solar module design, back contact TU Delft (Photo: Hans Roggen).

GENERAL FRAMEWORK

The Dutch PV market remained strong in 2014, breaching the bench mark of 1 GWp accumulated installed capacity somewhere in September 2014. The expectation of the total amount for 2014 is again a substantial growth of the yearly installed capacity. At this moment the estimates vary widely. In May 2015, the first official figures come in from the Central Bureau of Statistics. The national growth of the photovoltaic market is steadily progressing over the last years but still modest in comparison to the Netherlands neighbouring countries of Belgium and Germany. The main drivers of this development are really a combination of circumstances; the lower and now stabilizing prices of solar panels, the net metering scheme which is guaranteed until 2020, the various tax reduction schemes, the quality of installation and monitoring programs, the low interest rates which turn solar into a viable alternative for saving money, the now mandatory energy label (EPC) for houses for sale and probably the copycat behaviour of a much larger market segment of households and companies following the early adopters. For larger scale systems (up to and over 15 kWp) there exists a capped, exploitation subsidy scheme (SDE) since wholesale electricity prices are relative low. As of 2014 there is also a lowered tax regime for local energy cooperatives. The Netherlands have a policy goal of reaching 16 % of renewable energy source by 2020 without specific targets for individual technologies. The main question is when will this steep curve, charted since 2009, flatten out and what will be the main constraint for further development? More than 90 % of this market consists of private households with grid connected, roof top installations. Over the last two years these households invested 900 MEUR in solar panels (Stichting Monitoring Zonnestroom, 2014). There are almost no off-grid installations in the densely populated Netherlands, except for example, specialised systems in the transport sector.

NATIONAL PROGRAMMES

At a national level, there are government programs for market introduction such as the DEN (Sustainable Energy Netherlands) program which is not exclusively for solar and is accompanied by tax incentives (i.e., VAMIL, EIA and KIA), the SDE plus (which is an exploitation subsidy for larger systems up and above 15 kWp) and the net metering scheme for households and smaller systems. A tax reduction scheme exists for local energy cooperative with members living nearby and similar postal codes, the so called "postcoderoos." Apart from these instruments, so called "Green Deals" can still be closed concerning public-private partnership that contribute to the 2020 energy goals. The innovation is driven by a public-private partnership the TKI Solar (Top Knowledge Institute) which focuses on industry driven technology development and advices policy makers. Fundamental research is mainly executed by NWO (the Dutch National Science Foundation) and their branch DIFFER which focuses specifically on fusion and solar fuels. In a SER (Social Economic Board) national agreement on energy saving and renewable energy sources a limited role was foreseen for solar in comparison to the current growth rates.

RESEARCH AND DEVELOPMENT ACTIVITIES

In 2014, the TKI Solar allocated approx. 13 MEUR public funding to development projects, including a small amount directly allocated by the Ministry to ECN (the Energy Research Centre of the Netherlands). More data is gathered from all Dutch research efforts and presented later this year.

The TKI Solar focused on applied research in three areas. The key research partnerships in these three focus areas are:

- SEAC (Solar Energy Application Centre; an initiative of ECN and TNO) for systems & applications;
- Silicon Competence Centre (ECN, FOM-Amolf, TUD-Dimes) for wafer-based silicon PV technologies;
- Solliance (TNO, ECN, TU/e, Holst Centre, IMEC and FZ Jülich) for thin-film technologies.

Scientific research into solar technologies, production and applications is regionally dispersed in the Netherlands over various universities including Utrecht, Leiden, Amsterdam, Delft, Nijmegen, Eindhoven and the institutes already mentioned. Their academic track record is excellent and many Dutch patents have become mainstream in the international industry. Several academies offer educational programmes in renewable energy or industrial design including solar technologies and are involved in demonstration projects, installation practises and large scale renovation projects.

INDUSTRY STATUS

In 2014, a further consolidation took place in the industry and margins that have been under pressure started to improve again. Also, some hard hit production companies such as Solland Solar and Hyet Solar have changed ownership in previous years and are gearing up again. Equipment manufacturers of solar production lines form a major part of the Dutch value chain and are closely related to the extensive semiconductor industry in the Netherlands. Exports of machinery to Asia, Europe and the Middle East has picked up in 2014. In this dynamic market chemical concern DSM has jumped to the status of market leader for anti-reflective coatings and packaging. There is a noticeable increase in jobs in renewables in general and also in solar. The academic job pool is the most stable over the years and the installation branch most vulnerable to market fluctuations.

Fig. 2 - Roof top solar panels medium sized system, the Netherlands.

DEMONSTRATION PROJECTS

The phase of demonstration projects of PV modules is all but over in the Netherlands. A new national subsidy scheme (DEI) has been devised for demonstration projects very close to the market in which novel applications for solar technology can be partly financed with public funds.

The regional funds of the Dutch provinces also offer opportunities for large scale funding very close to the market or already with proven technology. These regional and revolving funds are not dedicated to solar but to energy efficiency and renewable energy sources in a broader sense and together these provincial funds add up to almost 900 MEUR.

Apart from technological demonstrations of solar technology the integration of PV into the grid is a recurring theme in many so called "smart grid" or "smart city" demonstration projects. The Netherlands do not have a national and urgent problem with PV grid integration, but local problems may arise, especially in the outer areas of the national grid and where there is a concentration of PV installations. The sector has been slow to pick up the lessons from other countries in this respect and still few projects are dedicated to these problems.

IMPLEMENTATION AND MARKET DEVELOPMENT

From 2008-2009 the Dutch government introduced a new FIT program with a financial cap since it was directly funded out of the public spending and not by higher energy tariffs. This revitalized the market until the sudden end of the program in 2010. The main goal of the innovation program IPZ was to prepare the Dutch market and installation branch for higher volumes to come. Since 2011, the main remaining incentive in the Netherlands is a net metering scheme for small residential systems up for own use. Together with on average falling prices of 50 %, this triggered market growth in 2012 with 220 MW installed mainly on residential rooftops and resulting in a total accumulated installed capacity of 365 MW. The average module price of 2,5 EUR/ kWp resulted in return on investments under ten years given optimal installation circumstances (source Stichting Monitoring, 2014). In 2013 an additional 360 MW were installed and the total capacity at the end of the year reached 722 MW.

As mentioned before, medium sized systems are increasing in the Netherlands especially on public buildings, business parks, holiday resorts and in the agricultural sector. The average system size in the SDE+ scheme in 2014 is 200 kWp. The main incentive for households is now net metering for own consumption which was before limited to 5 000 kWh for each connection but as of the first of January 2014 the upper boundary was removed. This net metering scheme is guaranteed until 2020 at least. Much public debate centers on the prolongation of this incentive and the socialization of external costs. Since in the Netherlands the obligation to register mounted solar panels is reluctantly obeyed, and the out roll of smart meters is only at its initial stages, the estimation of the amount installed capacity each year is delayed until the first official figures are published by the CBS. Under the assumption that the roof top installation will continue to grow at a similar rate as in 2013 and the larger system in the SDE scheme will increase, then an installed capacity of 386 MW is a conservative estimation; bringing the total accumulated capacity just above 1,1 GW in 2014. Official figures will be presented in May 2015 by the CBS after which adjustments can still regularly occur.

Dutch Installed Capacity Yearly and Accumulated MWp

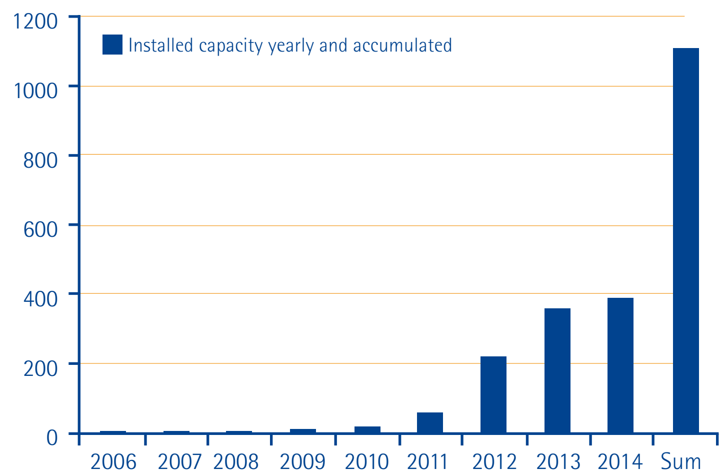

Fig. 3 - Conservative estimation for installed capacity in 2014 MWp (source CBS Statline until 2013).

However, the production of solar power will be somewhat higher than in previous years since 2014 was exceptionally sunny. Some 4 % more irradiation is predicted by the Stichting Monitoring (2014) based on meteorological reports.

NORWAY

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

BJØRN THORUD, THE RESEARCH COUNCIL OF NORWAY

Fig. 1 - At Asko Vestby, a 370 kWp system was installed during the summer of 2014. This is the largest system in Norway, and the system is built solely for self-consumption. The power is delivered to a refrigerated storage (Photo: Multiconsult).

GENERAL FRAMEWORK

For decades, hydro power has been the main source of electricity generation, covering roughly more than 99 % of the Norwegian demand. Since the annual precipitation varies from year to year, and thereby also the power production, the Norwegian electricity system is highly integrated in the Nordic power market. Despite a net population increase in recent years, the power consumption is relatively stable, due to energy efficiency measures and reduced activity in the metal industry. Focus on environmental issues, security of supply, etc., has lead to an increased interest in renewable electricity production, such as wind and small hydro, but also in bioenergy and heat pumps as substitutes to electric space heating.

2014 was the third year of operation of the common Swedish-Norwegian electricity certificate market. The el-certificate market is a technology neutral, market-based support scheme for power generation from renewable energy sources. The market is designed to increase power generation from renewable energy sources in the two countries with a total of 26,4 TWh/year before 2020. The total power production in Norway in 2014 was 141,6 TWh, whereas only 125,9 TWh was consumed. By the end of Q4 in 2014, a total of 814 GWh of new power production was installed and approved for the electricity certificate market.

Enova SF, a public agency owned by the Ministry of Petroleum and Energy, was established in 2001 as an instrument to improve energy system efficiency and increase renewable energy production. Enova offers support schemes in the areas in which the greatest effect in the form of saved, converted, or generated clean energy can be achieved. Since the introduction of the el-certificate market, Enova only supports new power generation technologies, i.e. demonstration projects including immature technologies or technologies new to the Norwegian market. Renewable power generation from wind, hydro, PV, etc., will receive support from the el-certificate market. Some of the projects that Enova supported under the demonstration support program in 2014 were so-called "plus energy buildings" or "Zero Emission Buildings" in which the use of PV was a central part of the concept.

Environmental qualities or aspects seem to become an increasingly important market parameter for actors in the Norwegian building and construction sector. Enova has a strong focus on energy efficient buildings and in 2014 a new support for buildings with energy efficiency requirements beyond "passive standard" was released. By the end of the year, Enova stated that they would launch a support-system for residential PV-systems by the beginning of 2015.

The entrance fee for the participation in the el-certificate market is minimum 15 000 NOK and this amount is generally too high for owners of small PV-systems. Thus the Norwegian market remains without any particular public support schemes for PV systems. Thus, the main market for PV in Norway continues to be related to off-grid applications in addition to a few grid connected systems on buildings. A fair exception is the municipality of Oslo, who has announced that they will include PV-systems in their environmental technology support program by 2014.

NATIONAL PROGRAMME

Currently, Norway has no defined goals when it comes to implementation of PV technology. The incentive scheme that was communicated to the press by the end of 2014 only covers private households from the beginning of 2015. The support is limited to 10 000 NOK plus 1 250 NOK/kWp, up to a maximal capacity of 15 kWp. In 2014 Enova granted support to a total of 7 projects where PV was part of the environmental friendly energy concept.

PV continues to be an important topic for government funded research and development, and it is one out of 6 research areas which is emphasized by the Norwegian National Research Strategy, Energi21.

In December 2014, the municipality of Oslo launched a support scheme for PV systems on residential buildings in Oslo. The municipality will give a financial support limited to 40 % of the investment cost for systems on buildings with less than four apartments. The budget of the program is limited to 2 MNOK.

RESEARCH AND DEVELOPMENT

The Norwegian Research Council (NRC) funds industry oriented research, basic research and socio-economic research within the energy field, including renewable energy sources.

The total NRC-funds for PV-related R&D projects were appr. 76 MNOK (8,6 MEUR) for 2014. Most of the R&D projects are focused on the silicon chain from feedstock to solar cells research, but also related to fundamental material research and production processes. A growing supply business is also filling out the portfolio of projects.

The Norwegian Research Centre for Solar Cell Technology has completed its fifth year of operation (www.solarunited.no). Leading national research groups and industrial partners in PV technology participate in the centre. The research activities are grouped into six work packages, five of which involve competence-building: Mono- and multi-crystalline silicon, next-generation modeling tools for crystallizing silicon, solar-cell and solar panel technology, new materials for next-generation solar cells, and new characterization methods. The sixth is a value-chain project that will apply the findings of the other five work packages to produce working solar cell prototypes. The total Centre budget is 374 MNOK over the duration of the Centre (2009–2017).

There are six main R&D groups in the universities and institute sector of Norway:

- IFE (Institute for Energy Technology): Focuses on polysilicon production, silicon solar cell design, production and characterization and investigations of the effect of material quality upon solar cell performance. A solar cell laboratory at IFE contains a dedicated line for producing silicon-based solar cells. Additionally, a characterization laboratory and a polysilicon production lab, featuring three different furnace technologies have been established.
- University of Oslo (UiO), Faculty of Mathematics and Natural Sciences: The Centre for Materials Science and Nanotechology (SMN) is coordinating the activities within materials science, micro- and nanotechnology.
- NTNU (Norwegian University of Science and Technology) Trondheim: Focuses on production and characterization of solar grade silicon.
- SINTEF Trondheim and Oslo: Focuses on silicon feedstock, refining, crystallisation, sawing and material characterisation.
- NMBU (Norwegian University of Life Sciences): Focuses on fundamental studies of materials for PV applications and assessment of PV performance in high-latitude environments.
- Agder University (UiA): Research on silicon feedstock with Elkem. Renewable Energy demonstration facility with PV systems, solar heat collectors, heat pump, heat storage and electrolyser for research on hybrid systems.
- Norut (Northern Research Institute Narvik): Development of silicon based solar cells and includes the whole production chain from casting of silicon to solar cell modules. Testing of PV systems under arctic conditions.

INDUSTRY AND MARKET DEVELOPMENT

The Norwegian PV industry is still going strong, despite the tough period it has gone through. Several companies scaled down their activities during this period, but in 2014 they started to ramp up the production again.

Renewable Energy Corporation (REC) REC – Renewable Energy Corporation, is still noted on the Oslo stock exchange with headquarter in Norway. However, there is no production left in Norway. The REC company was split into two companies in 2013; REC Silicon and REC Solar. The production facility of REC Silicon is in the USA, while REC Solar has its factory in Singapore and main office for the systems division in Münich. In 2014 Elkem Solar offered to purchase REC Solar, and this was approved by the general assembly in January 2015.

Elkem Solar is based on the so called metallurgical route; Elkem Solar has invested in a silicon production plant in Kristiansand in southern Norway. With a design capacity of 6 000 tons of solar grade silicon per year, the plant started to ramp up production during 2009. The production technology is now tested and verified, and according to Elkem, it enables the company to produce silicon with just 1/4 of the energy consumption compared with traditional technology. Following a standstill during 2012 and 2013, Elkem Solar started up its production of solar grade silicon in 2014. Through the year the production has been ramped up and it now runs at 100 % of the capacity. Furthermore, Elkem Solar has plans to expand the capacity to 7 500 t/y.

NorSun AS manufactures high performance monocrystalline silicon ingots and wafers at its plant in Årdal in the western part of Norway. Annual production capacity at the company's facility in Norway exceeds 300 MWp. In 2014, market conditions improved and the factory was running at full capacity while a number of cost reduction improvements were implemented.

Fig. 2 - Omsorgsbygg Oslo installed a 130 kWp system at Økern Sykehjem (a home for elderly people). The power from the system is for self-consumption (Photo: Fusen AS).

Norwegian Crystals was established in the former REC Wafer production facility for mono crystals in Glomfjord. The capacity of the factory is approximately 200 MW/y and is still ramping up. At end of the year they were running at 100 % capacity, and there are plans to expand the production capacity to 350 MW. The main product of Norwegian Crystals is mono crystalline silicon blocks for the international market, but they can also deliver high efficiency modules.

Scatec Solar is a provider of utility scale solar (PV) power plants and an independent solar power producer (IPP). The company develops, builds, owns and operates solar power plants and delivers power from 220 MW in the Czech Republic, South Africa and Rwanda. The Company has its head office in Oslo, but operates in the international market. In 2014, Scatec Solar went public and it is now noted on the Norwegian Stock Exchange.

