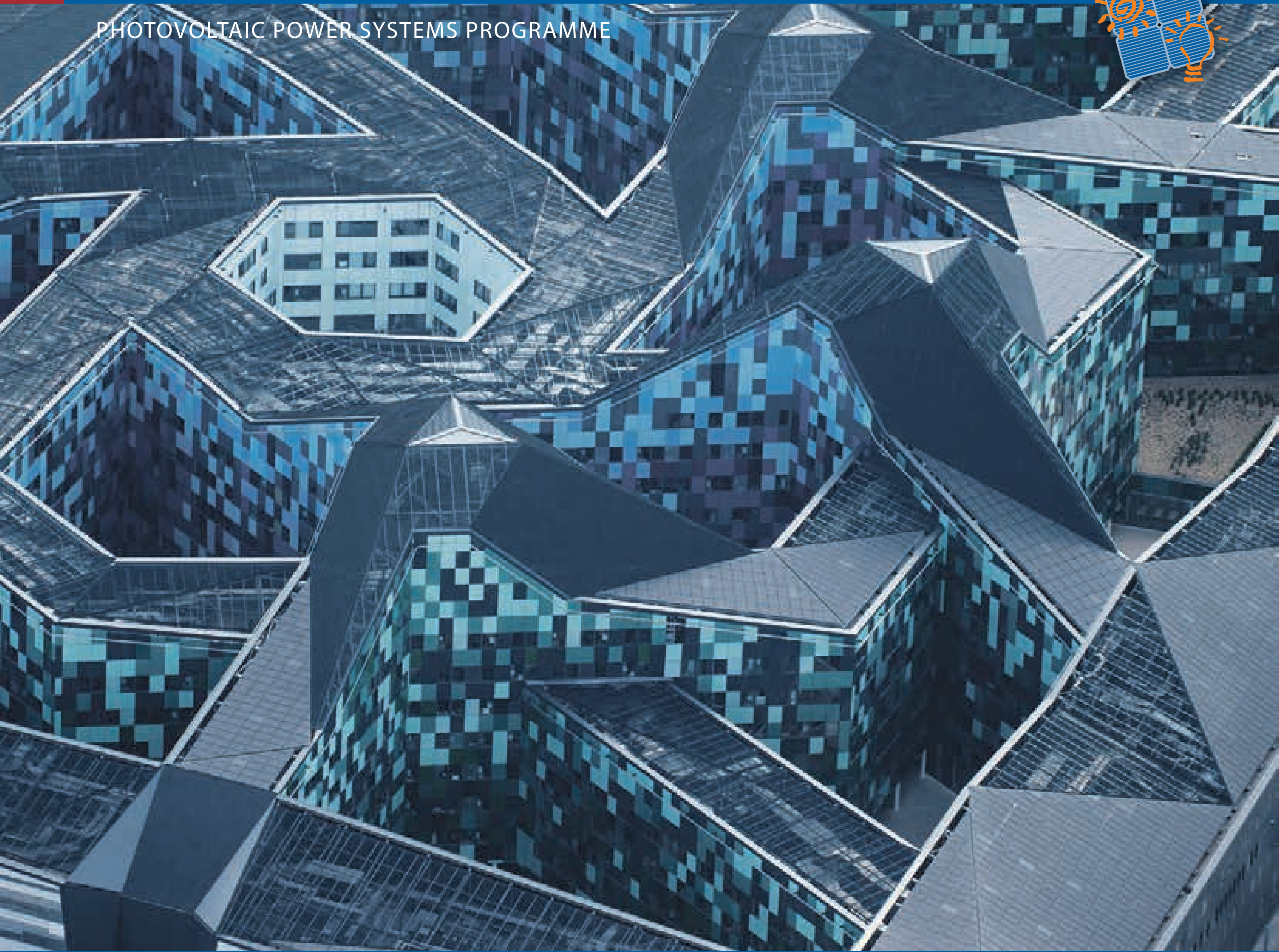
IEA INTERNATIONAL ENERGY AGENCY

PHOTOVOLTAIC POWER SYSTEMS PROGRAMME



PVPS

annual report 2015

PHOTOVOLTAIC POWER SYSTEMS
TECHNOLOGY COLLABORATION PROGRAMME

PHOTOVOLTAIC POWER SYSTEMS PROGRAMME

ANNUAL REPORT 2015

COVER PHOTO:

The BIPV roof of the new French Ministry of Defence, situated in the south-west of Paris.

The 7 000 m² of monocrystalline custom made PV cells make it the single largest PV roof in Paris (820 kWp). The installation is composed of 1 500 different module shapes, which are integrated in the roof using a non-visible mounting system.

PV installation planned and produced by:
Architects: A/NM/A Agence Nicolas Michelin & Associés, Gérald SELLIER
General Contractor: Bouygues Constructions
BIPV Contractor: ISSOL

Cover photo and above photo by: ©R. Nicolas-Nelson / Armée de l'Air

CHAIRMAN'S MESSAGE

The IEA Photovoltaic Power Systems Programme IEA PVPS is pleased to present its 2015 annual report. A further strong global market growth and a continued increase in competitiveness of solar photovoltaic (PV) power systems make PV one of the most vibrant developments in the present energy technology landscape. Achieving levelized costs of electricity from PV as low as below 5 USDcents/kWh, establishing Gigawatt (GW) scale markets in an increasing number of countries around the world and a continuous evolution of the market framework set the scene for our collaborative efforts focussed on a further sustainable development of PV technology, industry, applications and markets.

2015 has seen close to 50 GW of additional installed PV capacity worldwide, 25 % above 2014 and raising the cumulative installed capacity close to 230 GW. As in 2014, China, Japan and the USA represented the largest markets in 2015, accounting for two-thirds of the additional installed capacity. Meanwhile, more than 50 % of the global PV capacity is being installed in the Asia-Pacific region. Nevertheless, Europe also saw a growth in absolute terms. 23 countries have now reached cumulative installed capacities above 1 GW and in at least 20 countries, PV contributes with 1 % or more to the annual electricity supply, reaching between 7 and 8 % in some European countries.

Dynamic developments in PV technology, industry and market deployment form the framework for the activities of the IEA PVPS Programme. As a leading and unique network of expertise, our mission is 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. Anticipating future needs, IEA PVPS increasingly focusses on recent policy and market issues, new business models, sustainable policy frameworks as well as technical and market related integration of photovoltaics in the electricity and energy system at large. These issues relate to the latest developments and insights regarding e.g. self consumption or working more closely with utilities.

In a world where PV is becoming more and more a mainstream technology and where increasingly more stakeholders and organizations are active, providing well targeted, high-quality information about relevant developments in the photovoltaic sector as well as policy advice to our key stakeholders remain our highest priorities. Indeed, 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 and the outreach of our efforts becomes more and more relevant. Besides the continuous exchange and cooperation within the IEA technology network, stronger ties are being built with organizations such as IRENA and the IEC.

Interest and outreach for new membership within IEA PVPS continued in 2015. After being absent from IEA PVPS for more than 10 years, Finland has rejoined our programme in 2015. We very much welcome Finland back as partner in our network. Due to the UK which has left the programme, our membership has remained at 29, keeping IEA PVPS as one of the largest IEA technology collaboration programmes (TCPs). Exploration for membership continued with Chile, 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. We thereby strive to respond as much as possible to the increasing role that the new IEA Executive Director Fatih Birol has called for by the IEA TCPs.

Our overall communication and dissemination efforts were continued through systematic distribution of PVPS results through publications, conferences and workshops. 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 31st European Photovoltaic Solar Energy Conference in Hamburg (Germany) attracted a large number of visitors and provided an excellent forum for dissemination purposes. More than ever, our efforts aim to engage within and beyond our network, providing up-to-date information and ultimately contributing to relevant outcomes and impacts.

The detailed results 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. As a unique feature, the current status of photovoltaics in all PVPS member countries is described within the country section of this annual report.

Our work would not be possible without a committed community of experts and colleagues. I therefore wish to thank all Executive Committee members, Operating Agents and Task Experts, for their ongoing and dedicated efforts and contributions to IEA PVPS.

S. Nowak

Stefan Nowak
Chairman

TABLE OF CONTENTS

PHOTOVOLTAIC POWER SYSTEMS PROGRAMME

IEA

The International Energy Agency (IEA), founded in November 1974, is an autonomous body within the framework of the 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 Technology Collaboration Programmes 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 2015, 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, European Union, Finland, France, Germany, Israel, Italy, Japan, Korea, Malaysia, Mexico, the Netherlands, Norway, Portugal, SEIA, SEPA, SolarPower Europe, Spain, Sweden, Switzerland, Thailand, Turkey and the United States of America. Finland joined PVPS in 2015.

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.

46th IEA PVPS ExCo Meeting, Daegu, Korea, November 2015.

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 (concluded in 2014);
- 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 - PVPS Workshop in Bangkok, Thailand, September 2015, PV & Utilities @ Asean Power Week.

Fig. 2 - Participants at the IEA PVPS Task 1 Workshop, "Competitiveness, Soft Costs and New Business Cases for PV," in collaboration with IEA SHC and IEA RETD, at the EU PVSEC 2015 (Photo: EU PVSEC).

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 in four Subtasks, covering all new and legacy aspects of its activities.

SUBTASK 1.1: Market, Policies, Industrial Data and Analysis

Task 1 aims at following PV development evolution, 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 environment around the globe.

Fig. 3 - At the Electric Systems of the Future Workshop - Framing an Interactive Discussion for IEA PVPS on Electric System Evolution - held in conjunction with the Task 1 Expert meeting at NREL, Golden, Colorado, USA (April 2015). Discussion to identify the most important barriers and enablers for the future electric system. (Photo: Izumi Kaizuka).

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 and electricity utility interests.

20th Edition of the 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 providing the most accurate information on the evolution of the PV

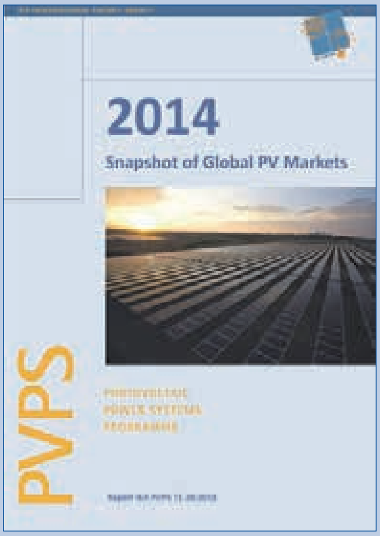


Fig. 4 – PVPS Report: A Snapshot of Global PV 1992-2014; Report IEA PVPS T1-26:2015.

Fig. 5 – Trends in Photovoltaic Applications – Survey Report of Selected IEA Countries between 1992 and 2014; Report IEA-PVPS T1-27:2015.

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 2015, twenty issues of Trends have been published. They are all available on the IEA PVPS website.

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 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 that respect, Task 1 has identified from 2013 to 2015 several subjects that led to the following specific activities:

- *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 an increasing interest. In 2015, Task 1's work was focused on self-consumption and net-metering policies, towards the finalization of a report, dedicated workshops and conferences.
- *PV and Utilities*: Electric utilities, producing, distributing and selling electricity to final customers have been identified as crucial actors for a large-scale development of PV. In this respect, Task 1 organized several workshops where utilities and PV experts exchanged information and visions about the role of utilities. These workshops were organized in three locations in 2015, depending on local specifics: NREL hosted the American workshop, IEA hosted the European one in Paris, while the Asian one took place during the Asean Power Week in Bangkok. IEA PVPS will continue to provide a platform where these actors can meet and exchange information.
- *Soft Costs*: The continuous decline of the costs of PV components has put the emphasis on better understanding how soft costs could contribute to further reduction in system prices in the coming years. This subject will be continued in 2016.
- *Registering PV Installations*: The fast development of PV in all continents requires that regulators and authorities perfectly understand the key features of PV technology development. IEA PVPS will provide a set of recommendations to build PV registries, in order to disseminate the vast experience acquired by its experts over the past years.

SUBTASK 1.3: Communication Activities

Task 1 aims at sharing 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 to events during energy or PV-related conferences and fairs. Workshops are organized on various subjects, sometimes in cooperation with other tasks of the PVPS program or external stakeholders. In 2015, the following workshops were organized in several locations around the world:

- Paris, France – April 2015: The first PV & Utilities Workshop was held in the IEA premises. It allowed participants from key European utilities and PV experts to exchange experience, insights and information on business models for PV development.
- Denver, Colorado, USA – April 2015: In the frame of the 43rd Task 1 Experts Meeting in the USA, a workshop was organized in parallel with the Task 1 meeting. The meeting focused on the role of utilities and drivers for PV market development with key US and global experts.
- Bangkok, Thailand – September 2015: In the frame of the Asean Power Week, in collaboration with the Ministry of Energy of Thailand, a workshop was organized. Utilities from Middle Eastern, Asian and Pacific countries examined the role of utilities and the challenges for PV development.
- Hamburg, Germany - September 2015: EU PVSEC Conference and Exhibition: A joint IEA PVPS, IEA RETD and IEA SHC workshop

Fig. 6 - Task 1 Experts, 45th Task 1 Meeting in Istanbul, Turkey, October 2015 (Photo: Task 1 Experts).

on competitiveness, soft costs and new business models for PV development was organized.

- Istanbul, Turkey - October 2015: An IEA PVPS workshop jointly organized with GÜNDER, the Solar Energy Association of Turkey, has been organized. This workshop focused on globalPV development trends with a specific focus on Turkish policies and trends.
- Busan, Korea – November 2015: A joint IEA-PVPS workshop took place within the PVSEC-25 conference. This workshop probed the questions of market development, including support policies and industry development.

Additionally, IEA PVPS partnered several events in 2015, including the ISES 2015 conference in Daegu, Korea, the Intersolar Turkey Conference in Istanbul, Turkey, and the MENASOL Conference in Dubai, UAE. Task 1 speakers represented the program in several conferences in 2015 in Japan, Germany, China, USA, France and Spain in 2015.

Publications: Task 1 publications have been described above. They aim at providing the most accurate level of information regarding PV development.

Website and Social Networks: Task 1 manages the website of the IEA PVPS program. IEA-PVPS is present on Twitter and LinkedIn.

IEA PVPS in the Media: New publications are also promoted by press releases to around 500 contacts. This list of contacts is progressively expanded to include more media from Asian, African and Latin American countries. Translation of press releases is done by some countries to enhance visibility.

Seven press releases have been issued in 2015, covering the two Task 1 reports (Snapshot and Trends), one update of the last Task 8 report (VLS-PV), two Task 9 reports (health facilities and business models), one Task 13 report (performance analysis), one Task 14 report (system operation) and the Annual IEA PVPS Report 2014.

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

SUMMARY OF TASK 1 ACTIVITIES AND DELIVRABLES PLANNED FOR 2016

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 analyze PV support policies and provide adequate and accurate information to policymakers and other stakeholders. In addition to the recurrent market and industry analysis, Task 1 will continue to study the evolution of business models, the role of utilities, system registration requirements and soft costs.

SUBTASK 1.1: Market, Policies, Industrial Data and Analysis

National Survey Reports will be published from the end of Q2 2016 on the PVPS website.

The target date for publication of the 4th issue of the Snapshot of Global PV report is the end of Q1 2016.

The target date for publication of the 21st issue of the Trends in Photovoltaic Applications report is the end of Q3 2016.

The enhanced report on self-consumption and net-metering will be published in 2016. A publication on requirement for PV registration will be edited in 2016, as well.

SUBTASK 1.2: Think Tank Activities

The main subjects developed in 2016 with regard to the Think Tank activities of PVPS can be described as follows:

- Expand the analysis on self-consumption based business models, including DSM and storage capabilities.
- The role of utilities with regard to PV development.
- Liaison with all PVPS Tasks and the Executive Committee in order to better exchange on the content, as well as 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, especially self-consumption policies.
  - Liaise with Task 13 and Task 14 for economic analysis.
  - Liaise with the new Task 15 on BIPV market statistics and support policies.
  - Support the Executive Committee in defining the future of the PVPS programme.

SUBTASK 1.3: Communication Activities

Task 1 will continue its communication activities in 2016. 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 2016.

SUBTASK 1.4: Cooperation Activities
Task 1 will continue to cooperate with adequate stakeholders in 2016. It will reinforce the link with IEA in particular and enhance its cooperation with IRENA and REN21. Regarding the cooperation among the IEA's Technology Collaboration Programs, a special focus could be put on the cooperation with the IEA SHC Task 53 (PV for heating & cooling systems) and IEA RETD (PV prosumers, electricity market design).

INDUSTRY INVOLVEMENT

Task 1 activities continue to rely on close co-operation with government agencies, PV industries, electricity utilities and other parties, both for collection and analysis of quality information and for dissemination of PVPS information to stakeholders and target audiences. This is achieved through the networks developed in each country by the Task 1 participants.