IMPLEMENTATION

Until 2014 the Norwegian PV market was mostly driven by off-grid applications, primarily the leisure market (cabins, leisure boats) and to a more limited extent, the professional market (mostly lighthouses/lanterns along the coast and telecommunication systems). However, the market for grid connected PV systems experienced a nearly 10-fold increase in the number of kWp installed from 2013 to 2014. Nevertheless, the market remains very small with a total volume of approximately 1,4 MWp. The off-grid market is stable at 0,5 MW. The market for grid-connected systems is mainly driven by actors seeking high energy performance of their buildings or high rankings in environmental classification systems such as BREEAM-NOR. The energy classification of buildings, which is administrated by the Norwegian Water Resources and Energy Directorate, also serves as a motivation.

Several of the systems that were installed in 2014 received attention from the media and among them were Powerhouse Kjørbo (310 kWp), Økern Sykehjem (130 kWp) and Asko Vestby (370 kWp). By the end of the year solar power received additional attention, when the Municipality of Oslo launched an investment support for PV systems addressed to private households.

PORTUGAL

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

JOÃO MACIEL, PEDRO SASSETTI PAES AND CATARINA CALHAU, EDP

Fig. 1 - Capwatt – Martim Longo HCPV Plant – 2 MW (photo: Pedro Lobo).

Fig. 3 - EDP Inovação – Sunlab Project.

Fig. 2 - EDP Renováveis – Estarreja PV Plant – 2 MW.

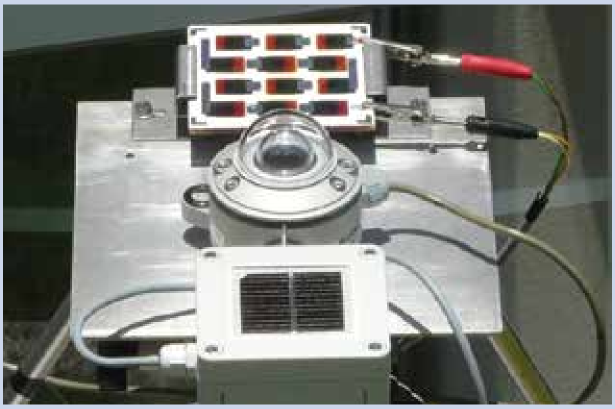

Fig. 4 - Solar Tiles national programme QREN project: testing devices at LNEG.

GENERAL FRAMEWORK AND IMPLEMENTATION

In the scope of the Renewable Energy Action Plan – REAP (2009/28/EC Directive), Portugal's target for the share of energy from renewable sources in gross final consumption is 31 % by 2020. To this end, the goal established for the electric sector is a total renewable capacity of 15 800 MW, which makes up about 60 % of total installed capacity. Solar energy should contribute to this target with 720 MW.

In 2014, 107 MW of PV were added, taking total PV capacity to 392 MW. Most of this capacity, about 88 MW, was connected under the Independent Power Producer framework, aimed at central PV plants. This capacity includes 5 MW of CPV technology which is an interesting development for this technology in Portugal.

Due to the drastic cut applied to the Feed-in-Tariff (FiT) under the scope of the Micro and Mini-generation schemes, an expected decline in new micro and mini installations was confirmed. Both these schemes were revoked in the end of 2014, due to a new framework that will enter into force in January 2015.

NATIONAL PROGRAMME

During 2014, three major programs concerning grid-tied PV systems were in place: The Independent Power Producer, the Micro-generation scheme and the Mini-generation scheme, all of which foresee a FiT, applicable to the total production.

However, the Independent Power Producer framework has been officially suspended since 2012. According to the REAP published in 2013, this suspension will be re-assessed in 2015. Yet, many new PV systems in 2014 were connected in the scope of this framework, all of which concern tenders that took place in 2009 and 2010.
The Micro-generation scheme is aimed at systems up to 5,75 kW (or 11,04 kW for condominiums). Since this initiative was launched, in 2008, a total of 93 MW has been installed. However, in 2014 only 3 MW was added, due to the severe cut in the FiT. In 2014, new micro-generators were awarded a FiT of 66 EUR/MWh in the first eight years of operation and 145 EUR/MWh in the following seven years.
The Mini-generation scheme, aimed at systems up to 250 kW, was launched in 2011. Since then, about 61 MW of PV systems have been installed. The FiT is based on a bidding system with an upper limit, which has gone down from 250 EUR/MWh to the current 106 EUR/MWh, valid for 15 years.

TABLE 1 – 2014 PV FRAMEWORK

LEGAL FRAMEWORK	INDEPENDENT POWER PRODUCER (DECREE-LAW 312/2001 AND 225/2007) SCHEME CURRENTLY SUSPENDED BY DECREE-LAW 25/2012, TO BE REVISED IN 2015	MINI-GENERATION (DECREE-LAW 25/2013 REVISING DL 34/2011)	MICRO-GENERATION (DECREE-LAW 25/2013 REVISING DL 118-A/2010 AND DL 363/2007)
Maximum capacity per system	No upper limit, but government may adopt specific tender procedures	250 kW	5,75 kW single or 3-phase; 11,04 kW 3-phase in condominiums
Starting Tariff	**Building integrated** • Less than 5 kW – 470 €/MWh • 5 kW to 150 kW – 355 €/MWh **Ground based** Less than 5 kW – 450 €/MWh More than 5 kW – 317 €/MWh	**Premium tariff** – 106 €/MWh (2014) • From 5,75 to 20 kW – full premium tariff • From 20 kW to 100 kW and from 100 kW to 250 kW – bidding process based on the premium tariff (two separated bidding processes) **Regular tariff** – Market price	**Premium tariff** – 66 €/MWh (2014) • Up to 3,68 kW production capacity or 11,04 kW (condominiums) and • Up to 2,4 MWh sold per year and **Regular tariff –** Annual Low Voltage (LV) regulated tariff
Starting tariff revision	Constant value based on formula incorporating technology and operation mode	Premium tariff revised down – 7 %/year	• Premium tariff revised down 130 €/MWh/year • Regular tariff revised annually
On-going update	Monthly updated at inflation rate	Fixed tariff for 15 years without inflation correction	**Special regime (Premium tariff)** • Fixed for the first 8 years after installation. Starting tariff in 2013: 196 €/MWh (- 130 €/MWh/year for subsequent years) • Fixed for the next 7 years of operation. Starting tariff in 2013: 165 €/MWh (- 20 €/MWh/year for subsequent years), **General regime (Regular tariff)** – Annually set at LV regulated tariff
Time frame	Tariff secured for 15 years or 21 MWh/kW capacity (becomes active for over 1 400 hours annual load factor)	Premium tariff secured for the first 15 years, after which will equal the market tariff	Premium tariff secured for the first 15 years, after which will equal the market tariff
Capacity cap	• Building integrated – 50 MW • Ground based – 150 MW (shared with CSP)	30 MW per year	11 MW per year
Other restrictions		• Up to 50 % of contracted consumption capacity can be connected to the grid • Design PV electricity production up to twice the electricity consumed in year prior to licensing • Establishment and implementation of an Energy Efficiency Plan	• Up to 50 % of contracted consumption capacity can be connected to the grid, 100 % for condominiums • At least 2 m2 solar water heating system installed or equivalent biomass boiler • 30 % CAPEX deductible on income tax up to 800 €

As mentioned before, both the Micro-generation and Mini-generation schemes were revoked in the end of 2014, giving place to a new diploma aimed at PV distributed generation, which will come into force in January 2015. This diploma foresees two different regimes: (1) Generation for primarily self-consumption and (2) small generation for total injection in the grid. In the first case, the maximum capacity per system will be the installation's consumption capacity and, simultaneously, the global yearly production must be smaller than consumption. However, occasional exceeding energy may be sold to the grid at pool prices. The second regime is designed for installations up to 250 kW that aim to sell all their production to the grid. The FiT for these installations is defined through a bidding process.

RESEARCH, DEVELOPMENT AND DEMONSTRATION

Research on photovoltaics in Portugal is spread in a number of fields through different universities and research institutions. The University of Minho and the New University of Lisbon are developing research in amorphous silicon solar cells. The University of Lisbon has a strong tradition in working with alternative processes for the production of multi-crystalline silicon solar cells. A few institutions, namely the University of Aveiro, the International Iberian Nanotechnology Laboratory (INL) and the National Laboratory for Energy and Geology (LNEG), are working with chalcogenide based thin film solar cells, with different absorber materials such as Cu(In,Ga)Se2 or Cu2ZnSn(S,Se)2. Dye sensitized solar cells, and in an initial stage perovskites solar cells, are the focus of groups present at the Science Faculty at the University of Porto, the University of Coimbra and also INL and LNEG. Finally, the Instituto Superior Técnico, is working with organic solar cells. There are other institutions and groups that occasionally perform research on solar cells but not on a regular basis.

Associations such as APISOLAR (Portuguese Association for Solar Industry), IPES (Portuguese Institute for Solar Energy) and APESF (Portuguese Association for Solar Photovoltaic Energy) are mainly focused on the promotion and protection of the solar energy sector industry.

INDUSTRY AND MARKET DEVELOPMENT

The PV sector in Portugal has benefited from the programs launched by the Portuguese government, in particular EPC companies and small installers. Since 2003, PV installed capacity has registered a compound annual growth rate of 31 %. This growth, especially concerning the micro and mini-generation systems, has fostered the creation of several SMEs, which work in the design, installation, operation and maintenance of PV systems.

Although this year's installed capacity (107 MW) was the highest ever in Portugal, most of this capacity concerns large scale projects, whereas micro and mini-generation capacity declined significantly, putting in risk the survival of some of these SMEs.
2015 will be a crucial year for some of these SMEs, and depends on whether the self-consumption market takes off.

In terms of module manufacturing, Portugal has the following capacity:

- Magpower (HCPV): 54 MW_p
- Jinko: 30 MW_p
- Martifer Solar: 50 MW_p
- Open Renewables: 60 MW_p

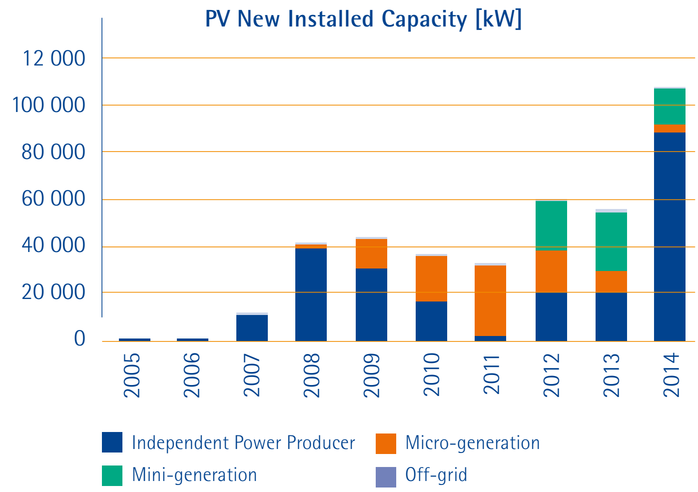

Fig. 5 - New PV power capacity installed yearly in Portugal (2005-2014).

TABLE 2 – CUMULATIVE PV POWER CAPACITY INSTALLED IN PORTUGAL (2004-2013)*

YEAR	OFF-GRID [MW]	GRID-TIED [MW]			TOTAL
		INDEPENDENT POWER PRODUCER	MICRO-GENERATION	MINI-GENERATION	
2005	2	0	0	0	3
2006	3	1	0	0	3
2007	3	12	0	0	15
2008	3	51	2	0	56
2009	3	82	14	0	99
2010	3	99	33	0	136
2011	3	103	63	0	169
2012	3	123	81	21	229
2013	4	144	90	46	284
2014	5	233	93	61	392

**Remark: Data for off-grid installations is estimated.*

SPAIN

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

ANA ROSA LAGUNAS ALONSO, CENTRO NACIONAL DE ENERGIAS RENOVABLES, CENER

Fig. 1 - PV plant from ATERSA, 30MW, one axis horizontal, c-Si technology in Cáceres, Spain.

Fig. 3 - PV plant built by ATERSA, 20MW, one axis horizontal, c-Si technology, in Jumilla, Spain.

GENERAL FRAMEWORK

The year 2014 has not experienced a big increase with respect to PV capacity installed in Spain. In fact total capacity has remained almost stable as only a few tenths of new MWs were added. Similar circumstances hold true for the other renewable technologies, so that the figure for percentage of electricity demand coverage by renewable energies is quite similar to the one in 2013. Figure 2 shows the evolution of that parameter since 2008 for the different renewable technologies (Hydraulic, Wind, Solar Photovoltaic, Solar Thermoelectric, Renewable Thermal and other low carbon sources).

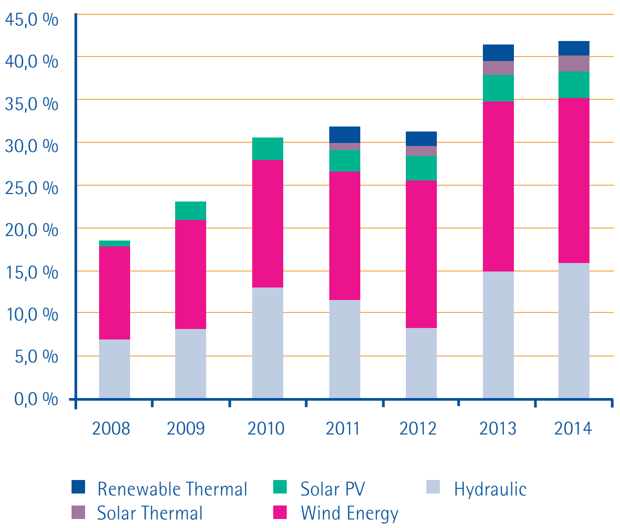

Fig. 2 – Spain's evolution of percentage of demand coverage from renewable energies (2008, 2009 data out of CNE, 2010 -2014 REE[1])

The total electricity demand in peninsular Spain decreased by 1,2 % in 2014 with respect to previous year. Only a 0,2 % of that reduction was due to economic activity. In these circumstances, contribution from RREE to total demand coverage has been 42,8 % (42,2 % in 2013), slightly higher than in 2013. However, the absolute electricity production numbers have a 1 % reduction with respect to the prior year. This reduction has been mainly due to lower generation from wind energy. Nevertheless, it should be mentioned that wind energy has been responsible for 20,4 % of the total (21,2 % in 2013) and also was the biggest contributor to electricity production in Spain during the months of January, February and November in 2014.

Concerning photovoltaic solar energy, this technology contributed to total electricity production with 8,211 GWh (including extra peninsular generation). In this scenario, demand coverage in 2014 by photovoltaic technology remained stable at close to 3,1 % as in previous years, allowing PV to be third place following Wind and Hydraulic in electricity generation out of RREE and in sixth place in the total classification. Figure 4 represents the various sources of electricity generation in Spain since 2007.

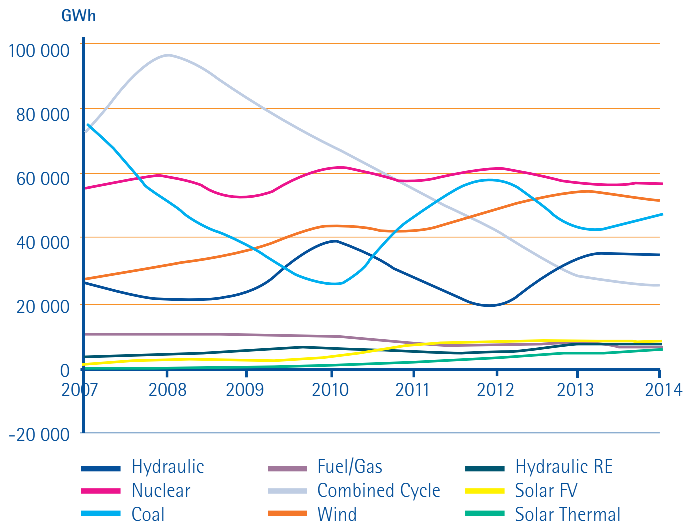

Fig. 4 - Evolution of electricity production in Spain (all energies).

[1] Preliminary data from grid operator Red Eléctrica de España (REE) as of December 2014

This 3,1 % value is the result of less newly installed power, specific meteorological aspects of 2014 and the level of absolute demand itself not growing at all. Figure 5 represents the accumulated PV installed per year and the annual energy production by PV. As could be expected, both the absolute total electricity production and percentage demand coverage by PV have remained more or less stable since 2012.

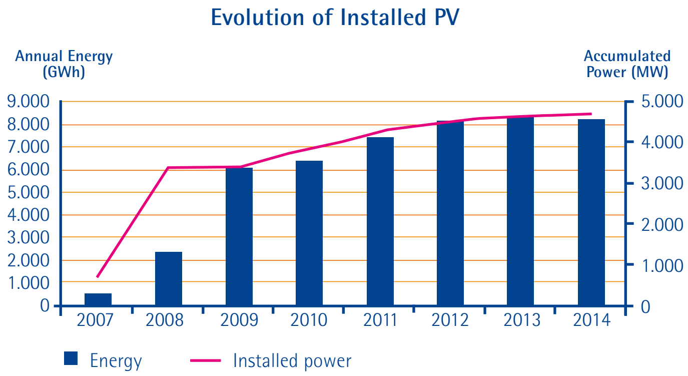

Fig. 5 - Evolution of yearly electricity generation and accumulated installed power for PV technology (Source: UNEF-CNMC; production 2012, 2013 and 2014 REE-preliminary data).

Another point of interest concerning electricity produced by PV means is the monthly demand coverage. In Figure 6, the parameter is presented since 2010. The maximum in the summer timeframe corresponds to the higher irradiation months and lower demand for lighting and acclimatization than in winter.

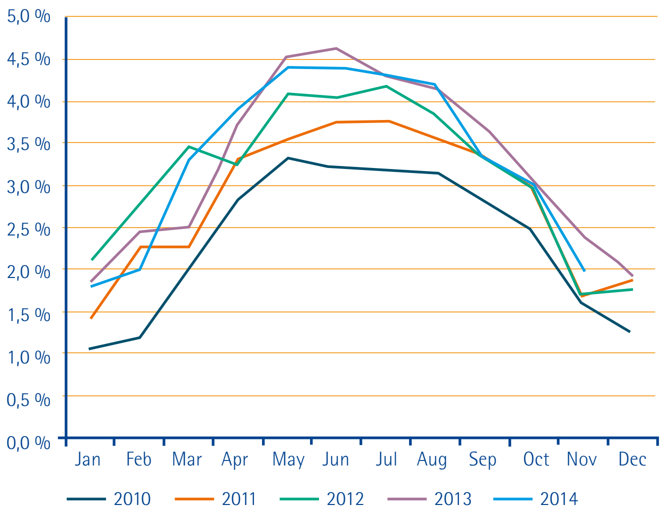

Fig. 6 - Monthly electricity demand coverage in Spain by PV.

Values for 2014 are obtained from preliminary data reported by grid operator REE (Red Eléctrica de España) as of December 2014 for both peninsular and extra-peninsular territories. Final information for the year will appear in the July 2015 timeframe.

NATIONAL PROGRAMME

The renewable energies plan (PER) 2011-2020 is governing the development of RREE in Spain. No modifications to that document happened yet so the original goal for gross electricity generation in 2020, established at 38,1 % [2] has been also overwhelmed in 2014 (demand coverage 42,8 %), based on preliminary data from grid operator. Continuous demand reductions are favouring that, as the capacity installed has not been growing significantly during the last 2 years for any renewable technology.

In the specific case of PV, Figure 7 represents the planned accumulated PV installed capacity until 2020 as written in PER (2011-2020). Values until 2014 are real ones, and from 2015 onwards remain according to the original plan. As a result of reduction of PV deployment due to recent legislation changes and the elimination of the feed-in-tariff, the evolution of accumulated installed capacity is on track and in delay with respect to the proposed values. Unless there are tendency and installation changes, even in low numbers such as a few hundred of megawatts starting again, the plan for 2020 could not be achieved.

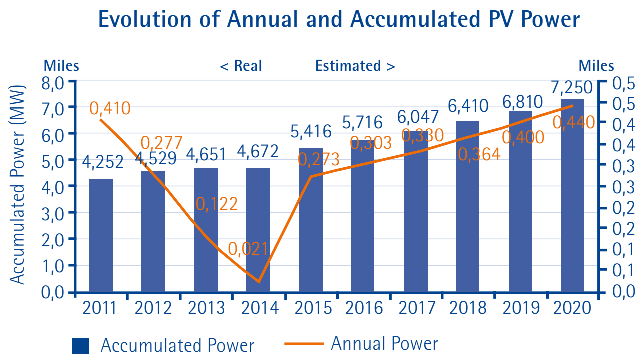

Fig. 7 - Accumulated and Annual installed PV. Real values up 2014, PER 2011-2020 from 2015 on.

R&D, D

R&D+I related to photovoltaic technology in Spain continues to be strong, but developments closer to market are suffering more due to the slowdown of PV deployment activity in the country, other than the basic research ones. Companies are less prone to invest in development of new products and the situation seems to have the same tendency as in the rest of European countries where installation activity is lower now, too. In this circumstance, National and European calls for research projects are the main way to finance R&D activities. Specifically, the new H2020 calls are receiving a very big amount of proposals and competition is fierce to achieve the financing. Not only projects presented with a consortium formed by European countries compete, but also there are specific calls for opening participation outside of European institutions (ERANET-MED for Mediterranean countries, ERANET-LAT for Latin American countries, etc.). All kinds of subjects from very applied PV systems activity for development and improvement of O&M in big plants, through to technological proposals for components design or basic R&D concerning new materials are present in the different calls.

[2] PER 2011-2020, approved by Ministers Council 11/11/2011

In Spain, the RETOS of society call assumes participation of research institutions and industrial partners looking for a higher TRL (Technology Readiness Level) result of the project, thinking on something closer to the market than basic research. However, the economic framework of the proposal is not always attractive enough for companies to go for it, and the actual situation of companies do not allow them to have great availability of resources to be used in R&D.

The Spanish Technology Platform (FOTOPLAT) is fostering activity and interaction among all potential players in the PV technology development. Its objectives concerning market and technologies are aligned with Europe's EERA (European Energy Research Alliance) scheme, and maintain technological working groups miming the ones established at the European level.

The main areas of interest remain on CPV technologies (recently granted H2020 project CPVMATCH with Spanish participation), BIPV components and innovative applications (some Spanish actors being part of the recently launched IEA PVPS Task 15 – BIPV in the Built Environment), upgraded metallurgical silicon development for use in PV cells and tools for improvement of PV plants performance and operation. Basic research concepts and development of technologies with a longer path to market, such as OPV are part of the "Plan Nacional de I+D" calls.

IMPLEMENTATION

It is not easy to have a precise number for capacity installed based on preliminary data. The absolute number of MW installed in 2014 might be finally in the low 10s. Most of them are small plants and even isolated from the grid. Preliminary values for electricity produced by PV for the year are 8,211 GWh (including extra-peninsular generation), not counting the isolated generation that, taking into account the difficulties to apply for an on-grid self-consumption by PV has forced some people to remain grid-isolated. Figure 8 presents the evolution of PV capacity installed in Spain since 2000. Absolute values go back to 2005.

Evolution of Installed PV

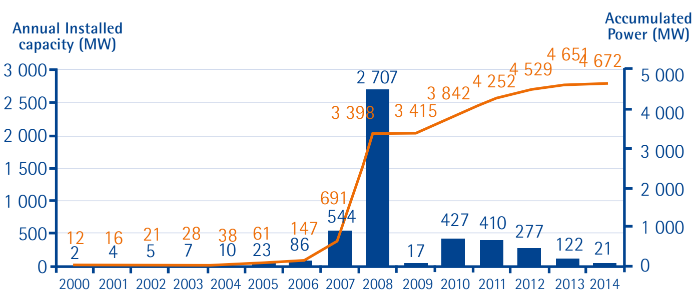

Fig. 8 – Evolution of PV power installed in Spain (Source: REE).

It is clear that since 2013, due to the inexistence of feed-in-tariff, the installation in Spain has only been driven by pure economic reasons, due to the capacity of PV technology of providing electricity at a cost that allows benefit with respect to other generation means. Figure 9 shows the evolution of feed-in-tariff values with the percentage of reductions per year. Comparison is done with respect to the average price EURcents/kWh paid for electricity generated (pool price) as of 2014.

Evolution of PV Feed-in-Tariff

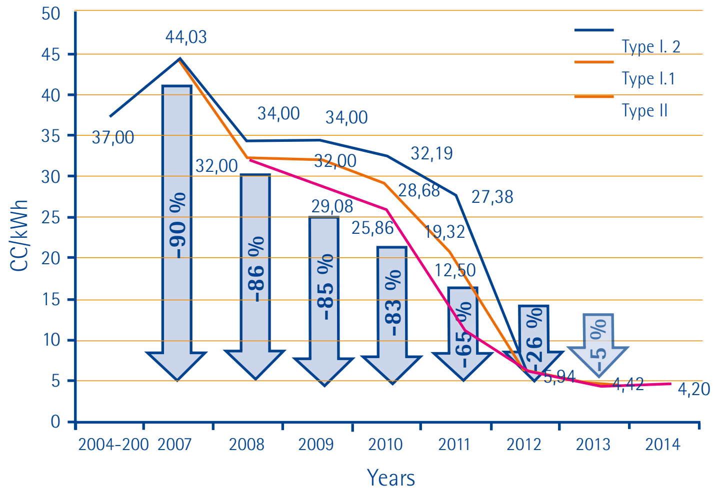

Fig. 9 – PV feed-in-tariff evolution in Spain (Source: UNEF).

Values used to calculate the evolution in Figure 7's graph are yearly averages. However, the spot price per kWh has an interesting evolution depending on various factors (mix of generation technologies, fuel price, renewable resource, demand, etc.). Figure 10 shows the monthly average spot price of electricity evolution during 2014.

Monthly Average Spot Price 2014

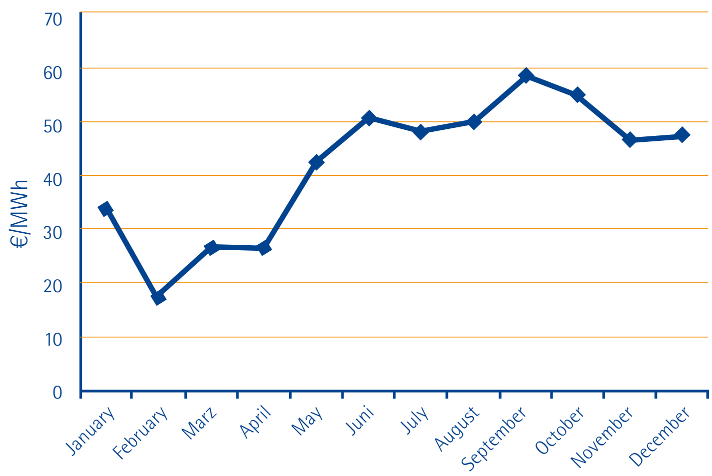

Fig. 10 – Monthly average spot price (Source: UNEF).

The average spot price is the same all around Spain, however, distribution of radiation and of peak power installed is not even throughout the country. Figure 11 represents peak power installed per autonomous community.

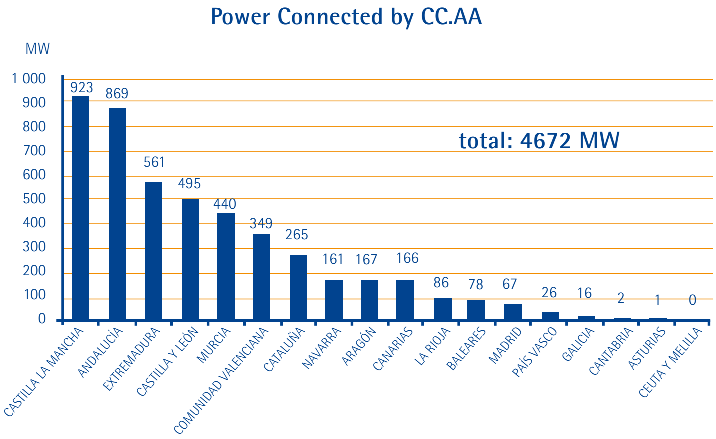

Fig. 11 - PV capacity installed per autonomous communities in Spain, 2014 (Source: CNE-UNEF).

Depending on radiation conditions of every region and overall demand, the impact of PV on the total generation mix used in every autonomous community is different. Also, the cost of electricity generated by PV means can be quite different among geographical regions making it really convenient to go for self-consumption PV, even when isolated from the grid. Figure 12 shows the evolution of electricity generated by PV per autonomous community, and Figure 13 shows the relative percentage of demand coverage in every case.

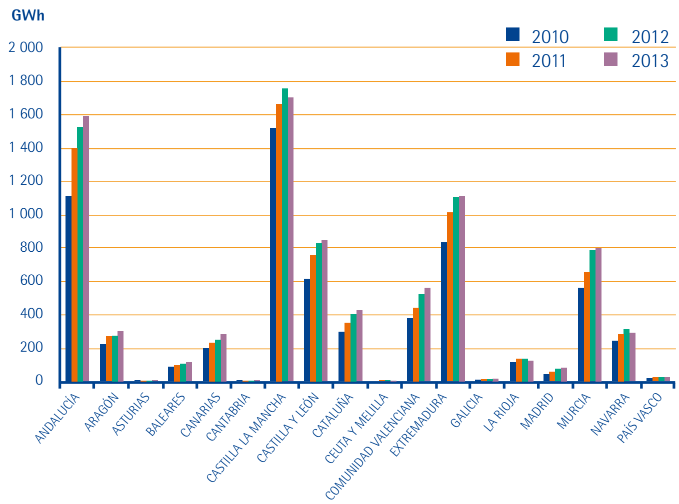

Fig. 12 - Evolution of electricity generated by PV per autonomous community.

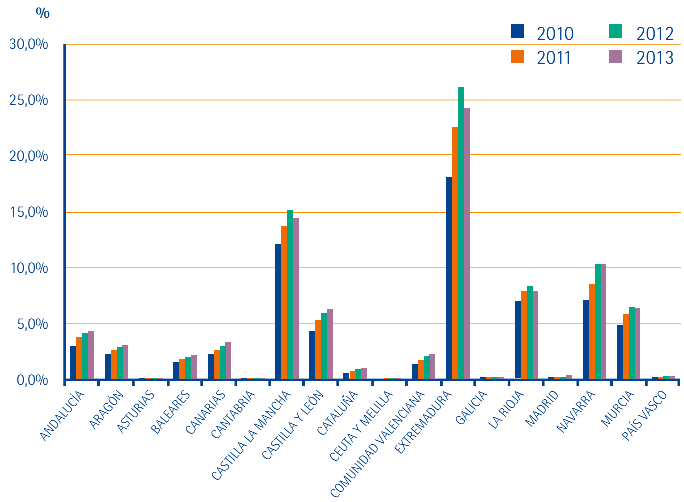

Fig. 13 - Percentage demand coverage per autonomous community (reference values of demand as of 2013).

The analysis of percentage demand coverage by PV technology per autonomous community shows that Extremadure leads the ranking with a value close to 30 % followed by Castilla la Mancha (15 %), Navarra (10 %), Rioja and Murcia close to 7 %. It is interesting to underline the highest values coming from very irradiated regions while 3rd and 4th correspond to autonomous communities with middle to low irradiation values.

INDUSTRY STATUS

The photovoltaic industry in Spain has been following the same path as the rest of Europe during 2014. Most of the manufacturing facilities concerning PV components have stopped activity. However, in the difficult situation for PV deployment, it is interesting to mention some companies that continue working, such as ATERSA, a pioneer PV module and inverter manufacturer in Spain that has intensified its activity as an installer throughout the world and who has even opened a manufacturing plant abroad in order to take advantage of local content on the product. Also INGETEAM, a PV inverter and storage manufacturer with factories in Spain and USA has experienced an increase in its sales for the year with more than 450 MW (4 GW accumulated power) and released a new family of string inverters to the market for connexion to the grid with powers of 2,5 and 6 kW single phase and 6 kW and 10 kW phase.

Going into the PV module technology, EVASA, a company with a strong technological base and focussed on innovation has become one of the main world suppliers of encapsulants with 2 GW of manufacturing capacity. Silicio Ferrosolar, part of Ferroatlántica Group, the first metallurgical silicon manufacturer worldwide, is developing an important R&D+I activity related to research on a new process to obtain upgraded metallurgical silicon for PV cells manufacturing with much less energy consumption.

Finally in the area of supporting structures and tracking systems, there is an important activity. Companies such as Abengoa Solar or STI Norland develop high precision trackers usable for CPV application and at the same time more simple ones for flat plate module technology. Nevertheless, the way for many Spanish companies to stay alive has been to apply their extensive experience in the promotion, installation and development of PV plants outside of Spain and throughout the world. Almost every week there is news concerning new plant start-ups, new projects and optimization of existing ones.

In summary, there is not much industrial activity in the country, most of activity is on the installation side, but the active companies are among the leaders in quality and products.

MARKET DEVELOPMENT

Market development in Spain has been very low in 2014. Preliminary data of installation accounts for tens of Megawatts. In that sense, the largely announced non-feed-in-tariff grid connected PV plants for 2013 have not been installed during 2014, at least not grid connected, even when some projecting, procuring or installing activity might have already started. So some of the projects remain alive and in process. However, according to PV Grid Monitor information (PGM), the generation costs of electricity by PV in the residential segment have decreased 5 % in Spain during the last year, due mostly to lower installation costs. In that circumstance, grid parity appears even more attractive to many customers.

Such good news that could foster self-consumption development is also a good sign for another business development, such as BIPV component industrialization. New ideas about using flexible PV for shadings, or proposals for PV-integrated roof tiles, micro-inverters, and structures for anchoring PV or BIPV components for buildings have a good potential market and the entrepreneurs have already identified the niche.