MEETING SCHEDULE (2015 AND PLANNED 2016)

The 43rd Task 1 meeting was held in Denver, USA, April 2015.
The 44th Task 1 meeting (exceptional) was held in Bangkok, Thailand, September 2015.
The 45th Task 1 meeting was held in Istanbul, Turkey, October 2015.
The 46th Task 1 meeting will be held in Las Palmas de Gran Canaria, Canary Islands, Spain, 11-15 April 2016.
The 47th Task 1 meeting will be held most probably in Australia, 18-21 October 2016 (tbc).

TASK 1 PARTICIPANTS IN 2015 AND THEIR ORGANIZATIONS

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

COUNTRY	NAME	ORGANIZATION
Australia	Warwick Johnston	SUNWIZ
Austria	Hubert Fechner	University of Applied Sciences Technikum Wien
Belgium	Grégory Neubourg	APERe
Canada	Patrick Bateman	CanSIA
	Yves Poissant	Canmet Energy
China	Lv Fang	Electrical Engineering Institute, Chinese Academy of Science
Copper Alliance	Angelo Baggini	ECD
Denmark	Peter Ahm	PA Energy AS
European Commission	Arnulf Jaeger-Waldau	European Commission, Directorate General for Energy
Finland	Jero Ahola	Lappeenranta University of Technology
France	Yvonnick Durand	ADEME
Germany	Dr Georg Altenhöfer-Pflaum	Forschungszentrum Jülich
	Klaus Prume	
Israel	Gideon Friedmann	Technologies & Renewable Energies, Ministry of National Infrastructure, Energy & Water Resources
Italy	Salvatore Guastella	RSE SpA
	Francesca Tilli	GSE SpA
Japan	Izumi Kaizuka	RTS Corporation
	Masanori Ishimura	NEDO

COUNTRY	NAME	ORGANIZATION
Korea	Chinho Park	Yeungnam University
	Sang Keun Gavin YU	KEMCO
Malaysia	Wei Nee Chen	SEDA
Mexico	Jaime Agredano Diaz	Instituto de Investigaciones Electricas, Energías no Convencionales
Norway	Øystein Holm	Multiconsult
Portugal	Pedro Paes	EDP
SEIA	N/A	SEIA
SEPA	N/A	SEPA
SolarPowerEurope	N/A	SolarPowerEurope
Spain	José Donoso	UNEF
	Vicente Salas	Universidad Carlos III de Madrid
Sweden	Johan Lindahl	Uppsala University
Switzerland	Pius Hüsser	Nova Energie
Thailand	Kulwaree Buranasajjawaraporn	Ministry of Energy Department of Alternative Energy Development and Efficiency
	Pathamaporn Poonkasem	
	Thanyalak Meesap	
	Thidarat Sawai	
The Netherlands	Otto Bernsen	Netherlands Enterprise Agency RVO, Energy Innovation
Turkey	Kemal Gani Bayraktar	GÜNDER
USA	Robert Margolis	NREL
	David Feldman	NREL
	Daniel Boff	Department of Energy

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 lays 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 the implementation phase 2012-2015 of Task 9 has been twofold:

- Produce substantive work on applications meeting the energy needs of rural communities such as for water pumping, for health (e.g. refrigeration, lighting), highly efficient integrated appliances for lighting and ICT needs ("pico PV services") and finally also on PV- and hybrid mini grids, as well as on relevant business models for deployment. The results of this Task 9 work are integrated in the dissemination process as described under the second objective.
- 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 Task 9 outputs and outputs of other technology-focused PVPS Tasks addressing these challenges, by adapting the messages and implementation frameworks in areas beyond the borders of OECD countries. These partnerships 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.

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. This Subtask's scope was to initiate and maintain interdisciplinary expert dialog in the field of PV and water supply. This Subtask's objective, led by Switzerland, was 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.

WORKPLAN 2012-2015

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 (100%) 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 multiple events (100%)	

Fig.1 – Task 9 Workplan's Achievements.

This Task was completed in 2012 with the publication of the position paper on *"Policy Recommendations to Improve the Sustainability of Rural Water Supply Systems"* and the material has been used for dissemination activities (6th Rural Water Supply Network Forum, Kampala, Uganda, 2011; First International Off-Grid Renewable Energy Conference IOREC organized by IRENA in Accra, Ghana, 2012).

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 sufficiently 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 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. After a rather "donor driven" dissemination phase, nowadays, devices of varying quality are flooding the market and large companies are disseminating Pico PV products on a purely commercial basis. Under Subtask 3 the concept of pico PV systems and their application in real-world circumstances have been analysed. The importance of understanding the dynamics of the demand side of this market has been elaborated, as well as the

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

nature and supply of the products, their economics, and experience with various business models. There are clear lessons for the roles that should be played by governments, donor bodies and others in the markets for pico PV products and services, essentially as providers of appropriate institutional frameworks and information.

The Subtask was completed in 2013 with the publication of the document *"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 4A and 7: PV and Mini-grids / Hybrids

After the publication of the document, *"Rural Electrification with PV Hybrid Systems - Overview and Recommendations for Further Deployment,"* on the PVPS webpage in April 2013 (Oct 2013, French version), it was decided to 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 the integration of small scale (mini-grid) distributed generation (<1MW) into the main grid may perhaps see a substantial growth in the future. Task 9 experts have been analyzing the current *"Trends in the Market for PV Diesel Mini-grids"* (planned as Subtask 7). The analysis is based on the results of a survey carried out among 61 experts - 50 % European, 50 % African - with different perspectives: consultancies, manufacturers, academic, research, utilities, NGOs, governmental (national/local) offices, international and donor agencies on *"The Future of PV Hybrid Systems within Mini-grids."* The originally planned publication on the topic has not been finalised but it was decided to make use of the very valuable results of the analysis in the next Task 9 Workplan; namely, the new *"Subtask 1: Mini-grids Integrating Diesel Generation and PV"* (led by Germany). For details see the section on "THE FUTURE OF TASK 9" below.

SUBTASK 5: Monitoring of Hybrid Systems in Rural Areas

Based on field experiences with PV-diesel hybrid systems and literature reviews a user guide has been developed *"For simple monitoring and sustainable operation of PV-diesel hybrid systems."* This activity was led by Sweden. The guideline offers system users a way of understanding if their system is operated in a way that will make it last for a long time. It gives suggestions on how to act if there are signs of unfavourable use or failures. The application of the guide requires little technical equipment, but does call for daily manual measurements. It provides information on required measurement equipment, required measurements, short and long term evaluation of the results, recommendations on measures to be taken in case of blackouts, etc. For the most part, the monitoring can be managed by pen and paper by people with no prior experience in power systems. At the time of being published, the guide had not been tested in full on any real case, meaning that - depending on feedback from users - it might be adapted in a later stage.

SUBTASK 6: 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 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 obstacles can be addressed and overcome in innovative ways.

SUBTASK "Deployment and Outreach"

This Subtask has been functioning as the operating arm of Task 9 to establish partnerships with regional organizations, countries, development bodies, etc.

During 2014 and 2015, the following dissemination activities have been performed:

- Participation of the (former) Task 9 Operating Agent, Anjali Shanker, the Task 1 Operating Agent, Gaetan Masson and Task 1/9 Expert Denmark, Peter Ahm 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 Switzerland, Thomas Mayer 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 in the Chinese-IEA PVPS PV Workshop in Beijing, China, November 29-30, 2014.
- PVPS Workshop on PV and Utilities (ASEAN Power Week, Bangkok Sept 1-3, 2015).

Fig. 4 - Task 9 Meeting in Istanbul, October 2015.

- Participation of the new Task 9 Operating Agent, Hedi Feibel, at the Steering Committee Meeting of the Clean Energy Mini-Grid - High Impact Opportunities (CEMG HIO), SE4ALL on November 19, 2015, with the presentation of the new draft Task 9 Workplan and investigation of possibilities for cooperation.

THE FUTURE OF THE TASK 9

After having completed its last four-year program with the results as presented above, in 2015 Task 9 continued through a transition phase; identifying a new Operating Agent (provided by Switzerland) and subsequently defining new general objectives and related activities. Following the opening address of the IEA's new Executive Director, Fatih Birol, in the Joint IA Meeting held on 18 September 2015, the IEA intends to become a real global network, building new bridges with emerging countries and establishing outreach activities especially in non IEA member countries. This statement gave a strong mandate to Task 9 and consequently, a decision has been made to continue **focusing on emerging countries by adapting and transferring relevant knowledge and information for such countries**:

I. By strengthening and extending its existing **network** with emerging countries and relevant bi- and multilateral organisations to ensure significant **outreach and impact** and

II. By selecting **topics of high relevance** for emerging countries, including:

a) PV in mini-grids (including hybrid systems)

b) Distributed PV in bigger grids (grid connected PV).