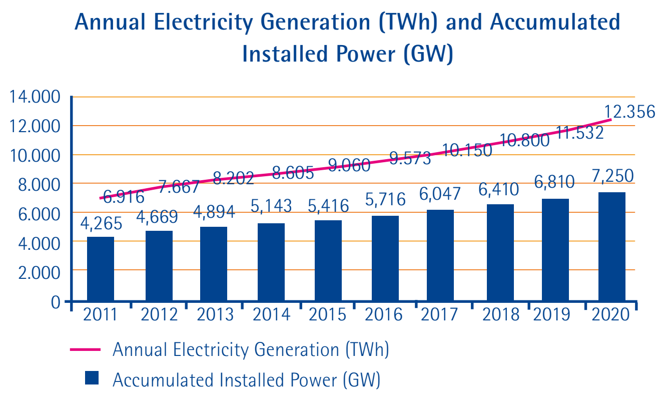

Fig. 14 - Evolution of Annual electricity generated (GWh) and accumulated installed power (GW) planned out of PER 2011-2020.

If in order to achieve the goals of energy for year 2020 the PER 2011-2020 must be accomplished and the PV installation during the next years in Spain should follow the path established by IDAE. Figure 14 takes into consideration both the path for electricity generation (GWh) and the numbers of MWs installed. As of 2014, 8,211 GWh generated puts Spain one year behind with respect to the original planning. The good purposes written in that document about promoting self-consumption (P. 456) should be renewed in order to accomplish the path planned.

On the other side, traditional issues related to the isolation of the Spanish grid structure from the rest of Europe are starting to be solved with the announcement of new connection lines between Spain and France. Recent interconnection increase (February 2015) has achieved 6 % of current demand in Spain, while Brussels requirement as of 2020 is 10 %.

FUTURE OUTLOOK

The future outlook for PV in Spain is not very different than the situation in the last year. By analysing its evolution, annual PV installation as of 2014 is at the levels of 2005, even the whole accumulated installed power is under the conservative plan of PER 2011-2020, so there is room for improvement, at least up to matching the original plan. That improvement should come from different approaches:

- Self-consumption, that with a reasonable regulation should ramp-up; and
- Big PV plants under construction that should be finished and connected to the grid.

There are no economic arguments (prices are reasonable), neither technical (efficiencies, durability and quality of components are high), to stop the development of PV. Activity is being undertaken in order to reduce or eliminate the problems that used to be wielded for preventing PV deployment. The traditional difficulty of handling a big amount of electricity production as generated by non-manageable sources such as RREE (mostly wind) and related to the isolation of Spanish grid structure from the rest of Europe is starting to be solved, too.

On the R&D+I side, large activity and knowledge among Spanish research groups exists related to handling and storing electricity in an optimum way, so that the micro-grid schemes can be another way of PV deployment in the urban environment.

Finally, know-how and capacity to re-start the industrial activity with the new paradigm of handling energy from PV exists in the country and the signs point towards an important opportunity during 2015 in that sense.

SWEDEN

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

TOBIAS WALLA, SWEDISH ENERGY AGENCY
GUNILLA ANDRÈE, SWEDISH ENERGY AGENCY

Fig. 1 - Sunrise over 150 kWp installation in Vänersborg (Photo: Solkompaniet AB).

Fig. 2 - 50 kWp on a church roof. Lambohovskyrkan, Linköping (Photo: PPAM.se Sweden AB).

GENERAL FRAMEWORK AND IMPLEMENTATION

The vision of Swedish energy policy is social, economic and ecological long-term sustainability of the energy system, while maintaining security of supply. This is to be achieved via an active energy policy, incentives and research funding. Already today, CO_2-emissions related to electricity production are relatively low, since hydro, nuclear, bio and wind energy are the main contributors.

Since a capital subsidy was introduced in 2009, the number of grid-connected installations has increased rapidly. The original subsidy covered up to 60 % of the costs of a PV system, but following decreasing prices this level has been lowered to between 20 and 30 % in 2014. The subsidy has been successful and the volume of applications is much greater than the available funds. The cumulative installed grid-connected power has grown from only 250 kW in 2005 to 70 MW in 2014. However PV still accounts less than 0,05 % of the Swedish electricity production.

In December 2014 a new tax deduction scheme on small-scale electricity production was settled, which will apply from 2015 and on. The scheme entitles the owner of a PV system to a tax deduction of 0,06 EUR per kWh of electricity fed into the grid, as long as you are a net electricity consumer. The tax deduction will apply on the income tax, and has a cap of 1 900 EUR per year.

The main incentive for renewables in Sweden is the electricity certificate scheme. It is a market-based support scheme, in cooperation with Norway, which is designed to increase power generation from renewable energy sources such as wind, solar, waves and biomass.

There is solid public support for PV technology in Sweden, and about 80 % of the population thinks that efforts towards implementation should increase.

NATIONAL PROGRAMME

The Swedish Energy Agency is the governmental authority responsible for most energy-related issues. In 2012, a new strategy for energy research was formulated. It states that PV research in Sweden should continue to cover several different subjects. It has been suggested that 2 TWh should be produced from PV in Sweden in 2020; however this figure is not a confirmed national target.

In 2014 a government-initiated testing program started, with the ambition of disseminating information on the quality of modules and inverters to the public.

The Swedish Energy Agency is responsible for the national energy research programme. In 2012 a new research programme was launched, covering PV, concentrated solar power, and solar fuels. The budget for the entire programme period (2013-2016) is about 15 MEUR. So far, two different calls have been performed, one focusing on outstanding research, and one focusing on more applied research.

In 2014, a second call was opened in SolEl-programmet; an applied research program in cooperation with the industry. Five projects, all of them relevant to the current PV deployment in Sweden, are so far approved.

The Swedish Energy Agency funds solar cell research via its main energy research program, and a yearly total budget of about 4,5 MEUR are channelled to PV related research. Additional resources to PV research come from several research councils, universities and private institutions. Sweden is also a member in the newly formed Solar ERA NET, where a first call was held in 2013. A new pre-proposal call opened in December 2014.

Fig. 3 - These modules are part of a national testing programme on PV modules and inverters (Photo: Swedish Energy Agency and Oskar Lürén).

RESEARCH, DEVELOPMENT AND DEMONSTRATION

There are strong academic environments performing research on a variety of PV technologies, such as CIGS thin film, dye sensitized solar cells, polymer solar cells, nanowire solar cells and more. There is also research on enhancement techniques for conventional silicon cells. Comprehensive research in CIGS and CZTS thin film solar cells is performed at the Ångström Solar Center at Uppsala University. The objectives of the group are to achieve high performing cells while utilizing processes and materials that minimize the production cost and the impact on the environment. The Center collaborates with the spin-off company Solibro Research AB, and Midsummer AB.

At Lund University, the division of Energy & Building Design studies energy-efficient buildings and how to integrate PV and solar thermal into those buildings. There is research at the same university on multi-junction nanowire solar cells. The research is performed in collaboration with the company Sol Voltaics AB. Sol Voltaics is using nano-wires in order to enhance solar cell performance. They have developed a product called Solink in recent years which is designed to be compatible with existing crystalline silicon or thin film production lines.

An ongoing collaboration between Linköping University, Chalmers University of Technology and Lund University, under the name Center of Organic Electronics, carries out research on organic and polymer solar cells. Different areas of use are being investigated, such as sunshade curtains with integrated solar cell.

Research on dye-sensitized solar cells is carried out at the Center of Molecular Devices, which is a collaboration between Uppsala University, the Royal Institute of Technology (KTH) in Stockholm and the industrial research institute Swerea IVF. A scientific highlight is the discovery and development of a new effective electrolyte based on cobalt.

Others which are involved in PV research are the Universities of Chalmers, Dalarna, Karlstad and Mälardalen.

INDUSTRY AND MARKET DEVELOPMENT

The installed capacity in Sweden in 2014 was 79,5 MW, with seven times as much grid-connected installations compared to off-grid installations. These 79,5 MW can produce about 72 GWh in a year, which leaves a large potential for growth. It has been estimated that the potential for electricity produced by roof-mounted solar cells in Sweden amounts to several tens of TWh per year.

Fig. 4 - King Carl Gustaf inaugurates a new pilot plant for dye-sensitized solar cells production. It was completed during 2014, and the technology is developed by Swedish company Exeger within EU LIFE+ (Photo: Exeger).

Today, there's only one active module producer in Sweden, namely SweModule AB. The assembly line of SweModule is highly automated, and more than 1 MW of PV modules is produced per employee and year.

There are two companies exploring newer types of solar cells. Midsummer AB inaugurated their factory in 2011, where they produce thin-film CIGS cells to develop their manufacturing equipment, which is their main product. Exeger AB is developing transparent dye sensitised solar cells for integration in glass windows, and during 2014 they completed a pilot plant. A few innovative companies exist that develop balance-of-system equipment, e.g. inverters.

A growing number of small to medium-sized enterprises exist, that design, market and sell PV products and systems. Many of these companies depend almost exclusively on the Swedish market. The capital subsidy programme has resulted in more activity among these companies and since there has been a lot of interest from private households there are several companies that market products specified for this market segment. Several utilities are selling turn-key PV systems, often with assistance from PV installation companies.

SWITZERLAND

PV TECHNOLOGY STATUS AND PROSPECTS

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AND STEFAN OBERHOLZER, SWISS FEDERAL OFFICE OF ENERGY (SFOE)

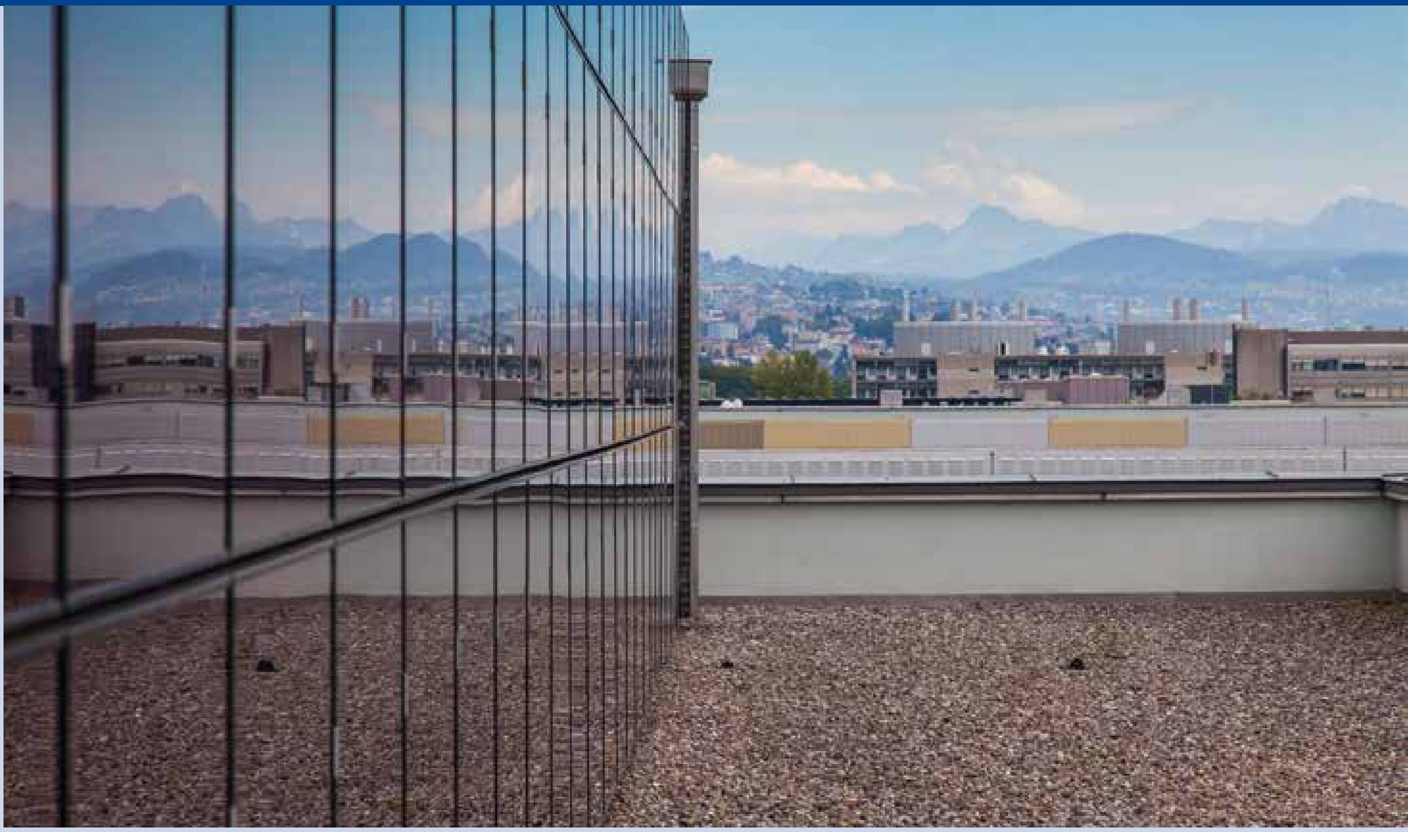

Fig. 1 - PV-façade system on EPFL campus, Lausanne, Switzerland (Photo: © NET Ltd. /DanielForster.com).

GENERAL FRAMEWORK AND IMPLEMENTATION

There is a general consensus in Switzerland that solar photovoltaics will play an important role in the long term future Swiss electricity supply. According to the official scenarios, 10 – 12 TWh should come from photovoltaics by 2050. Compared to the annual national electricity consumption of close to 60 TWh in 2014, this would represent close to 20 % of this value. The Swiss solar industry claims such contributions to be achievable much sooner than 2050 (www.swissolar.ch).

In 2014, on the levels of Swiss policy and administration, work continued extensively regarding the preparation of the various measures in conjunction with Switzerland's phase-out of nuclear energy decided in 2011 in the framework of the new energy strategy 2050. These measures will have impacts on all levels from research to implementation and use, as well as regarding legislative and normative issues. Before coming into force, there will likely be a public vote on the new energy strategy, expected in 2016.

While the final form of the new energy strategy 2050 and its set of policy measures continue to be defined and shaped, a number of decisions have already been made by the national parliament in view of this strategy. These concern, for instance, an action plan for an increased energy research activity throughout all relevant energy technologies. Building on existing research activities, eight new national competence centres for energy research (SCCERs) have taken up their activities during 2014. The goal of these centres is to build up new permanent research and innovation capacities and institutional networks in the different technology areas. Alongside this structural measure, important additional financial means have been invested to support research activities in the different areas on the project level. Moreover, the financial means for pilot and demonstration projects have been further increased, aiming at speeding up the technology transfer from research into industrial processes, products and applications.

On the implementation level, support continues to be provided by an evolving regulatory framework. The deployment of photovoltaic power systems in the short term, namely up to 2016, is governed by a differentiated support scheme. Since early 2014, the following conditions apply: Besides the feed-in-tariff scheme used since 2009 with decreasing tariffs and increasing shares attributed to photovoltaics, systems between 2 and 10 kW now benefit from a onetime investment subsidy and are not supported in the feed-in-tariff scheme any longer. Systems between 10 and 30 kW may choose between the investment subsidy and the feed-in-tariff whereas systems below 2 kW have no support at all at the federal level. Systems of 30 kW and more continue to benefit from the feed-in-tariff as before. As an additional new element, self-consumption of the electricity produced is allowed and accounted for. These measures were also meant to relieve a long waiting list in the feed-in-tariff scheme. However, by the end of 2014,

Fig. 2 - PV systems on different farmhouses, Moosseedorf, Switzerland (Photo: © NET Ltd. /DanielForster.com).

Fig. 3 - 538 kW roof-integrated PV system, Affentranger Bau AG, Altbüron (Photo: © NET Ltd. /DanielForster.com).

more than 35 000 systems were still on this waiting list. The future of the Swiss feed-in-tariff support scheme depends on the decisions on the political level concerning the amount of the levy on the electricity price reserved to finance the feed-in-tariff.

The development of the photovoltaic sector in Switzerland builds on a strong research and technology base, a diversified industrial activity and, more recently, an acceleration of the market deployment efforts. A comprehensive research programme covers R&D in solar cells, modules and system aspects. The Swiss energy research strategy is defined by an energy RTD master plan updated every four years. The master plan developed by the Federal Commission for Energy Research (CORE) in cooperation with the Swiss Federal Office of Energy (SFOE) is based on strategic policy goals (energy & environment, science & education, industry & society) (www.energy-research.ch).

Concerning market implementation, the photovoltaic sector in Switzerland further developed in the year 2014. Following some difficult years going along with the worldwide consolidation within the PV industry, some of the industrial activities show signs of a renewed uptake whereas others continue to face financial difficulties, with some companies abandoning their activities in the PV area. Nevertheless, activities in the Swiss PV supply industry remain high with an increasing emphasis on technology development and innovation. R&D activities in the public sector confirm this increasing trend. Several industrially oriented projects aiming at pilot production facilities were intensified throughout the year. On the technology front, the key competence centres continued their efforts in their respective domains (solar cells, modules and systems) while increasing their cooperation with industry and on the international level.