Especially with regard to II.b), it will be crucial to **closely cooperate with other Tasks of PVPS**, to analyse their activities and outputs with regard to their relevance for emerging countries, and where useful, "translate" such results to the specific conditions in emerging countries.

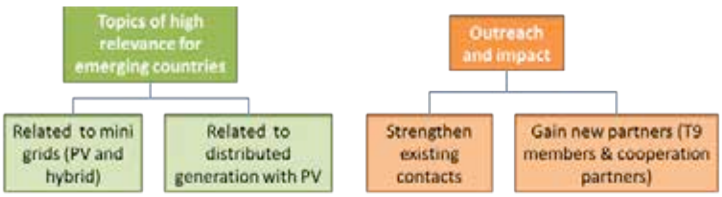


Fig. 3 - Future Fields of Task 9 Activity.

Task 9 Experts are currently elaborating a new Task 9 Workplan. At present, the following subjects have been selected as future Subtasks:

Subtask 1: Mini-grids Integrating Diesel Generation and PV (lead Germany, 4 years)

This Subtask is targeting two main aspects:

1) Evaluation of existing diesel-PV hybrid systems (how are they operating, what are main difficulties, etc.) and

2) The potential of PV to replace electricity generation based on diesel generators in mini-grids as well as in bigger systems (PV as fuel saver).

In the past, a guideline had already been developed with recommendations on PV-diesel hybrid systems which can be used as a basis for the planned work. In addition, under the former "Subtask 4A" (see above) a survey had been implemented on hybrid schemes. The results of this survey will also be taken into account. Based on valuable market information by addressing e.g., producers of diesel generators, an assessment can be made on where diesel generators are deployed. This allows evaluating potential future opportunities to at least partly replace electricity generation by diesel generators with clean electricity from PV systems.

Subtask 2: Deployment Strategy for 100% RE on Small Islands (lead Australia, 4 years)

This Subtask intends to illustrate and analyse all kinds of island specific, technical and non-technical issues and possibilities to solve them. Based on broad experience in the Pacific islands (e.g. Cook Islands) which have set a 100 % RE target, information will be collected and analysed with the final target to draw useful conclusions for other islands (e.g. Caribbean). Wherever overlap with other Tasks occurs, e.g., Task 14 (High Penetration PV in Electricity Grids) exists, cooperation will be sought. This work will also fertilise the activities of Subtask 1 on mini-grids.

Subtask 3: Mainstreaming PV-related Training in National Training Institutions Frameworks (lead Australia, shall be finalised at the beginning of 2016)

The lack of technical experts in many emerging countries leads to numerous breakdowns and low performance of systems. One crucial activity to improve this situation is the mainstreaming in training. The objective is to develop a "Guideline on Mainstreaming PV-related Training in National Training Frameworks."

Subtask 4: Mirror Study on "PV Development as Prosumers: The Role and Challenges Associated with Producing and Self-consuming PV Electricity" (lead France, cooperation with Task 1, 1 year)

Task 1 has been working on a study on the above mentioned topic based on an analysis in 18 PVPS member countries (Australia, Belgium, Brazil, Canada, China, Chile, Denmark, France, Germany, Italy, Israel, Japan, Mexico, Spain, Switzerland, Netherlands, United States). This Task 1 study was expected to be finalised in September 2015. Based on the results of this study, IED, France will lead a study in 10 selected emerging countries which target or have already put net metering policies into place (countries to be selected out of the following: Africa and Middle East: Kenya, South Africa, Mauritius, Namibia, Lebanon,

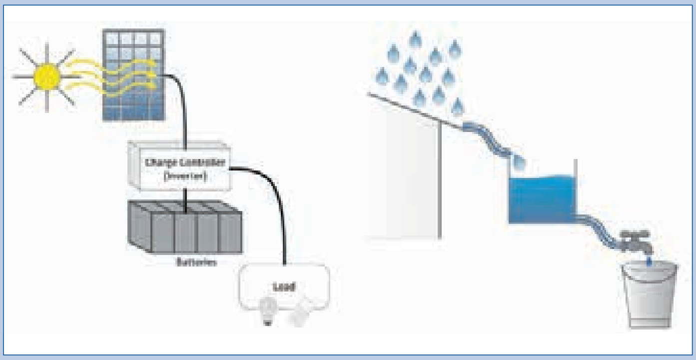


Fig. 5 - Simple analogy to explain energy storage system (from the above mentioned publication).

Fig. 6 – Task 9 Publications: Innovative Business Models and Financing Mechanisms for PV Deployment in Emerging Regions; and PV Systems for Rural Health Facilities in Developing Areas.

Jordan and several ECOWAS countries; namely Ghana, Senegal, Burkina Faso; Asia: India, Philippines, Sri Lanka, Vietnam, Mongolia; *Latin America (optional)*: Guatemala, Costa Rica, Nicaragua, Honduras, Uruguay). In many emerging countries, self-consumption can provide possibilities for prosumers to reduce their electricity bills and helps them to have electricity even though breakdowns happen in the national electricity grid. The objective of the analysis is to collect best practices of policies for self-consumption and net-metering in 10 countries and provide an overview on development of prosumers based on the mechanisms introduced and recommendations for countries currently on their way to introduce a respective legislation (strong interest from Ghana and ECREEE).

Subtask 5: Interaction with Standardisation Bodies (lead Germany, ongoing)

The main activity of this "ongoing Subtask" will comprise information, dissemination & deployment of state of the art knowledge into standardisation bodies: IEC 62109 (Safety of charge controllers), IEC-TC82 (Solar photovoltaic energy systems), CIGRE (conseil international des grands réseaux) and IEA working group 28 (wind energy). The objective is to mainstream and harmonise useful standards.

Subtask 6: Grid-connected PV-battery Combinations (contribution from Denmark, but no lead so far)

With increasing grid penetration of PV systems, the combination of PV and storage is gaining importance ("marriage of PV and storage"). Some (mainly OECD) countries have broad experience regarding technical and non-technical aspects related to this topic. To collect relevant information from different countries (from OECD countries, from other PVPS Tasks, etc.) would allow analysing the state of the art. Based on this, the existing experience would have to be "adapted" to conditions in emerging countries. It would be important to link with other IAs working on this topic, with the former PVPS Task 11 activities and other Tasks and Subtasks. The topic is of high relevance for emerging countries because national grids are often weak (voltage fluctuations, breakdowns, etc.) and PV systems in combination with storages can help to stabilise such grids.

Subtask 7: Recommended Practice Guides for Mini-grids and Island Grids (interest from SE4ALL, but no lead so far)

Task 9 during its first phase (before 2008) [1] developed various useful "recommended practice guides" which were mainly focusing on Solar Home Systems (SHS). Similar guides would now be required for mini-grids, but do not exist yet. The idea is to review these existing SHS related manuals and guidelines and check if a simple updating and amendment is possible to suit larger scale units and today's needs; thus, "re-putting in value" existing Task 9 information and know-how.

Subtask 8: Outreach and Dissemination (lead Switzerland)

In the current situation of re-animating Task 9 activities, in strengthening networks for outreach and for gaining new members to support Task 9, this "outreach and dissemination" Subtask is of outstanding importance. Switzerland has the role of Operating Agent and shall lead this Subtask but shall also involve additional Task 9 members wherever possible. The activities will mainly focus on:

1 coordination, support and management of activities of the subtasks
2) making contacts, dissemination of existing and new outputs and networking.

The main objectives of these activities are to identify new Task 9 members and to improve the outreach of the Task 9 activities. A focus will be put on building international relationships, e.g. with IRENA, SE4ALL, GIZ, SDC, AfDB, etc.

KEY DELIVERABLES PUBLISHED IN 2015:

December 2015: "A User Guide to Simple Monitoring and Sustainable Operation of PV-diesel Hybrid Systems; Handbook for System Users and Operators."

KEY DELIVERABLES PLANNED FOR 2016:

"Guideline on Mainstreaming PV-related Training in National Training Frameworks" (expected March 2016).
"Mirror Study on PV Development as Prosumers: The Role and Challenges Associated with Producing and Self-consuming PV Electricity" (expected end of 2016).