The support of the national PV RTD programme can be expected to continue with a focus on innovative research activities, rapid technology transfer, industrial developments, new products for niche markets and ongoing international involvement. Due to the strong Swiss currency, global competition for the heavily export oriented industry remains an issue. Nevertheless, the efforts to bring Swiss technology to the market place continue. Efforts in the technology development will concentrate on short to medium term market oriented approaches and continuous quality assurance.

The strategy to promote international co-operation on all levels continued, related to activities in the 7th Framework and the new Horizon 2020 Programme of the European Union, the European PV Technology Platform, the IEA PVPS programme and in technology co-operation projects.

With a strong research base and leading activities in various PV technologies, an ongoing diversified industrial base along the entire value chain, an increasing market deployment activity and an overall favourable policy framework, the signs continue to be positive for an increased role of PV, from research over industry all the way to the market.

NATIONAL PROGRAMME

Switzerland has a dedicated national photovoltaic RTD programme which involves a broad range of stakeholders in a strongly coordinated approach (SFOE PV RTD programme, 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 accompanying measures for market stimulation. On the technical level, silicon heterojunction and different thin film solar cells, their variations and building integration are the topics of highest priority. New concepts such as perovskite solar cells and tandem cells with these are increasingly being investigated. The programme is organised along the entire value chain and addresses the critical gaps from research over technology to the market place. Thorough component and system analysis, as well as testing, aim at increasing efficiency and performance. Accompanying measures to raise the quality and reliability of photovoltaic power systems include work on environmental issues, standards and design tools.

RESEARCH, DEVELOPMENT AND DEMONSTRATION

In 2014, more than 70 projects, supported by various national and regional government agencies, the European Commission and the private sector, were conducted in the different areas of the photovoltaic energy system. Innovative solutions, cost reduction, increased efficiency and reliability, industrial viability and transfer as well as adequate market orientation are the main objectives of the technical R&D. For solar cells, the previous strong focus on thin film solar cells is diversifying with projects in a wider variety of materials

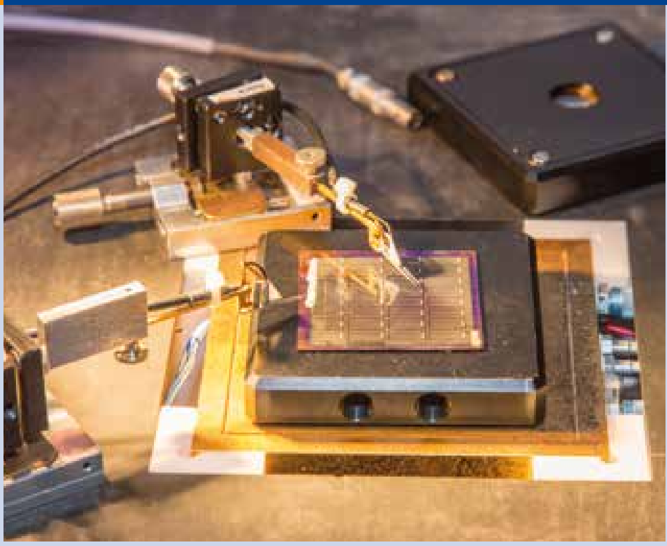

Fig. 4 - CIGS flexible solar cell analysis at EMPA (Photo: © NET Ltd. /DanielForster.com).

Fig. 5 - CSEM Christophe Ballif and Laure-Emmanuelle Perret-Aebi with white and colored PV-modules (Photo: CSEM).

(crystalline silicon, amorphous and microcrystalline silicon, compound semiconductors, dye-sensitised, perovskite and organic solar cells). Work at the Swiss Federal Institute of Technology (EPFL) in Neuchâtel continued on thin film micromorphous solar cells and increased on advanced structures for high-efficiency crystalline silicon solar cells. Further progress is being achieved in the area of high-efficiency heterojunction silicon solar cells, reaching efficiencies up to 22,4 %. On the more fundamental R&D side, a new project on high-efficiency tandem configurations involving perovskite solar cells started in 2014. At the other end, industry co-operation was extended with various companies. The CSEM (Centre Suisse d'électronique et microtechnique), a close partner of the PV-Lab at EPFL, further developed its new photovoltaic technology centre in Neuchâtel. The mission of this PV technology centre is to accelerate the transfer of innovative PV technologies to the industry by an increased collaboration and a dedicated infrastructure.

With regard to CIGS solar cells, the Swiss Federal Laboratories for Materials Testing and Research EMPA continued their work focussed on high efficiency flexible CIGS cells on plastic and metal foils (Fig. 4) . As one of the highlights towards industrial implementation of this technology, a new pilot machine on roll-to-roll CIGS deposition was commissioned in 2014. At the end of the project the pilot machine is ready to demonstrate the transferability of the multistage low-temperature CIGS deposition process from small scale, static laboratory equipment to medium scale, inline equipment with industrial relevance.

For dye-sensitised solar cells, work continues at EPFL on new dyes and electrolytes as well as high temperature stability of the devices. Further rapid progress has been achieved at the Laboratory of Photonics and Interfaces at EPFL concerning perovskite-sensitized solar cells which have reached solar cell efficiency values of 18 % and more. Perovskite-sensitized solar cells thus continue on the path of the steepest efficiency increase in recent years and attract a large interest from the global PV research community.

Organic solar cells are the research subject at the Swiss Federal Laboratories for Materials Testing and Research EMPA, the University of Applied Sciences in Winterthur (ZHAW) as well as at CSEM in the Basel region. In this technical area, CSEM coordinates the large European project, Sunflower.

An increasing interest for photovoltaic technology can be observed at various research institutions as well as from industry. In line with the international trend to a broader scientific and technological base, increased activities take place in the fields of nanotechnology, chemistry and numerical modelling.

On the part of application oriented research, emphasis continues to be given to building integrated photovoltaics (BIPV), both for new solutions involving different solar cells as well as for new mounting systems and structures for sloped roofs and facades. New design options involving coloured PV modules are progressively being developed. In this regard, a highlight of 2014 was the announcement of white PV modules by CSEM (www.csem.ch/white-pv) (Fig. 5). A dedicated website deals with the application aspects of BIPV (www.bipv.ch) and includes information about available products.

As a recent topic rapidly gaining relevance in some countries and regions, grid integration has continued to generate interest and recent projects have extensively analysed the implications of PV on the distribution grid. Methods to considerably increase the share of PV in distribution grids have been identified based on detailed modelling work. Based on these more theoretical studies, new pilot projects have started investigating different approaches and experiences with high penetration PV in various grid configurations. High levels of PV penetration in distribution grids are thus no longer considered as insurmountable barriers.

With the ongoing market development, quality assurance and reliability of products and systems, as well as standardisation, continue to be of high priority. The Swiss centres of competence at the Universities of Applied Sciences of Lugano and Burgdorf carefully evaluate products such as PV modules, inverters and new systems. The test infrastructure (Fig. 6) is continuously expanding and includes the accredited test centre for IEC module certification (Lugano, http://www.supsi.ch/isaac/swiss_pv_module_test_centre.html) as well as the largest solar simulator for inverter testing up to 100 kW capacity (Burgdorf, www.pvtest.ch). Long term experience with the operation of photovoltaic power systems is carefully tracked for a number

Fig. 6 - Spectral Responsivity test lab at SUPSI-ISAAC, Canobbio, Switzerland (Photo: © NET Ltd. /DanielForster.com).

Fig. 7 - 32 000 m² PV system with 5,2 MWp, producing 6,8 GWh per year, Migros, Neuendorf (Photo: © NET Ltd. /DanielForster.com).

of grid-connected systems, ranging between 10 and more than 30 years of operation. Continuous development of system solutions has resulted in a number of industrial products well positioned in the export market.

Work continued on the second prototype of the solar powered airplane SolarImpulse (www.solarimpulse.com) by Bertrand Piccard, André Borschberg and their team. Meanwhile, further flight experience was gained throughout the year with the goal to start the first round the world flight in early 2015.

International co-operation continues to form a strong pillar of the R&D activities with more than 20 projects running in the 7th framework and Horizon 2020 RTD programmes of the European Union during 2014. The co-operation within the IEA PVPS programme has remained a further strategic activity.

Regarding international co-operation within the recent European SOLAR-ERA.NET project (www.solar-era.net) coordinated by Switzerland, first joint projects started in 2014, namely by EMPA on front contacts for CIGS solar cells. In parallel, a second joint call was executed during 2014 covering both PV and concentrated solar power (CSP) which again had a high and more focussed resonance in the research community. The collaboration with the European Photovoltaic Technology Platform (www.eupvplatform.org) continued throughout the year with a new Swiss participant in the Steering Committee.

INDUSTRY AND MARKET DEVELOPMENT

For a few years, Swiss industrial PV products cover the full value chain starting from materials, production equipment and small scale manufacturing of solar cells, over diverse components and products all the way to system planning and implementation. Due to the fierce competition and the ongoing consolidation in the global PV industry, important changes have taken place in the Swiss PV industry landscape as well. Due to the decreased investment in new production facilities worldwide and slower market growth in Europe, the export volume of Swiss photovoltaic products has continued on a reduced level. At the same time, due to a comparatively strong domestic PV market, the export share is presently estimated at 50 % of the total turnover.

On the PV industry supply side, different products count among the world leaders. The largest equipment supplier for complete PV module manufacturing lines and advanced PV module technologies continues to be Meyer Burger. The company continues its efforts in advanced solar cell technology and has officially opened a silicon heterojunction solar cell pilot production line with CSEM in late 2014. The pilot line has a production capacity of 600 kilowatts from which heterojunction manufactured cells are built into modules and tested in both the laboratory and in the field. The target upon further process optimisation is to reach a PV module efficiency of 21 % with a production cost below 0,6 CHF/Wp. Measuring equipment for PV module manufacturers is produced by Pasan (a part of Meyer Burger Group). Solar plugging systems are offered by Multicontact as well as Huber & Suhner.

Flisom, a company active in the CIGS technology, has started setting up the facilities for a 15 MW pilot production in Switzerland. Flisom continues to work closely with the Swiss Federal Laboratories for Materials Testing and Research EMPA. Further companies are active in the manufacturing of coloured PV modules (swissinso) and dye-sensitized solar cells (glass to energy, Solaronix).

With the acquisition of the US company Power One, ABB has strengthened its business in the inverter market and is becoming a leading worldwide inverter supplier. One of the traditional Swiss PV inverter companies, Sputnik Engineering, had to close its business due to insolvency issues. On the other hand, Studer Innotec continues as a leading producer of stand-alone and grid-tied inverters, increasingly combined with storage units for self-consumption.

Alongside an increasing PV capacity being installed in Switzerland, a clear growth of the number of companies as well as that of existing businesses involved in planning and installing PV systems can be observed. 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. System sizes have increased over the past years with up to 5 MW systems (Fig. 7) being installed on building complexes.

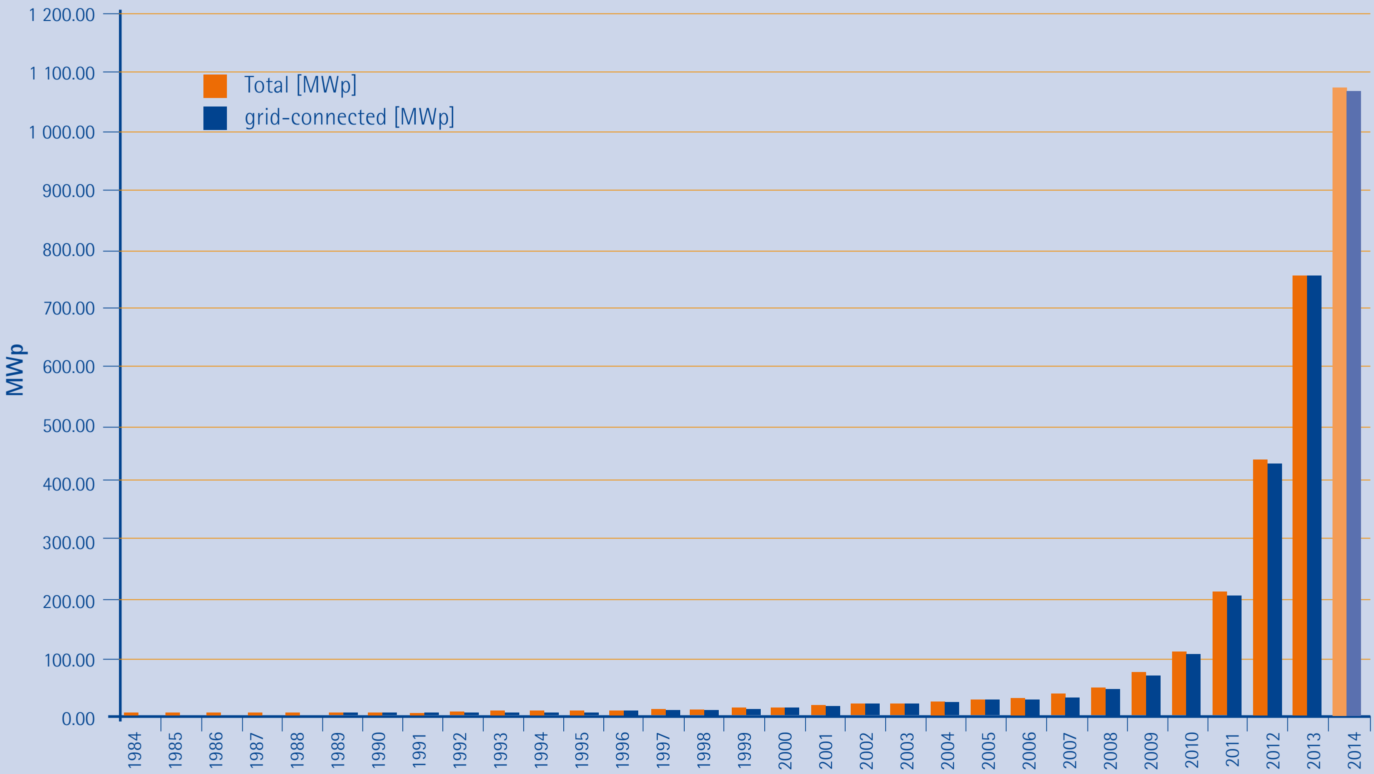

Fig. 8 – 30 years of PV in Switzerland: Evolution of the installed photovoltaic capacity in Switzerland between 1984 and 2014 (total and grid-connected, estimated values for 2014).

Formerly mostly driven by utilities own green power marketing schemes, there has been a strong development in the framework of the new feed-in tariff support scheme in recent years. This PV feed-in tariff distinguishes between three different categories of systems, namely ground based, building applied and building integrated systems (BIPV) for which the highest tariff can be obtained. The applicable tariff also depends on the size of the PV system. In this way, a differentiated scheme is used which is based on regular market analysis to follow the dynamics of the market. Due to the limited financial volume available within the feed-in tariff for PV systems up to now, many systems could not benefit from the feed-in tariff and are on a waiting list (see also introduction). This has led to a variety of intermediate support schemes by regional governments and utilities, thereby diversifying the possible market support.

The combination of the various support schemes and the increased cost-competitiveness of PV systems have led to an annual market volume for grid-connected systems estimated to at least 300 MWp, which represents about the same market size as for 2013. The total installed capacity has now risen to above 1 GW (Fig. 8) corresponding to about 130 W/capita. With this installed capacity, roughly 1 % of the annual national electricity consumption can now be covered by photovoltaics in Switzerland.

THAILAND

PV TECHNOLOGY STATUS AND PROSPECTS

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YONGYUT JANTARAROTAI, DEPUTY DIRECTOR GENERAL, DEPARTMENT OF ALTERNATIVE ENERGY DEVELOPMENT AND EFFICIENCY
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GENERAL FRAMEWORK AND IMPLEMENTATION

In July 2013, Thailand revised its 10-year Alternative Energy Development Plan (AEDP 2012-2021), while the total target remains at 25 % share of renewable energy of total energy consumption for the year 2021. The plan includes target for power generation, heat production and utilization and biofuel. The revised plan has increased the solar power generation target from 2 000 MWp to 3 000 MWp, while the solar thermal target remains at 100 ktoes.

At the end of 2014, the country escalated the solar power target to 3 800 MWp by the end of 2015. Currently, the Ministry of Energy is developing the new long-term Energy Master Plan for the country which includes all energy plans: The Alternative Energy Development Plan (AEDP), the Energy Efficiency Development Plan (EEDP), the Power Development Plan (PDP) and the Oil and Gas Development Plan. The Master Plan will be planned for 20 years (2015-2036). These plans will enable Thailand to have good management of the energy sector, in terms of energy security and the balance of the country's energy demand and supply in the long run.

NATIONAL PROGRAMME

Thailand has continued the feed-in tariff (FiT) measure that was started in September 2013. The FiT will be applied to new PV system installations, both for ground-mounted installations and for rooftop system installations.