TASK 9 MEETING SCHEDULE (2015 AND PLANNED 2016)

2015

45th IEA PVPS ExCo Meeting, Paris, France, April 28-29, 2015
IEA PVPS & GÜNDER Workshop, Istanbul, Turkey, October 27, 2015; Task 9 Operating Agent's participation
45th Task 1 Experts Meeting, Istanbul, Turkey, October 27-30, 2015; Task 9 Operating Agent's participation
33rd Task 9 Experts Meeting, Istanbul, Turkey, October 30, 2015

2016

IEA PVPS Task 9 Workshop, Zurich, Switzerland, February 29, 2016
34th Task 9 Experts Meeting, Zurich, Switzerland, March 1, 2016
35th Task 9 Experts Meeting, Bad Hersfeld, Germany, September 20, 2016

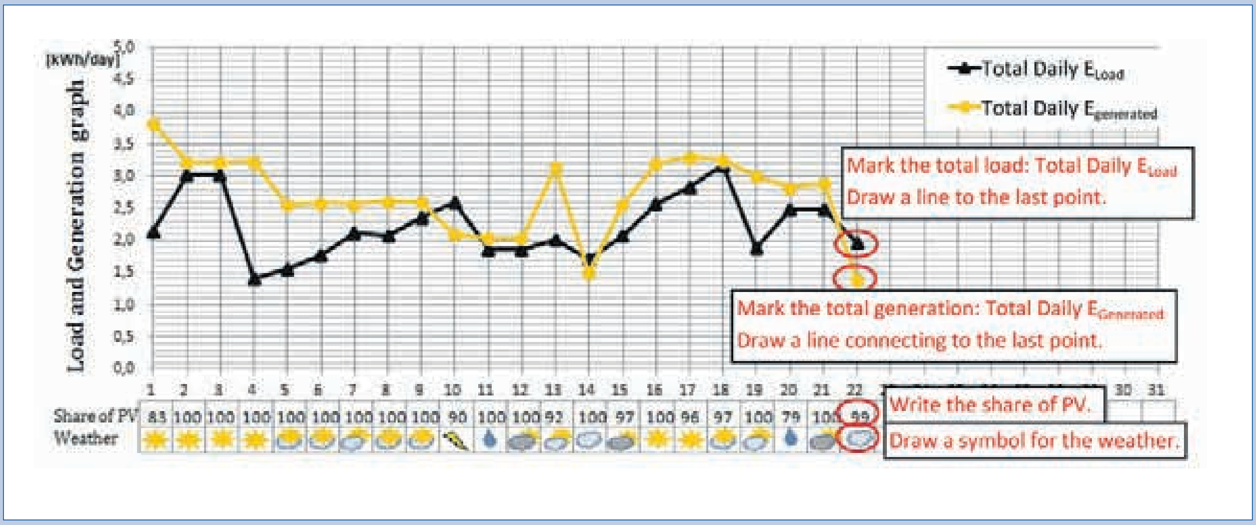


Fig. 7 - Simple analogy to explain energy storage system (from the above mentioned publication).

TASK 9 PARTICIPANTS

COUNTRY	PARTICIPANT	ORGANISATION
Denmark	Peter Ahm	PA Energy Ltd.
Finland	Christer Nyman	Soleco Oy
France	Anjali Shanker	IED
France	Silvia Puddu	IED
France	Taric de Villers	IED
France	Gregoire Lena	IED
France	Jean-Christian Marcel	Consultant
Germany	Georg Bopp	Fraunhofer ISE
Germany	Friedemar Schreiber	Fraunhofer ISE
Germany	Adnan Al-Akori	Fraunhofer ISE
Germany	Michael Müller	STECA
Germany	Bozhil Kondev	GIZ
Japan	Takayuki Nakajima	Japan Photovoltaic Energy Association (JPEA)
Japan	Masanori Ishimura	NEDO
Netherland	Erik Lysen	Lysen Consulting Engineer
Norway	Hanne Cecilie Geirbo	University of Oslo
Sweden	Frank Fiedler	Dalarna University
Sweden	Caroline Bastholm (Nielsen)	Dalarna University (SERC)
Switzerland	Thomas Meier	ENTEC
Switzerland	Alex Arter	ENTEC
Switzerland	Stefan Kessler (OA)	INFRAS, Research and Consulting
Switzerland	Hedi Feibel (OA)	SKAT Consulting Ltd.
Turkey	Muhyettin Sirer	UNDP
Turkey	Yesilata, Bulent	GÜNDER
Turkey	Kemal Gani Bayaktar	GÜNDER, Izocam
Austria, SE4ALL	Martin Niemetz	Country Action Officer, SE4ALL, GFT (observer)

- *Although not officially, GIZ (Germany), Dalarna University (Sweden) and IRENA actively contributed to the work of this Task.*
- *Observers: Thailand, Ministry of Energy and EGAT, Malaysia, ECREEE, Austria/SE4ALL/GFT Martin Niemetz*

TASK 12 - PV ENVIRONMENTAL HEALTH & SAFETY ACTIVITIES

Fig. 1 - Task 12 Experts Meeting, Basel, Switzerland, September 2015.

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, like EPIA in Europe or the China Photovoltaic Society to develop and help implementing voluntary or binding policies – like 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.

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 January 2016, Task 12 published (Activity 2.1.a) the expanded 3rd edition of the "Methodology Guidelines on Life Cycle Assessment of Photovoltaic Electricity", and also recently updated the associated report on life-cycle inventories (LCI) (Activity 2.2) with data on the photovoltaic life-cycle materials and processes, necessary for conducting LCA studies. A key improvement we accomplished with the latest LCI report edition is to make our LCIs publically available not only in reports, but in LCA-software readable formats to facilitate their use by LCA professionals.

Importantly, Task 12 also recently published (Activity 2.1.b) methodological guidelines for net energy analysis of PV to provide guidance for the conduct and reporting of these often controversial assessments of the energy return on energy invested for PV (or similar metrics). A 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.

Finally, at the end of 2014 (Activity 2.2d), Task 12 published a new report on: Life Cycle Assessment of Future Photovoltaic Electricity Production from Residential-scale Systems Operated in Europe. This report provided prospective LCA projections of life cycle impacts to 2050 based on Task 12's LCI's and technology development roadmaps.

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 2015

SUBTASK 1: Recycling of Manufacturing Waste and Spent Modules

Andreas Wade, who is the chairman of the SolarPower Europe's sustainability working group, and SolarPower Europe'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 Subtask 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).

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. In addition, this new report will provide an updated global, regional and country-level high-low scenario-based projection of waste modules.

Task 12 is developing two new projects on PV recycling: a review of the global status of module recycling research and development (R&D); and an LCA on recycling processes based on primary data from module recyclers. More will be reported on these projects as they develop.

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 2.1c. 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 seven 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, SolarPower Europe, the International 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. There is approximately one year remaining in the project period, with many milestones forthcoming which will produce but private and public information.

Another new project (Activity 2.1.d) within this Subtask area is the development of a web service for providing screening level environmental performance assessment of different PV technologies (and configurations) globally through an interactive, user-driven web interface. A web service is the analytical and visualization back-end engine that a web client (website) can call. Development of a front-end web client will be proposed subsequently upon discussion with potential host institutions.

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. Most of the work laid out in Task 12's five year Workplan will be accomplished within this topic after information collected regarding water use in PV manufacturing (Activity 2.2c) and C-Si recycling (Activity 2.2e) has been incorporated.

SUBTASK 3: Safety in PV Industry

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

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, including new technologies or techniques, for firefighters, the PV industry, and PV users in operation and maintenance to prevent fires.

GOVERNANCE, DISSEMINATION AND NEXT MEETINGS

Membership: Membership has held steady in 2015. Total membership now stands at eleven countries and one industry association, with ~sixteen active experts.

Engagement with International Standards on PV Sustainability:

Task 12 experts are members on several international standard development committees:

1. IEC – Building on the active liaison relationship between IEA and IEC at the technical committee level (IEC TC 82: Solar photovoltaic energy systems), the PVPS Executive Committee has approved Task 12 to form a liaison relationship with the PT 62994-1 (Environmental Health and Safety (EH&S) Risk Assessment for the sustainability of PV module manufacturing). This PT is led by Korea. Task 12's next meeting, in Korea, will include further discussion of the role Task 12 could play.
2. ANSI – a new ANSI standard is under development led by the NSF International regarding PV sustainability (NSF 457: Sustainability Leadership Standard for PV Modules). This standard, if approved, is meant to inform bulk purchasing of PV modules such that high-performing modules in terms of sustainability can be easily, transparently and credibly recognized in the market, and therefore incentive is provided for manufacturers to advance sustainability of their products through a market pull. Task 12 is not formally a member of the Joint (steering) Committee for NSF 457, but several Task 12 members are on the JC. Task 12's Methodological Guidelines for PV LCA form one major foundation for development of this sustainability standard, as could the new NEA Guidelines.

PLANS FOR 2016

2016 will see the completion of several important projects for Task 12 – the EC's Product Environmental Footprint Category Rule, the screening-level environmental performance web service, the report on global regulatory status of PV recycling and the report reviewing PV fire safety issues, amongst others. We will also be active in developing several new projects including the global status of PV recycling R&D and an LCA of PV module recycling.

PUBLICATIONS

Methodology Guidelines on Life Cycle Assessment of Photovoltaic Electricity, 3rd edition, IEA PVPS Task 12, International Energy Agency Photovoltaic Power Systems Programme. Report IEA PVPS T12-08:2016, ISBN 978-3-906042-39-8.

Methodological Guidelines on Net Energy Analysis of Photovoltaic Electricity, IEA PVPS Task 12, Report IEA PVPS T12-07:2016, ISBN 978-3-906042-38-1.

Life Cycle Assessment of Future Photovoltaic Electricity Production from Residential-scale Systems Operated in Europe, Subtask 2.0 "LCA", IEA-PVPS Task 12, Report IEA PVPS T12-05:2015. ISBN 978-3-906042-30-5.

Life Cycle Inventories and Life Cycle Assessments of PV Systems. IEA PVPS Task 12, International Energy Agency Photovoltaic Power Systems Programme. Report IEA PVPS T12-04:2015, ISBN 978-3-906042-28-2.

Methodology Guidelines on Life Cycle Assessment of Photovoltaic Electricity, 2nd edition, IEA PVPS Task 12, International Energy Agency Photovoltaic Power Systems Programme. Report IEA PVPS 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 IEA PVPS 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 IEA PVPS T12-01:2009.

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
And co-Operating Agent:
Carol Olson, Energy Research Center of the Netherlands (ECN), The Netherlands

MEETING SCHEDULE (2015 AND PLANNED 2016)

In 2015, **the Task 12 Experts meet** March 11-12 in Vienna, Austria and September 10-11 in Switzerland.
In 2016, **Task 12 will meet** April 7-8 in Korea, with our Fall meeting to be scheduled.

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
Solar Power Europe	Andreas Wade	Solar Power Europe
France	Isabelle Blanc	MINES ParisTech
Japan	Junichi Hozumi	NEDO (Technology Development Organisation)
	Keiichi Komoto	Mizuho Research Institute 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)
	Parikhit Sinha	First Solar
	Geoffrey Kinsey	U.S. Department of Energy

TASK 13 – PERFORMANCE AND RELIABILITY OF PV SYSTEMS

Fig. 1 - Task 13 Expert Meeting in Leoben, Austria, 17-19 March 2015 (Photo: Montan University Leoben).

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.

Accurate energy yield predictions in different climates as well as reliable 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 42 institutions in 20 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 August 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 and analyze the economic aspects of PV system performance and reliability by reviewing the current practices used in financial modelling of PV investments with focus on the input that reflect the technical risks related to the PV module and other key components, the technical design of the PV system as well as the operation and maintenance of the plant 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 the 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

Subtask 1 addresses and analyses the economic aspects of PV system performance and reliability. By reviewing current practices used in financial modelling of PV investments with focus on the input that reflects the technical risks related to the PV module and other key components, the technical design of the PV system as well as the operation and maintenance of the plant over the system's service life. The impact of the uncertainties and failure statistics of these technical parameters and input to the financial models will be analysed in terms of economic importance reflected in both investment costs and Levelized Cost of Electricity (LCOE).

In this Subtask, a questionnaire has been developed to collect data on how technical parameters are taken into account in PV investment models in order to calculate the expected energy production and determine the investment as well as the operation and maintenance costs. A draft version of this questionnaire was presented and discussed during the meeting in Leoben, Austria, in March 2015 and preliminary results were presented at the October 2015 meeting in Uluru, Australia. The final version of the questionnaire was sent to the contributors in December 2015 and the final analysis of these data is expected by mid-2016.

Based on the internal analysis and report, screening of the scientific literature and discussions with key stakeholders during a couple of public meetings, the current practices will be compared with available scientific data to identify important gaps. Finally, general guidelines and recommendations will be put forward on how to manage these technical risks by selecting and utilizing appropriate and relevant technical assumptions in the financial models.

SUBTASK 2: System Performance and Analysis

In Subtask 2, entire PV systems and their performance are focused on. The system character of this work topic implies a broad variety of components and their interplay are of relevance. In turn, this implies various scientific disciplines are involved already. Various stakeholders are involved, as well. In fact, with PV becoming main stream, this stakeholders' base seems to be ever increasing. Presumably millions of individuals own small PV systems as of today, and individual large-scale systems are closing in to the Gigawatt range of installed capacity. In order to approach the broad range of related work topics, the Task 13 group has structured the work programme of the extended Task period such that four distinct activities are addressed. The following gives a brief summary of each of these four activities and work conducted in 2015:

- Subtask 2.1 – Performance Databases
- Subtask 2.2 – Failure Prediction on the PV System Level
- Subtask 2.3 – Uncertainty Framework for PV Monitoring and Modelling
- Subtask 2.4 – PV Performance Modelling Collaborative.

Within Subtask 2.1 – Performance Databases, observed performances of PV systems are collected. This data is then structured and presented such that actual PV performances are easier to access and evaluate as was previously possible. To this end, the "Task 13 Performance Database" allows almost instant access to monthly averages of PV performance data, for anyone who is interested. The link to the internet server hosting the database can be found prominently on the PVPS webpage since it went online in 2014. New data is continuously collected and added to the Performance Database, but it remains a challenge to contribute substantial amounts of data for all countries of high PV market penetration.

Within Subtask 2.1, the innovative approach to collect PV performance data using so-called web-scraping techniques has been introduced, in addition to the "Task 13 Performance Database". Here, electricity yields of substantial amounts (many thousands) of PV installations all over Europe have been gathered in 2015. Final yields are displayed by colour-encoding on a geographical map. However, the lack of any on-site irradiation data means higher uncertainty of figures reported. Furthermore, the sheer amount of PV installations used in this approach currently prohibits any quality assurance procedures regarding, e.g., the monitoring equipment that is deployed within these thousands of sites. At the same time, scientists involved in this activity rightfully quote the sheer number of installations to be in favour of performance accuracies; when looking at the mean of the performance distributions and their particular shape, dubbed "power of statistics". With all countries in Western Europe included in this innovative approach in 2015, it will be interesting indeed to see, where this mean will be and how the distributions are shaped, resulting from this innovative approach.

Within Subtask 2.2 – the topic is "failure prediction on PV system level". Here, retrospective evaluations of operational PV system data are performed to find out, if PV system failures and electrical faults can actually be predicted in advance. A number of parameters made available through inverter data acquisition automatically today are currently not used in traditional analysis of PV system performance. Therefore, the idea is to use a purely statistical approach to evaluate virtually all accessible data today to determine any possible correlation of set(s) of parameter(s) that may indicate immanent system faults. In 2015, evaluating large sets of parameters in retrospect were documented by Task 13 participants, and correlations indicating immanent system failures were found. In particular, the system isolation, a parameter recorded by inverter as a standard, gave interesting leads. However, underpinning statistical and mathematical procedures are highly complex and the work to be continued throughout 2016 will perhaps show even more possibilities for failure prediction.

Within Subtask 2.3, work of the former Task 13 period is continued in the areas of PV performance monitoring and modelling on the system level, with the focus on addressing remaining residuals when comparing measured with modelled data. The analysis of residuals may help to shed more light on remaining uncertainties and may allow for a more structured description of uncertainties in the area of PV energy yield. This work on uncertainties is not limited to uncertainties involved in data acquisition and subsequent modelling, but also includes the broader pictures of financial interests on the one side (with links to Subtask 1) and methodological questions of module stability aspects on the other side (with links to Subtask 3, especially ST 3.4).

One of the intermediate results is depicted in Figure 2, which shows different uncertainties of annual PV energy yield over the operational period of 20 years for different investment strategies. The largest area reflects the relatively large uncertainty for lifetime energy yield predictions for an individual PV power plant and an operational period of 20 years. Assuming investment into a portfolio of PV power plants, the combined uncertainty for expected energy yields integrated over the lifetime is about 5,8 %, which is a reduction by about one third compared to the uncertainty of the yield for a single system. Investing into a portfolio of PV systems for a limited duration may help to reduce related uncertainties even further, as depicted by the smallest area in Figure 2. The combined uncertainty for this investment strategy may be reduced to as little as about 4,2 %.