In 2014, the new solar power policies have been approved by National Energy Policy Committee (NEPC). (1) The ground-mounted PV power plants with installed capacity up to 90 MWp which have been submitted the application of selling electricity before June 2010, and have not received acceptance from utilities, will be back in the process of acceptance. The project should accept the new FiT rate of 5,66 THB/kWh for a supporting period of 25 years and Commercial Operation Date (COD) by December 2015. (2) Solar Rooftop for residential scale with installed capacity up to 10 kWp, will receive the new rate which has been adjusted to 6,85 THB/kWh. The target is set at 69,36 MWp and COD by December 2015. (3) The former Solar Community Program indicated for ground mounted installations with the target of 800 MWp has been changed to the solar program for governmental agencies and agricultural cooperatives. The target remains at 800 MWp and the FiT rate has been set at 5,66 THB/kWh and COD by December 2015, as well. As a result of new solar power policies, Thailand's solar power target has been raised to 3 800 MWp by the end of 2015.

Moreover, the National Energy Policy Committee (NEPC) has approved the new FiT rate for the year 2014-2015 and Table 1 summarizes the FiT for the three solar PV supporting programmes.

In 2014, Thailand's new solar power installed capacity was 474,71 MWp with the cumulative capacity for both PV on grid and off grid at 1 298,51 MWp. Cumulative and annual installation PV capacities from 2005-2014 are shown in Table 2 and Figure 1.

TABLE 1– NEW FEED IN TARIFF FOR SOLAR POWER FOR 2014-2015

INSTALLED CAPACITY (MWp)	FIT RATE FOR 2014		
	FIT RATE (THB/kWh)	FIT RATE (USD/kWh)	SUPPORT PERIOD
PV Ground mount			
≤ 90 MWp	5,66	0,17	25 Years
PV Rooftop (Household)			
≤ 10 kWp	6,85	0,21	25 Years
PV Rooftop (Commercial/Factory)			
> 10 – 250 kWp	6,40	0,20	25 Years
> 250 – 1,000 kWp	6,01	0,18	25 Years
PV Ground mount (Government site and Agriculture Cooperative)			
≤ 5 MWp	5,66	0,17	25 Years

TABLE 2 – DEVELOPMENT OF PV APPPLICATIONS BETWEEN 2005 AND 2014 (MWP/YEAR)

YEAR	CUMULATIVE INSTALLATION (MWp)			ANNUAL INSTALLATION (MWp)		
	On-grid	Off-grid	Total	On-grid	Off-grid	Total
2005	1,77	22,11	23,88	0,01	13,04	13,05
2006	1,86	28,66	30,52	0,09	6,55	6,64
2007	3,61	28,90	32,51	1,74	0,24	1,98
2008	4,06	29,34	33,39	0,45	0,44	0,89
2009	13,67	29,49	43,17	9,62	0,16	9,77
2010	19,57	29,65	49,22	5,89	0,16	6,05
2011	212,80	29,88	242,68	193,23	0,23	193,46
2012	357,38	30,19	387,57	144,89	0,15	145,04
2013	794,07	29,73	823,80	436,69	-0,45*	436,24
2014	1 268,77	29,73	1 298,51	474,71	0**	474,71

**Some of the off-grid systems were dismantled.*
***Preliminary data, since the 2014 installations have not yet*

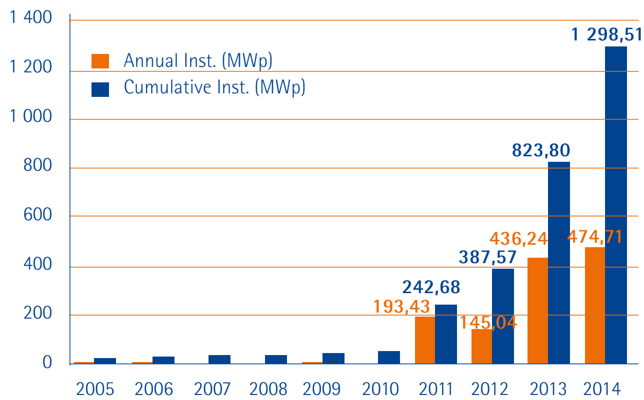

Fig. 1 - Cumulative Installation of PV Power Generation in Thailand as of 2014.

Fig. 2 - Solar PV Off-Grid System 2 kWp at Koh Phaluai School by Department of Alternative Energy Development and Efficiency, at Phaluai Island (Green Island), Suratthani, Thailand.

Fig. 3 - Solar PV Rooftop System 5 kWp at Department of Alternative Energy Development and Efficiency, Bangkok, Thailand.

In addition, the Government has also facilitated the installation of solar power generation by improvement of laws and regulations, as follows:

- 1) Exemption of the license factory requirement for solar PV rooftop installation with installed capacity less than 1 000 kWp.
- 2) In the process of the exemption of Building Act for installation of household solar PV rooftop installations with installed capacity up to 10 kWp, which is expected to be finalized in early 2015.

RESEARCH, DEVELOPMENT AND DEMONSTRATION ACTIVITIES

Currently, priority research topics are long term monitoring and system evaluation, PV penetration to the grid, acceleration testing for tropical climates and solar PV rooftop installation standards for quality and safety assurance. Several collaborations of the private sector, universities and research institutes are working towards long term monitoring of PV systems such as the National Energy Development Company (NED) with the King Mongkut's University of Technology Thonburi (KMUTT), NED-MUTT; SMA Solar Technology AG (SMA) with KMUTT, SMA-KMUTT; and The Petroleum Authority of Thailand (PTT) with the National Science and Technology Development Agency (NSTDA), PTT-NSTDA. In addition, the Energy Research Institute of Chulalongkorn University and the Department of Alternative Energy Development and Efficiency (DEDE) have conducted policy research to continually improve the Thailand renewable energy policy, such as the Thailand PV Roadmap.

The utilities are also very active in research and development of utilization of solar power. The Electricity Generating Authority of Thailand (EGAT), which has more than 25 years of experience in renewable energy applications and PV power generation demonstration projects, has approved and started the renewable energy learning center project in the Amphoe Thap Sakae PrachuapKhiri Khan Province in 2014.The project includes 5 MWp of different PV module technologies which consists of 1 MWp of crystalline silicon modules with sun tracking system, 1 MWp without tracking system, 2 MWp of amorphous silicon modules, 1 MWp of microcrystalline amorphous silicon modules, 1 MWp of copper indium diselenide modules (CIS), 250 kW of Wind Turbine and 500 kW of biogas power generation from Napier grass.

Distributed utility, Provincial Electricity Authority (PEA) with about 20 years of experience in renewable energy application for both PV systems and wind turbine generation, has focused more on the user side. The plan is to set up a learning center in which a smart home prototype will be demonstrated. This smart home consists of electricity generation by PV system and Wind turbine. The PEA smart home project will be started in 2015.

INDUSTRY AND MARKET DEVELOPMENT

Since the 1990s, most of PV system installations in Thailand have been from imported crystalline silicon PV cells and modules from Japan and Germany. With the Solar Home System Project in 2005, PV manufacturing factories for both crystalline and amorphous silicon modules were established. Since the introduction of the "Adder" scheme in 2007, PV modules have been mainly imported from China. Inverters and BOS have been imported from foreign countries, as well. The types of PV modules used are amorphous, monocrystalline, polycrystalline, amorphous/ microcrystalline or tandem, copper indium gallium selenide (CIS) and cadmium telluride (CdTe). The majority of solar power plants use silicon type modules, amorphous and polycrystalline.

Thailand's PV manufacturing activities are 200 MWp of PV modules and cells production and one local inverter manufacturer.

The PV association, "Thai Photovoltaic Industries Association" (TPVA) was established in 2011. The members come from both local and international companies. Moreover, TPVA also welcomes those who have businesses in other industries willing to be members of the association. The current number of members is ~ 90 companies.

In 2014, the average prices for PV systems in Thailand were approximately 1,96 - 2,73 USD/Wp, for residential scale, 1,76 - 2,12 USD/Wp for commercial scale and 1,58 – 1,76 USD/Wp for ground-mounted installations. The variable of price depends on system warranty and maintenance service.

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TURKEY

PV TECHNOLOGY STATUS AND PROSPECTS

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GENERAL FRAMEWORK AND IMPLEMENTATION

With a population reaching 76,7 million [1], Turkey's energy consumption based on primary energy resources is continuing to increase. Total installed capacity of electricity is 69 516 MW and when broken down by resources is 59,7 % thermic (natural gas, coals, liquid fuels etc.), 34 % hydro, 5,2 % wind and 1,1 % other renewables [2]. Turkey pays millions of dollars for its energy imports every year. Solar energy has the potential to reduce this cost in outstanding size, in the medium and long term. The Turkish Electricity Transmission Company (TEİAŞ) has projected the installed electricity capacity should reach from 64 008 GW (in 2013) to 80 307 GW (in 2018) to meet the demand [1].

Turkey has finalized the privatization of regional distribution to allow for an independent merchants' market. The privatization of state-owned generation assets has also continued with an increase in the share of the private sector in the energy generation. Additionally, one of the big advantages of Turkey is its operating as an energy hub between Europe and the Middle East. In order to establish a common energy market with the European Union, Turkey plans to interconnect its energy system with UCTE (Union for the Coordination of Transmission of Electricity) grid [3].

The total amount of investments to be made to meet the energy demand in Turkey until 2023 is estimated at around 130 BUSD. In the face of increasing oil prices and the need for national energy security, it is widely recognized that it is imperative for Turkey to increase the contribution of renewable energy resources rapidly.

NATIONAL PROGRAMME

In parallel to its population and GDP growth, Turkey has been experiencing rapid demand growth in all segments of the energy sector for decades. Turkey is developing an integrated energy policy aimed at securing a reliable supply of energy, as well as to achieve a low-carbon and environmentally sustainable future. Turkey also intends to promote employment and economic growth through its energy development. Solar energy has a major role in Turkey's renewable energy roadmap since the country is located geographically in a region called the "solar band."

Solar Energy is the most important alternative clean energy resource which is still untapped in Turkey. Cumulative installed PV power in Turkey is about 55 MW and still very little when compared to its high potential. The yearly average solar radiation is 1 311 kWh/m^2 per year and 3,6 kWh/m^2 per day. The total yearly insulation period is approximately 2 460 hours per year and 7,2 hours per day. The energy yield potential for a PV plant is 1 300-1 600 kWh/kWp.

The Law 6094 titled: "Utilization of Renewable Energy Resources for Electrical Energy Production" and related regulations prescribe the technical and financial procedures and principles for supplying energy to the grid. According to the Law 6094, a purchase guarantee of 13,3 USDcents/kWh is given for solar electric energy production for ten years. Some supplementary subsidies for domestic products are as follows:

- PV module installation and mechanical construction, (+0,8 USDcents/kWh)
- PV modules, (+1,3 USDcents /kWh)
- PV cells, (+,5 USDcents /kWh)
- Inverter, (+0,6 USDcents /kWh)
- Material focusing solar energy on PV modules, (+0,5 USDcents /kWh)

The Ministry of Energy and Natural Resources (ETKB) has updated its Strategy Plan (2015-2019) and it was declared to the public on December 3rd, 2014 [4]. According to this plan, it is aimed to reach 3 000 MW by the end of 2019 (see Table 1).

TABLE 1: THE PROJECTED SOLAR ENERGY CAPACITY BY ETKB [4]

	2015	2017	2019
PV Power Plant (MW)	300	1800	3000

Fig. 1 - The largest PV system in Turkey with the installed capacity of 5,3 MW in Malatya.

INDUSTRY AND MARKET DEVELOPMENT

The acceptance process (preliminary, final) to obtain production licenses for small-scale PV power projects up to 1 MW are ongoing and Turkish Electricity Distribution Company (TEDAŞ) is speeding up the process. The legislation defines the unlicensed electricity power limit at a maximum of 1 MW. Only the unlicensed PV plants have been installed in Turkey so far. Some investors preferred to setup MW scaled PV plants in total by covering a few unlicensed plants. 112 of 1 183 small-scale PV power projects (up to 1 MW) are already installed with 40 MW in total, in 2014, while the rest of projects with a capacity of 833 MW applied to the Turkish Electricity Distribution Company (TEDAŞ) are being evaluated to receive the acceptance. 264 of these applications with 197 MW received the preliminary acceptance by the end of 2014. Although the installed capacity is only 55 MW up to now, it proves to be an acceleration since the cumulative grid-connected installed PV power was about 2,5 MW and 6 MW at the end of 2012 and 2013, respectively. Additionally, the first license application round for a total of 600 MW projected PV projects larger than 1 MW has been completed by exceeding the proposed capacity by 15 times with 496 applications made to Energy Market Regulatory Authority (EPDK); reaching 8,9 GW in total. For the license applications, the presentation of at least 6 months of on-site measurement data to Energy Market Regulatory Authority (EPDK) is obligatory. Large-scale PV power projects of 13 MW received their preliminary licenses in 2014 and the rest of 600 MW (230 MW of this amount in the short term) is expected to receive the licenses following the competition process driven by Turkish Electricity Transmission Company (TEİAŞ) in 2015 which will be given by Energy Market Regulatory Authority (EPDK). These projects are 5 MW in Erzurum (Halk Enerji) and 8 MW in Elazığ (Solentegre Enerji Yatırımları San.Tic. A.Ş.). It is expected that the other tenders and license procedures will be concluded in 2015. The Ministry of Council will determine the new capacity for licensed projects after 2015.

Regarding PV manufacturing activities, currently there are not any manufacturers of feedstock, ingots or wafers in Turkey. China Sunergy Co. Ltd. (CSUN) is still the only cell manufacturer in Turkey. CSUN has an integrated cell and module manufacturing in the Trade Free Zone in Tuzla / İstanbul. The currently operating PV module manufacturing plants in Turkey are listed in Table 2, as noted by GÜNDER. The annual production capacities are given by one shift. There are also a few PV module constituents (glass, frame etc.) manufacturers in Turkey.

TABLE 2: THE OPERATING MODULE MANUFACTURERS IN TURKEY

COMPANY	ANNUAL PRODUCTION CAPACITY (MW)
Alfa Solar	10 MW
Ankara Solar	16 MW
Antak	6 MW
Bereket Enerji	150 MW
Csun	80 MW
Endüstri Elektrik	12 MW
Gazioğlu Solar	12 MW
Gest	13,5 MW
Gtc	6 MW
Ödül Solar	25 MW
Pekintaş Solar	24 MW
Pi Enerji	52 MW
Plurawatt	38 MW
Solartürk	20 MW
Solimpeks	12 MW
Tera Solar	15 MW
Zahit	12 MW

In 2012, the Izmir Development Agency initiated a "Renewable Energy and Environmental Technologies Financial Support Program." The program attracted 107 different applications, in which 24 of them was non-profit organizations. A total of 30 MTRY budget was reserved for the program and 42 applications were supported, of which 23 were PV system installation projects. Most of the projects was installed successfully in 2014.

Fig. 2 - 500 kW PV system in Izmir, Turkey; one of the supported projects by IZKA.

The solar PV market is being accelerated and development is seen in all dimensions, from production to installation, with the support of raising awareness in all levels of society. The Turkish Solar Energy Associations continued their endeavors to facilitate information flow for healthy market development. One of the events organized by GÜNDER and UFTP entitled, "SOLARTR 2014 Conference and Exhibition," was concluded in Izmir on November 19-21, 2014; in addition to several trainings, meetings and workshops organized for capacity building and removing the barriers throughout the entire year. The conference was organized with the participation of the leading orğanizations in the solar energy industry. From researchers to industry representatives, from public to contractors, all stakeholders came together to evaluate solar energy and the development of the industry. [5, 6]

Fig. 3 - SOLARTR 2014 Conference and Exhibition, November 2014.

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[3] "Republic of Turkey Prime Ministry – Investment Support and Promotion Agency," www.invest.gov.tr

[4] "Republic of Turkey Ministry of Energy and Natural Resources – Strategic Plan (2015 – 2019)," www.enerji.gov.tr

[5] www.gunder.org.tr

[6] www.solartr.org.tr

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UNITED KINGDOM

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

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UK GOVERNMENT SOLAR STRATEGY

In April 2014, the government published the 2nd part of its Solar Strategy, which aimed to encourage certain types of solar PV deployment. The strategy hinted at forthcoming changes in support mechanisms to discourage large ground mounted installations (which have sometimes been a subject of concern due to siting) but to encourage a breaking down of barriers for the non-domestic rooftop sector. This sector is not merely commercial roofs, but also public buildings. For example, figures from the Building Research Establishment (BRE) indicate that there are approximately 10 million square meters of roof space available on National Health Service properties alone.

The policy changes include allowing non-domestic system owners to take their PV system with them if they move premises and a relaxation of planning consent for roof-mounted systems up to 1 MW.
In order to act as an exemplar, the government has announced its plans to install 1 GW of PV on its own estates in the forthcoming year. The BRE National Solar Centre [1] has been working with the Institute of Engineering Technology to produce new installation guidance aimed at raising the quality of installations, and this is to be applied to the government estate projects.