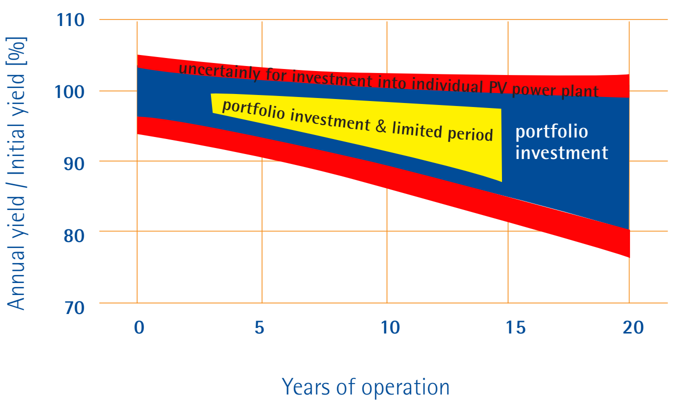


Fig. 2 - Expected uncertainties for lifetime energy yield predictions and potential uncertainty reduction (see paper of Müller et al., 42nd IEEE PVSC).

Subtask 2.4 bundles activities of Task 13 participants within the PV Performance Modelling Collaborative (PVPMC, https://pvpmc.sandia.gov). The PVPMC website maintains a collection of simulation models and provides a platform for information sharing and model publication. 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 methods. One goal of this activity is to add uncertainty information to a number of these models. Also, for a number of "standard procedures" like Performance Ratio (PR) assessments or yield estimations, methods for the determination of an overall uncertainty may be discussed between the participants.

The results and lessons learnt from the 4th PV Performance Modelling and Monitoring Workshop in Cologne in October 2015 (see ST 4 to this report) will be compiled and published in a technical report.

SUBTASK 3: MODULE CHARACTERISATION AND RELIABILITY

Subtask 3 aims to provide recent scientific and technical findings and recommendations on suitable measurement, testing and characterization 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, USA and Asia.

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:

Subtask 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 analyze, explain and reduce deviations between indoor and outdoor power rating; and assess the influence of measurement uncertainty on modelling results.

Subtask 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.

Subtask 3.3: *Characterization of PV Module Condition in the Field - Guidelines on IR and EL in the Field* consists of two parts. The aim of part 1 is to collect field data on PV modules aged multiple years in the field. The team in different climates has used the Visual Inspection Sheet developed in former work to document observed conditions of PV modules aged in a range of climates and identified existing sources of literature and local reports with such data. Participants have started to collect and share with other participants' field data from several hundred PV modules with minimum two years field exposure. After defining methods for module selection and data collection, a database tool has been developed to aggregate and analyze the available field data for trends to identify the most common failures using visual inspection and whether these failures can be correlated with climate or system type.

Part 2 will provide an overview of different methods to collect infrared (IR) and electroluminescence (EL) images in the field. The aim is to develop recommendations and guidelines for the standardized handling of IR and EL images to identify the most common failures

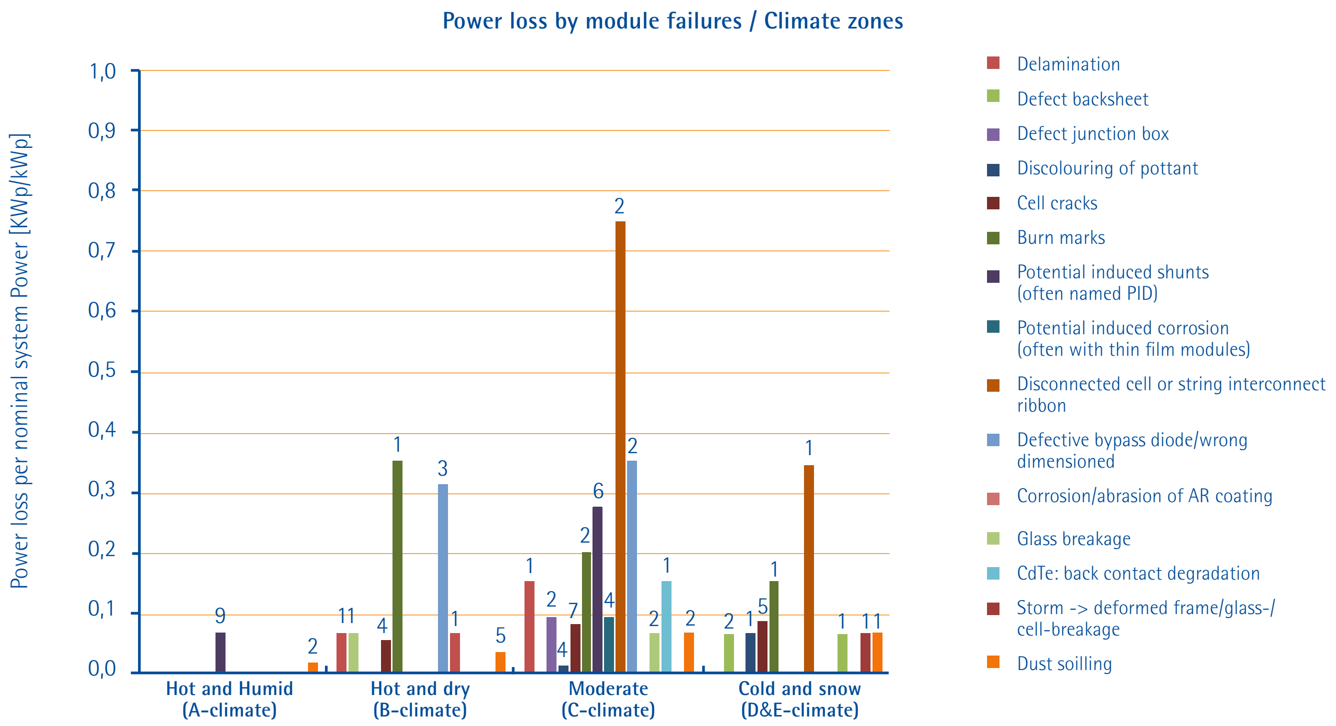


Fig. 3 - The power loss of various PV module failures is documented as a function of the climate zone (preliminary results). The columns' marking numbers count the occurrence of a specific failure type.

in the field. There are various approaches and only a few guidelines to collect IR and EL data in the field. For instance, the images of whole arrays can be recorded with hand-held equipment, or single dismounted modules are scanned with a mobile test center on site. The team has prepared a literature review of existing guidelines for recording IR and EL images as well as a market research of common test devices for IR and EL imaging. The existing collecting methods and guidelines will be summarized and evaluated, whereas recommendations and guidelines for best practices of the measurements to handle EL and IR images in the field will be developed.

Subtask 3.4: *Assessment of PV Module Failures in the Field* aims to provide the status of the ability to predict the power loss of PV modules for specific failure modes. The team summarizes interactions and incompatibilities of lamination materials to better understand PV modules failures. For well-known PV module failures modelling approaches to forecast the power loss are summarized from literature. To identify the impact of the various failures on the module's performance, a survey on the impact of PV system failure in different climatic zones is conducted. The data is collected from various sources and 71 PV system failure reports have been included and analysed up to date. Figure 3 shows the power loss of a PV system if a specific failure type occurs for these systems. The data is preliminary and data collection is still in progress. These results will be evaluated to assess the relevance of standard test methods for different climate zones. Furthermore, new test methods are introduced to qualify PV modules for various climate zones.

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.

Published Task Reports and Task flyers were distributed at the following conferences, workshops and PV events:

- Conference SolarExpo: Workshop on PV Operation & Maintenance & Performance, Milan, Italy, 9 April 2015
- Task 13 Workshop at Intersolar 2015, Munich, Germany, 9 June 2015
- Exhibition booth of TÜV Rheinland, SolarPower Europe, 3E at Intersolar 2015, Munich, Germany, 10-12 June 2015
- Task 1 Workshop at EU PVSEC 2015, Hamburg, 14 September 2015
- Exhibition booth of IEA PVPS at EU PVSEC, Hamburg, September 2015
- Workshop organized by SolarPower Europe at EU PVSEC, Hamburg, 17 September 2015.