INSTALLATION FIGURES

The Department of Energy and Climate Change (DECC) [2] publishes monthly updates on solar deployment. The government's view is that at the end of 2014, overall solar PV capacity had reached 5,095 MW, an increase of 79 % (2,249 MW) on that at the end of 2013. This represented 649 787 installations, which is an increase of 28 % (141 316 installations) on that at the end of 2013. At the end of January 2015, DECC's figures show that overall UK solar PV capacity reached 5,143 MW, across 658 676 installations, with more than 500 000 of these being domestic systems.

However, some industry commentators regard these figures as conservative because there can be a time lag of several months before certain types of project are registered. Figure 1 shows the climb in PV capacity in the UK from 2008 to the end of 2014, according to DECC's records.

As well as the feed-in tariffs, the other main driver for larger PV installations in the UK have been the tradable Renewable Obligation Certificates (ROCs), which are issued to registered generators of renewable electricity, based on amount of energy generated. However, the ROC system for systems over 5 MW has been closed to installations of 5 MW and above from 1st April 2015. This was a surprise announcement in the April 2014, as the scheme had been scheduled to continue until 2017 for all systems above 50 kW. This has caused some large projects to stall, whilst others are rushing to complete before the deadline. Systems below 5 MW are unaffected by this announcement.
The government's intention is for ROCs to be replaced by a guaranteed pricing scheme called Contracts for Difference (CfD). In this scheme, a defined generation capacity is auctioned to the lowest bidder.
The UK conducted its first CfD auction in March 2015, in which solar technologies competed for support with other technologies, such as on-shore wind, small hydro and electricity from waste projects. Only 72 MW of capacity was won by 5 PV projects compared to approximately 750 MW of onshore wind. A total of 27 contracts is worth 315 MGBP, and has been offered to projects that will deliver over 2 GW of renewable energy in England, Scotland and Wales.
The domestic sector continues with steady growth at approximately 3 000 systems per week being completed.

Solar Photovoltaics Deployment (quarters)

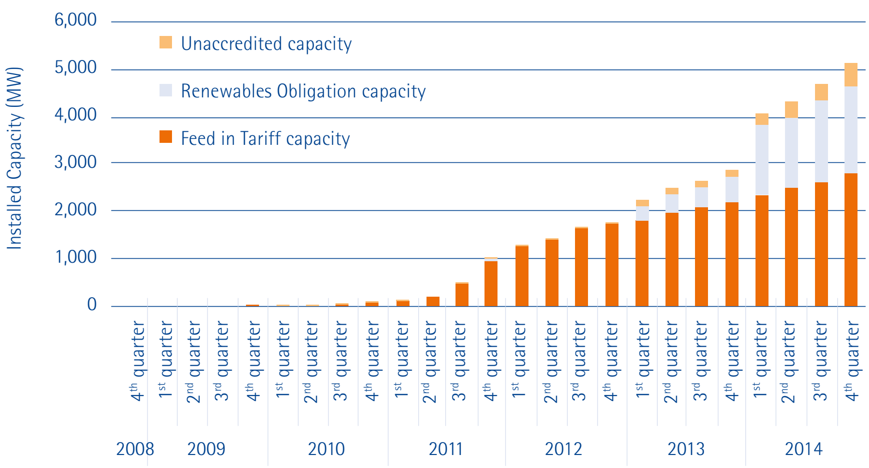

Fig. 1 - Total UK installed PV capacity. Source: DECC.

[1] www.BRE.co.uk/NSC
[2] www.gov.uk/DECC

THE UNITED STATES OF AMERICA

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

DAVID FELDMAN, NATIONAL RENEWABLE ENERGY LABORATORY

Fig. 1 - A residential home retrofitted with photovoltaic (PV) panels in Lakewood, CO (Photo: Dennis Schroeder / NREL).

GENERAL FRAMEWORK AND IMPLEMENTATION

The United States (U.S.) photovoltaic (PV) market development is supported by both national and state level financial incentives, yet state and local policies in support of increased solar deployment are more varied than national policies. In 2014, the U.S. Environmental Protection Agency (EPA), which regulates power plant carbon emissions, issued proposed rules for carbon emissions reductions of 30 % (from 2005 levels) by a state-by-state approach to be implemented between 2020 and 2030. These rules are not finalized nor will there necessarily be specific solar adoption targets, however if implemented these regulations could encourage significant PV adoption in several areas of the United States. To date a national level mandate has not been implemented, however there have been individual state mandates successfully executed. Despite the lack of a unified national framework, existing policy at the national and state level has enabled PV to continue growing rapidly in the U.S. as a result of local and state initiatives, with the U.S. adding 6,2 GW_{DC} of PV capacity in 2014. At the end of 2013, cumulative installed PV capacity in the U.S. totaled approximately 12,1 GW, bringing the U.S. cumulative installed total at the end of 2014 to 18,3 GW [1].

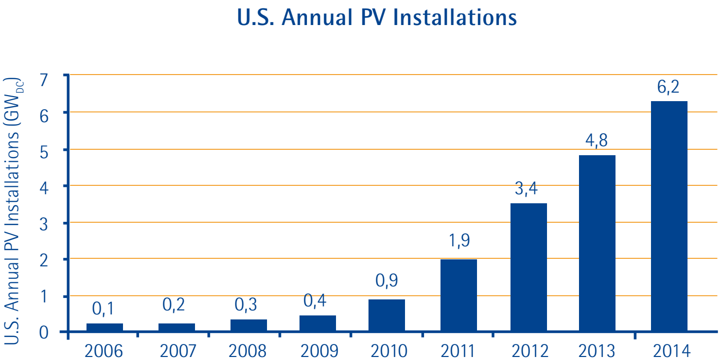

Fig. 2 – U.S. Annual PV Installations. Source: GTM/SEIA, U.S. Solar Market Insight Report. 2014 Year-In-Review. March 2015.

Several policy and financing mechanisms are emerging that have the potential to incite further solar market expansion through the establishment of widespread local and utility programs. Such policies include low-cost loan programs tied to a customer's utility bill or property taxes as well as time of use rate structures. Third-party ownership has also gained significant popularity for financing the installation of PV systems, particularly in the residential sector, where in some markets it has achieved 70 % - 80 % market penetration. In 2014 several companies have introduced loan products structured to enable customers to receive many of the benefits of third-party ownership while enjoying the benefits of ownership. Companies have also issued innovative financing mechanisms to raise cheaper sources of capital through public markets.

NATIONAL PROGRAM

The U.S. supports the domestic installation and manufacturing of PV generating assets for domestic consumption. Financial incentives for U.S. solar projects are provided by the national government, state and local governments, and some local utilities. Historically, national incentives have been provided primarily through the U.S. tax code, in the form of a 30 % Investment Tax Credit (ITC) (which applies to residential, commercial, and utility-scale installations) and accelerated 5-year tax depreciation (which applies to all commercial and utility-scale installations and to third-party owned residential, government, or non-profit installations).

State incentives in the U.S. have been driven in large part due to the passage of Renewable Portfolio Standards (RPS). An RPS, also called a renewable electricity standard (RES), requires electricity suppliers to purchase or generate a targeted amount of renewable energy by a certain date. Although design details can vary considerably, RPS policies typically enforce compliance through penalties, and many include the trading of renewable energy certificates (RECs). A clean energy standard (CES) is similar to an RPS, but allows a broader range of electricity generation resources to qualify for the target. As of September 2014 twenty-three states and Washington D.C. had RPS policies with specific solar or customer-sited provisions. [2] Many states also require utilities to offer net metering, a billing mechanism which credits

[1] GTM Research/ SEIA. Q3 2014: U.S. Solar Market Insight. December 2014.

[2] Database of State Incentives for Renewables & Efficiency. Accessed January 22, 2015. http://www.dsireusa.org/documents/summarymaps/RPS_map.pdf

Fig. 3 - 2014 NREL South Table Mesa Campus. Aerial view of the RSF, S&TF, and ESIF, at the National Renewable Energy Laboratory (NREL), South Table Mesa campus (STM) Aerial view of the National Renewable Energy Laboratory (NREL), South Table Mesa campus (STM). (Photo: Dennis Schroeder / NREL).

electricity produced by a solar energy system fed back to the grid. In 2014 the number of states with net metering laws increased to 44 and several states expanded the amount of installed capacity which could participate in these programs.

The U.S. government also supports PV manufacturing and deployment through its work at the Department of Energy's SunShot Initiative, discussed in the Research and Development section below.

RESEARCH, DEVELOPMENT & DEMONSTRATION

The DOE is one of the primary bodies that support research, development, and demonstration (RD&D) of solar energy technologies. In February 2011, the Secretary of Energy launched the SunShot Initiative, a program focused on driving innovation to make solar energy systems cost-competitive with other forms of energy. To accomplish this goal, the DOE is supporting efforts by private companies, academia, and national laboratories to drive down the cost of utility-scale solar electricity to about 6 USDcents per kilowatt-hour, and distributed solar electricity to be at or below retail rates. This in turn could enable solar-generated power to account for 14 % of America's electricity generation by 2030 (assuming other systemic issues are addressed as well). [3] By funding selective RD&D concepts, the SunShot Initiative promotes a genuine transformation in the ways the U.S. generates, stores, and utilizes solar energy.

DOE's Solar Energy Technologies Office (SETO), Office of Science, and Advanced Research Projects Agency - Energy (ARPA-E) collaborate to accomplish the goals of the SunShot Initiative. The majority of RD&D funding under the initiative is provided by SETO, thus this summary focuses on the RD&D funded by SETO. The initiative focuses on removing the critical barriers for the system as a whole, including technical and non-technical barriers to installing and integrating solar energy into the electricity grid. In addition to investing in improvements in solar technologies and manufacturing, the department focuses on integrating solar generated energy systems into the electricity grid and reducing installation and permitting costs. The DOE focuses on innovative technology and manufacturing process concepts as applied to PV. It also supports PV systems integration, by developing radically new approaches to reduce the cost and improve the reliability and functionality of power electronics; by supporting industry development through test and evaluation standards; and by developing tools for understanding grid integration issues. Emphasis is also placed on market transformation areas to quantitatively address non-hardware related balance-of-system costs including streamlined permitting, inspection, and interconnection as well as performing key analyses of policy options and their impact on the rapid deployment of solar technologies.

Examples of SETO funded research and development activities in 2014 include:

- Working with small businesses to eliminating market barriers and reduce non-hardware costs and to encourage technology innovation to support SunShot goals.
- Working with industry, national laboratories and university researchers to advance the state of the art for solar forecasting, speed solar energy innovation, and lower costs and improve grid inter-connection.
- Working with utilities to develop adaptable and replicable practices, long-term strategic plans, and technical solutions to sustain reliable operations with large proportions of solar power on the grid.

[3] U.S. Department of Energy (DOE). (2012). SunShot Vision Study. DOE/GO-102012-3037. Washington, DC: U.S. Department of Energy. Accessed 2013: http://www1.eere.energy.gov/solar/pdfs/47927.pdf

RESEARCH	MUSD	45
DEVELOPMENT	MUSD	79
DEMONSTRATION	MUSD	65
DEPLOYMENT	MUSD	68
TOTAL	**MUSD**	**257**

Fig. 4 - Breakdown of Solar Energy Technologies Program FY 14 R&D Activities.

It is estimated that the RD&D funding provided by SETO, as shown in Figure 4, accounts for approximately 50 % of all public RD&D in the U.S. In addition, U.S. RD&D funding also comes from the Department of Energy's Office of Science and ARPA-E, as well as the National Science Foundation, the Department of Defense, the National Aeronautics and Space Administration, and states such as California, New York, Florida and Hawaii.

INDUSTRY AND MARKET DEVELOPMENT

In 2014, the U.S market increased its annual installation by approximately 1,4 GW, from roughly 4,8 GW in 2013 to 6,2 GW in 2014. U.S. annual installations have been growing rapidly during the past five years, from 0,9 MW in 2010 to 6,2 MW in 2014. [4] Much of the recent growth came from utility-scale installations, though the residential market has also increased in size. PV capacity continues to be concentrated in a small number of states, such as California, Arizona and New Jersey, which comprise two-thirds of the market. However, this trend is changing slowly as 25 states currently have 50 MW or more of PV capacity and 15 states each installed more than 50 MW in 2014 alone. [5] With more than 3,4 GW of PV projects under construction as of February, that have individual capacities above 1 MW in size, total installations in 2015 are expected to increase yet again [6]. Though some incentive programs in the U.S. have expired or been reduced, many projects currently under construction have already qualified to receive an award. In addition, due to the continued reduction in system pricing as well as the availability of new loan products and third-party ownership arrangement with lower financing costs, a significant portion of PV systems have recently been installed without any state incentives. Finally, state RPS targets require a larger amount of renewable energy additions in 2015 than in previous years, encouraging more growth within the market.

U.S. PV manufacturing, which contracted in 2011-13 after having shipment growth of 10 times from 2003-2010, began to recover in 2014. At least seven companies announced in 2014 that they would be adding manufacturing capacity in the U.S. over the next five years which could more than double U.S. cell and module manufacturing capacity.

Additionally, U.S. manufacturing has a significant presence in other parts of the PV value chain, including polysilicon, encapsulants, wiring, and fasteners. U.S. solar manufacturing jobs increased by 9 % from 2013-2014, to a total of approximately 2 500 employees. In 2015, this number is projected to increase another 14 %. [6] Additionally, manufactured hardware is only a portion of the total solar value chain. Industry-wide, approximately 80 000 jobs relating to solar were added from 2010 to 2014, growing to a total of 174 000 employees (31 000 of which were added in 2014 alone). The growth rate from 2013 to 2014 of 22 % was twenty times faster than what the overall U.S. economy experienced during that same time period. [7]

[4] GTM Research/ SEIA, Q3 2014: U.S. Solar Market Insight. December 2014.
[5] GTM Research/ SEIA, Q3 2014: U.S. Solar Market Insight. December 2014.
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COMPLETED TASKS
TASK 2 - PERFORMANCE, RELIABILITY AND ANALYSIS OF PHOTOVOLTAIC SYSTEMS

OVERALL OBJECTIVE

The objective of Task 2 was to provide technical information on PV operational performance, long-term reliability and costs of PV systems, which is very important for an emerging technology. This service was given to a diverse target audience including PV industry, research laboratories, utilities and manufacturers, system designers, installers, standardisation organisations and the educational sector. Task 2 aimed to provide performance data for both general assessments of PV system technologies and improvements of system design and operation.

MEANS

Task 2 work was structured into seven subtasks in order to achieve the objectives.
These were achieved through the development and continuous update of the PV Performance Database, an international database containing information on the technical performance, reliability and costs of PV power systems and subsystems. Task 2 also analysed performance and reliability data for PV systems and components in their respective countries. Activities included the work on the availability of irradiation data, performance prediction for PV systems, shading effects and temperature effects as well as long-term performance and reliability analysis, monitoring techniques, normalised evaluation of PV systems, user's awareness and quality aspects of PV system performance.

Subtasks 1, 5, 6 and 7 were terminated at the end of 2007, while Subtask 3 was concluded in 1999 and Subtasks 2 and 4 were terminated in 2004. Task 2 was officially concluded in 2007.

SUBTASK 1: PV PERFORMANCE DATABASE

Participants worked on the development and update of a PV Performance Database, an international database containing information on the technical performance, reliability and costs of PV systems and subsystems located worldwide. The information was gathered and presented by means of standard data collection formats and definitions. The database allows the comparison of components' quality, long-term operational results, analysis of performance and yields, long-term operational results, analytical calculations, yield prediction and checking of design programmes. A collection of such a variety of high quality operational data presents a unique tool for PV system performance analysis. The performance data are available at the IEA PVPS website: www.iea-pvps.org. In addition, the complete database programme can be downloaded from the same website.

SUBTASK 2: ANALYSIS OF PV POWER SYSTEMS (FROM 1999 TO 2004)

Participants analysed performance and maintenance data for PV power systems and components in their respective countries, both in order to ensure the quality and comparability of data entered in the database under Subtask 1 and to develop analytical reports on key issues such as operational performance, reliability and sizing of PV systems. Participants also compared existing data on operational reliability and developed recommendations on maintenance aspects.

SUBTASK 3: MEASURING AND MONITORING APPROACHES (FROM 1995 TO 1999)

Participants worked on a handbook covering PV system monitoring techniques, normalised analysis of PV systems and national monitoring procedures in the IEA member countries. This document covered measuring and monitoring in the context of PV systems and expanded in breadth and details the issue of monitoring. It helped orientating and relating technical explanations and details of existing experiences and guidelines. Available documentation on measuring and monitoring approaches was brought together and assessed for their scope and contents.

SUBTASK 4: IMPROVING PV SYSTEMS PERFORMANCE (FROM 1999 TO 2004)

Participants worked on recommendations on sizing of PV power systems and suggested improvements for better PV system performance. Participants identified tools to process and analyse data for performance prediction and sizing purposes. Applied energy management schemes were analyzed from the energy and operating cost points of view. Participants took account of the work performed in other Subtasks and worked in collaboration with Task 3.

SUBTASK 5: TECHNICAL ASSESSMENTS AND TECHNOLOGY TRENDS OF PV SYSTEMS

Participants analysed and validated expertise and performance results from grid-connected (GCS), stand-alone (SAS) and PV-based hybrid systems. The aims of this subtask were to demonstrate up-to-date performance validation criteria for a qualitative ranking of PV grid-connected, stand-alone and PV-based hybrid systems. It also identified high performance products, technologies and design methodology in order to foster the development of maximum conversion efficiency and optimum integration of PV. Activities included evaluating PV performance over time and failure statistics, analysing the end-user's consciousness on PV system performance and the use of satellite images for PV performance prediction.

SUBTASK 6: PV SYSTEM COST OVER TIME

Task 2 identified and evaluated 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. Participants worked on national case studies on performance and costs in their countries to provide a good insight of performance and cost trends of PV systems for a 10-year-period.

SUBTASK 7: DISSEMINATION ACTIVITIES

Task 2 put enhanced efforts to disseminate Task 2 results & deliverables to target audiences on the national and international level using websites, workshops & symposia as well as presentations at conferences and seminars. Task 2 deliverables range from the PV Performance Database to technical reports and conference papers. The public PVPS and Task websites enabled downloads and technical information to be provided quickly and cost-effectively to the users. The Task 2 website is available in eight different languages spoken by the Task delegates. For gaining information on the user profile and customers of Task 2 deliverables, monthly download statistics were prepared on a regular, biannual basis.

Activities included seminar presentations, training courses for system designers and installers (Italy), European master course and university seminars to advanced students (France, Germany), conference contributions for national and international audiences as well as presentations and distributions of the Performance Database programme and other Task 2 deliverables.

Task 2 developed a web based educational tool in close cooperation with Task 10. This tool represented a detailed, practical source of information on building integrated PV from the idea to the long-term operation of PV systems.

TASK 2 REPORTS AND DATABASE

Task 2 produced the following technical reports, workshop proceedings and database programme from 1997 to 2007:

Database

IEA PVPS Database Task 2, T2-02:2001

Task 2 Technical Reports

1. Analysis of Photovoltaic Systems, T2-01:2000, April 2000
2. Operational Performance, Reliability and Promotion of Photovoltaic Systems, T2-03:2002, May 2002
3. The Availability of Irradiation Data, T2-04:2004, April 2004
4. Country Reports on PV System Performance, T2-05:2008, December 2004
5. Cost and Performance Trends in Grid-Connected Photovoltaic Systems and Case Studies, T2-06:2007, December 2007
6. Performance Prediction of Grid-Connected Photovoltaic Systems Using Remote Sensing, T2-07:2008, March 2008

Task 2 Internal Reports

1. Handbook on Monitoring and Monitoring Approaches, ECN, Netherlands, November 1998
2. Proceedings of Workshop "PV System Performance, Technology, Reliability and Economical Factors of the PV Industry", ISFH, Germany, October 2005
3. Report on Users' Awareness of PV System Performance, AIST, Japan, September 2007.

DELIVERABLES – WHERE TO GET THEM?

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

PARTICIPANTS

Thirteen countries supported Task 2 activities:
Austria, Canada, European Union, EPIA, France, Germany, Italy, Japan, Poland, Sweden, Switzerland, United Kingdom, United States.

Participants represented the following sectors: research & development, system engineering, PV industry and utility.

CONTACT INFORMATION

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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

SCOPE FOR FUTURE ACTIVITIES

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

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.

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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 pea 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

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COMPLETED TASKS
TASK 6 - DESIGN AND OPERATION OF MODULAR PHOTOVOLTAIC PLANTS FOR LARGE SCALE POWER GENERATION

OVERALL OBJECTIVE

Task 6 officially completed its activities in May 1998. The main objective of this Task was to further develop large-scale modular photovoltaic plants for peaking and long-term baseload power generation in connection with the medium-voltage grid.

MEANS

The Task 6 work was performed by structural engineers and PV industry experts. The work was structured into four subtasks, for a total of fifteen activities.

SUBTASK 10: Review of Design and Construction Experiences of Large-Scale PV Plants

To perform, on the basis of the Paestum Workshop results, an in-depth review of existing large-scale PV plants aimed both to identify the remarkable technical solutions adopted in such plants and the main common criteria applied for their design, installation, operation, monitoring, and to perform a detailed cost analysis of the plants taken into account.

SUBTASK 20: Review of Operational Experiences in Large-Scale PV Plants

To perform, also utilising the work in progress of Subtask 10 and on the basis of the Paestum Workshop results, an in-depth review of operational experiences in existing large-scale PV plants. The analysis of the acquired data was focused on the comparison between the expected and actual results, both technical and economical; the information flow was continuously updated through acquisition of data from all the plants in operation.

SUBTASK 30: Development of Improved System Design and Operational Strategies for Large-Scale PV Plants

Based on the work of Subtasks 10 and 20, the evaluation work, together with the information gathering activity, let the assessment of most appropriate, innovative technical options for modular design of large-scale PV plants. Both PV and BOS components were dealt with, taking into account: performances improvement, costs reduction, and realisation simplification.

The co-operation among utilities and industries of many countries offered the opportunity to review in detail the performance data and the technical aspects which determined the design approach of the largest PV plants in the world, and to develop improved system design, and operational strategies for such plants.

SUBTASK 40: Outlook of Perspectives of Large-Scale PV Plants

Based on the assumption that large grid connected PV power plants have proven their applicability under the technical point of view, the Subtask was aimed at identifying the path in order to let such plants become a substantial option and play an increasing role in a future oriented energy concept in OECD countries, as well as in developing countries.

TASK 6 REPORTS AND WORKSHOP PROCEEDINGS

Task 6 produced the following reports and workshop proceedings from 1993 to 1998:

1. The Proceedings of the Paestrum Workshop.
2. A PV Plant Comparison of 15 plants.
3. The State of the Art of: High Efficiency, High Voltage, Easily Installed Modules for the Japanese Market.
4. A document on "Criteria and Recommendations for Acceptance Test."
5. A paper entitled: "Methods to Reduce Mismatch Losses."
6. Report of questionnaires in the form of a small book containing organized information collected through questionnaires integrated with statistical data of the main system parameters and of the main performance indices.
7. The "Guidebook for Practical Design of Large Scale Power Generation Plant," edited by the Japanese expert.
8. The "Review of Medium to Large Scale Modular PV Plants Worldwide."
9. Proceedings of the Madrid Workshop.

DELIVERABLES - Where to get them?

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

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COMPLETED TASKS
TASK 7 - PHOTOVOLTAIC POWER SYSTEMS IN THE BUILT ENVIRONMENT

OVERALL OBJECTIVE

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

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

For this, active involvement of urban planners, architects and building engineers is required. Task 7 motivated the collaboration between these groups and PV system specialists, utility specialists, PV and building industry and other professionals involved in photovoltaics.

Task 7 considered all grid connected systems other than classified as «ground based arrays». Primary focus of this Task was on the integration of PV into the architectural design of roofs and facades of residential, commercial and industrial buildings and other structures in the built environment (such as noise barriers, parking areas and railway canopies), and on other market factors, both technical and non-technical, that need to be addressed and resolved before wide spread adoption of PV in the built environment will occur. Task 7 officially started on January 1, 1997 and finished end 2001. In 2002, the last reports and deliverables were published. At the end of 2003 there remained only one outstanding issue: the publication of the book «Designing with Solar Power». This book is expected in Spring 2005.

SUBTASK 1: Architectural Design of Photovoltaic Power Systems in the Built Environment

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

SUBTASK 2: Systems Technologies for Photovoltaic Power Systems in the Built Environment

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

SUBTASK 3: Non-Technical Barriers in the Introduction of Photovoltaic Power Systems in the Built Environment

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

SUBTASK 4: Demonstration and Dissemination of Photovoltaic Power Systems in the Built Environment

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

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

TASK 7 REPORTS

Task 7 produced the following reports from 1999 to 2002:

1. Literature Survey and Analysis of Non-technical Problems for the Introduction of BIPV Systems, B. van Mierlo & B. Oudshoff, IVAM Environmental Research, 1999. To be ordered at IVAM Environmental Research, NL, Fax + 31 20 525 58 50
2. PV in Non Building Structures - A Design Guide, M.A. Romero, EcoCode-Miljö och Architectur, 1999. To be ordered at Energiebanken, SE, Fax: +46 652 13 427
3. Potential for Building Integrated Photovoltaics, M. Gutschner, NET Nowak Energie & Technologie 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.

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Task 7 deliverables: www.iea-pvps.org
Task 7 demosite: www.demosite.ch

COMPLETED TASKS
TASK 10 - URBAN SCALE PV APPLICATIONS

OVERALL OBJECTIVE

The objective for Task 10 was to develop the tools, analysis and research required to mainstream PV in the urban environment.
The Task 10 products render the explosive market growth experiences from many countries into an array of relevant information for the multiple stakeholders required to continue PV growth in the world's energy portfolio.

The definition for urban scale PV applications:
Urban-scale applications include small, medium and large installations on both existing and new buildings, homes, sites, and developments as well as point-of-use, targeted load solutions on a distributed basis throughout the high density urban environment.

MEANS

There were four Subtasks in Task 10. The total range of deliverables was 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. Through developing and producing these deliverables, Task 10 contributed to achieving the vision of mainstreaming urban-scale PV. Targeted stakeholders were the:

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

SUBTASK 1: Economics and Institutional Factors

This subtask provided opportunities for stakeholders to look beyond a single-ownership scenario to the larger multiple stakeholder values of the PV technology. In this way, utility tariffs, community policy, and industry deployment strategy could be used to create scenarios which combined all stakeholder values to the PV system investor through sustained policy-related market drivers.

SUBTASK 2: Urban Planning, Design and Development

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

In 2009 the book, *Photovoltaics in the Urban Environment: Lessons learnt from Large Scale Projects*, was published and launched at the 2009 EU - PV Solar Exposition and Conference in Hamburg, Germany. The book contains case studies of 15 existing and 7 planned urban PV communities, as well as information on regulatory framework and financing and design guidelines.

The report Urban Photovoltaic Electricity Policies was also published in 2009. The report provides information and analysis on both direct and indirect urban policies relating to PV.

SUBTASK 3: Technical Factors

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

An extensive body of work was finalised into a report on grid issues, *Overcoming PV Grid Issues in Urban Areas*. The report documents the issues and countermeasures relating to integrating PV on the grid. The report also provides three case studies of high penetration urban PV projects in Japan, France and Germany.

SUBTASK 4: Targeted Information Development and Dissemination

This subtask focused on the information dissemination of all deliverables produced in Task 10. The range of activities in this task included workshops, educational tools, databases, and reports. An innovative deliverable involved holding two marketing competitions for urban-scale PV designs and application targeted at urban solutions. Both competitions were sponsored by industry.

TASK 10 KEY DELIVERABLES

Reports

- *Analysis of PV System's Values Beyond Energy -by country, by stakeholder,*
- *Promotional Drivers for Grid Connected PV*
- *Urban PV Electricity Policies*
- *Municipal utility forward purchasing*
- *Residential Urban BIPV in the Mainstream Building Industry*
- *Community Scale Solar Photovoltaics: Housing and Public Development Examples Database*
- *Overcoming PV Grid Issues in Urban Areas*
- *Compared assessment of selected environmental indicators of photovoltaic electricity in OECD cities*
- *Lisbon Ideas Challenge I*
- *Lisbon Ideas Challenge II*

Book

Photovoltaics in the Urban Environment: Lessons learnt from Large Scale Projects

Databases
Databases
Educational Tool of BIPV Applications from Idea to Operation.
Database of community and BIPV applications.

PowerPoint
Network Issues and Benefits Visual Tool

Workshops
2nd International Symposium - Electricity From the Sun, Feb. 11, 2004 Vienna, AUS
PV integration in urban areas, Oct.6, 2005, Florence, ITA
Photovoltaics in Buildings - Opportunities for Building Product Differentiation, Mar.16, 2005, Lisbon, POR
Photovoltaic Solar Cities - From global to local, June 1, 2005, Chambéry, FRA
International Workshop: Photovoltaic in Cities, Sept 13, 2006, Malmö, SWE
Lisbon Ideas Challenge (LIC I) Final Ceremony, Nov. 23, 2006, Lisbon, POR
PV in the Urban Planning Process, Oct 24, 2007, Madrid, ESP (PV-UP-Scale)
PV international experiences towards new developments, May 13, 2009 Rome ITA

DELIVERABLES - WHERE TO GET THEM?
All reports are available for download at the IEA PVPS website: http://www.iea-pvps.org and the Task 10 website: http://www.iea-pvps-task10.org

PARTICIPANTS
Fifteen PVPS members supported Task 10 activities:
Australia, Austria, Canada, Denmark, France, Italy, Japan, Korea, Malaysia, European Union, Norway, Portugal, Sweden, Switzerland and the USA. Moreover, through PV-UP-Scale, Germany, The Netherlands, Spain and the United Kingdom made contributions to Task 10 work.

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COMPLETED TASKS
TASK 11 – HYBRID SYSTEMS WITHIN MINI-GRIDS

INTRODUCTION
Task 11 was 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 was on mini-grid systems in which energy generators, storage systems and loads are interconnected by a "stand-alone" AC distribution network with relative 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.

TASK 11 STRATEGY AND ORGANIZATION
In general, Task 11 followed a strategy, similar to previous PVPS Tasks, in which the current states of technology and design practice in the participating countries were first assessed and summarized. Further work then focused 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.

Task 11's Workplan was divided into four subtasks and a number of detailed work activities on key aspects of PV hybrid and mini-grid technology and implementation.

SUBTASK 10: Design Issues
Subtask 10 addressed PV hybrid system design practices. Tradeoffs have to be made between first cost, energy efficiency, and reliability. The correct choice of components and system architecture is critical. The subtask had the following three activities:

- Review, analysis and documentation of current hybrid mini-grid system architectures;
- Evaluation and comparison of software based design tools for PV hybrid systems and mini-grids;
- Documentation of best practices for design, operation, and maintenance of PV hybrid projects.

SUBTASK 20: Control Issues
Subtask 20 addressed 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 had the following five activities:

- Investigation of existing methods for stabilizing voltage and frequency in mini-grids and recommendations for further development;
- Investigation of data communication architectures and protocols for mini-grids;
- Evaluation of supervisory control parameters and strategies for mini-grids;
- Evaluation of the role of energy storage technologies to stabilize mini-grid operation;
  Investigation of 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 addressed the goal of increasing the use of the PV resource in PV hybrid systems and displacing fossil fuel resources. It had the following two activities:

- Development of performance assessment criteria for PV hybrid systems that allow objective comparison of different systems;
- Development of recommendations to increase the solar fraction in hybrid systems through demand side management and optimization of the battery energy storage system.

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

- Documentation of field experience and learning that demonstrate the social and political framework for successful operation of PV hybrid systems within mini-grids;
- Evaluation of the financial aspects of PV hybrid power systems, considering both first costs and operating costs, and determining the conditions for economic sustainability;
- Evaluation of the environmental impacts and benefits of PV hybrid systems with focus on greenhouse gas emission mitigation and potential for recycling of system components.

TASK 11 KEY DELIVERABLES
Task 11 completed the majority of its Workplan. The following deliverable reports were published:

1. Worldwide Overview of Design and Simulation Tools for PV Hybrid Systems - T11-01:2011
2. The Role of Energy Storage for Mini-Grid Stabilization - T11-02:2011
3. Sustainability Conditions for PV Hybrid Systems: Environmental Considerations - T11-03:2011
4. COMMUNICATION BETWEEN COMPONENTS IN MINI-GRIDS: Recommendations for communication system needs for PV hybrid mini-grid systems - T11-04:2011
5. Social, Economic and Organizational Framework for Sustainable Operation of PV Hybrid Systems within Mini-Grids - T11-05:2011
6. Design and operational recommendations on grid connection of PV hybrid mini-grids - T11-06:2011
7. PV Hybrid Mini-Grids: Applicable Control Methods for Various Situations - T11-07:2012
8. Overview of Supervisory Control Strategies Including a MATLAB® Simulink® Simulation - T11-08:2012

DELIVERABLES – WHERE TO GET THEM?
Task 11 deliverable reports have been published electronically on the IEA PVPS website http://www.iea-pvps.org.

PARTICIPANTS
In the final year of the Work Plan, eleven IEA PVPS countries participated in Task 1l: Australia, Austria, Canada, China, France, Germany, Italy, Japan, Malaysia, Spain, and the USA. The management of the Task - the Operating Agent - was executed by Canada.

SUBSEQUENT ACTIVITY
PVPS Task 9 has taken on the dissemination and further development of several of the Task 11 results and activities.

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