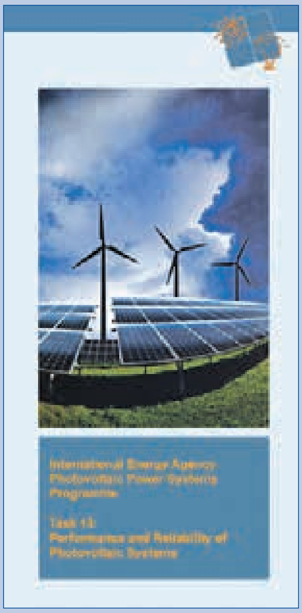


Fig. 4 - IEA PVPS Task 13 flyer, version: September 2015.

In accordance with the Workplan, Subtask leader TÜV Rheinland has prepared a new version of the Task 13 flyer, which Task 13 experts use for distribution at the national and international conferences and other solar PV events. The new Task 13 flyer is available electronically and in paper copy (see Fig. 4).

As a parallel event and part of the Intersolar Europe's conference programme, a Task 13 Workshop entitled *"PV Performance Analysis and Module Reliability"* was held in Munich, Germany, on 9 June 2015. During this workshop, a number of international experts presented the achievements of Task 13's common work, drawing on their experiences in different countries. First results of the extended Task were also included, particularly on PV module reliability (module handling, hail impact and influence of back sheet). The workshop attracted 60 participants from research, industry including module and inverter manufacturers, utilities, system operators, system owners, developers and construction companies, investors, banks and insurance companies.

TÜV Rheinland, Sandia National Laboratories, and the IEA PVPS Task 13 have co-organized the *"4th PV Performance Modelling and Monitoring Workshop"* held at TÜV Rheinland headquarters in Cologne, Germany, 22-23 October 2015. This workshop brought together solar PV professionals and researchers to discuss and share results related to predicting the performance and monitoring the output from solar photovoltaic systems. The workshop was divided into six topical sessions exploring advances in the areas of solar resource assessment, effects of irradiance spectrum on PV performance, soiling losses, bifacial PV performance, modelling tools, and monitoring applications. This workshop was stimulating, interactive, and providing valuable information for modellers, model developers, and other users of PV performance model results. The focussed workshop programme included talks, poster presentations as well as panel discussions. The programme included 40 oral presentations by international experts (five Task 13 experts), 12 visual presentations and 220 participants from Europe, the USA, Asia and Australia (Figure 5).

Fig. 5 - 220 participants from Europe, the USA, Asia and Australia at the 4th PV Performance Modelling and Monitoring Workshop in Cologne, Germany, 22-23 October 2015.

All publications and Task 13 presentations from both workshops held in 2015 are publicly available for download from the Workshops section on the IEA PVPS website: http://www.iea-pvps.org/index.php?id=164.

MEETING SCHEDULE (2015 AND PLANNED 2016)

The 12th Task 13 Experts' Meeting was held in Leoben and Vienna, Austria, 17-19 March, 2015

The 13th PVPS Task 13 Experts' Meeting took place in Yulara / Alice Springs, Australia, 9-13 October 2015.

The 14th PVPS Task 13 Experts' Meeting will be hosted by EURAC and will be held in Bolzano, Italy, 06-08 April 2016.

The 15th PVPS Task 13 Experts' Meeting will be hosted by SANDIA National Laboratories and will take place in Albuquerque, NM, USA, 27-29 September 2016.

TABLE 1 – TASK 13 PARTICIPANTS IN 2015 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 • KU Leuven
China	• Institute of Electrical Engineering, Chinese Academy of Sciences (CAS)
Denmark	• SiCon • Silicon and PV consulting
Finland	• Fortum Power & Heat Oy • Turku University of Applied Sciences
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.

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

COUNTRY	ORGANIZATION
Japan	• National Institute of Advanced Industrial Science and Technology (AIST) • New Energy and Industrial Technology Development Organization (NEDO)
Malaysia	• Universiti Teknologi Malaysia (UTM) • Universiti Teknologi MARA (UiTM)
Netherlands	• Utrecht University, Copernicus Institute
Norway	• Prediktor • University of Agder
SOLARPOWER EUROPE	• SOLARPOWER EUROPE
Spain	• DNV GL - Energy - Renewables Advisory • National Renewable Energy Centre (CENER)
Sweden	• ABB AB, Corporate Research • Paradisenergi AB • Solkompaniet • SP Technical Research Institute of Sweden
Switzerland	• Scuola Universitaria Professionale della Svizerra Italiana (SUPSI) • TNC Consulting AG
Thailand	• King Mongkut University of Technology Thonburi (KMUTT)
USA	• Case Western Reserve University • National Renewable Energy Laboratory (NREL) • Sandia National Laboratories (SNL)

TASK 14 – HIGH PENETRATION PV IN ELECTRICITY GRIDS

INTRODUCTION

With PV becoming an integral part of the electricity generation portfolio in a growing number of countries around the globe, proper understanding of the key technical challenges facing high penetrations of PV is crucial to ensure further smooth deployment of PV and avoid potential need for retroactive measures. Key issues include the variable nature of PV generation, the power electronics interconnection to the grid and its primary connection to the distribution grids typically designed only for supplying loads. Power system protection, quality of supply, reliability and security may all be impacted.

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.

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. Following the ongoing growth, PV has today become a visible player in the electricity generation not only on a local, but country wide level in more and more countries.

While during the initial phase of Task 14 from 2010 to 2014, 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.

Following the official endorsement of Task 14's second term by the IEA PVPS Executive Committee in April 2014, 2015 marked the first year of the collaboration with an extended scope and work programme.

In its work programme from 2014-2018 Task 14 addresses the full interconnected electricity system consisting of local distribution grids and wide-scale transmission grids. Furthermore, also autonomous power systems such as "mini grids", which are an increasingly used solution to electrify remote villages and towns, are within the scope of Task 14, in particular in those countries (e.g. Australia) where such power systems form significant parts of the national electricity system.

SUBTASKS AND ACTIVITIES

Task 14's work programme until 2018 addresses primarily the technical issues of high penetration of PV in electricity networks. Issues related to implications of high-penetration PV on the level of electricity markets are considered, based on the local expertise of the Task 14 experts group.

Technical issues which are covered by the Task 14 work programme include energy management aspects, grid interaction and penetration (see Figure 2) 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 started in 2015 which addresses the possible roles of PV in future Smart Grids scenarios.

The work programme is organized into five main technical Subtasks (1 to 5), covering the areas mentioned. An additional cross-cutting Subtask, which is intended to be a hub to all Subtasks and which will investigate the implications of the technical solutions on the electricity market is currently under development.

- Cross-cutting Subtask: Market implications with High PV Penetration (currently under development)
- 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: Communication and Control for High Penetration of PV

PROGRESS AND ACHIEVEMENTS

The massive deployment of grid-connected PV in recent years has brought PV penetration into the electricity grids to levels where PV – together with other variable RES – have become a visible player in the electricity sector. This fact not only influences voltage and power flows in the local distribution systems, but also influences the demand-supply balance of the overall power system. In parallel, the size of PV systems continued to grow to the extent that GW-scale systems could be developed in the coming years.

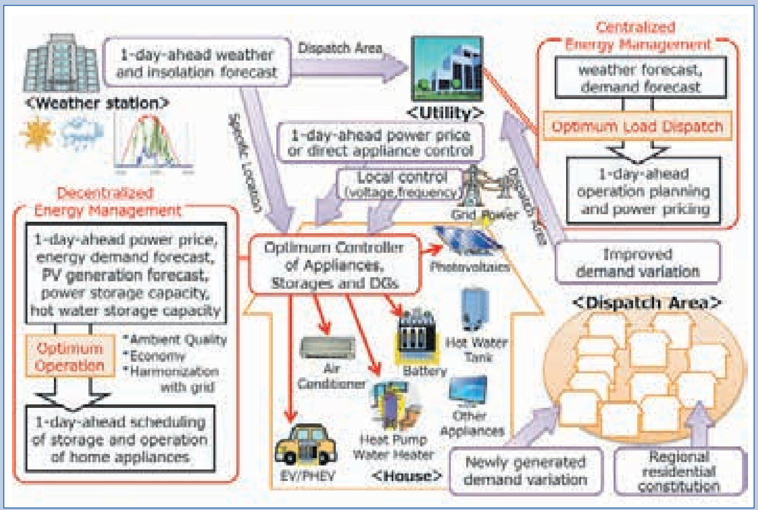


Fig. 1 - The enhanced power system operation by optimized utilization of the whole resources of flexibility against the smoothed variability (Source: Ogimoto, Laboratory).

Fig. 2 - IEA PVPS Task 14 Organization.

The aspect related to key challenges for operating small- and wide area power systems with high penetrations of PV are addressed in the Task 14 report "Power System Operation and Augmentation Planning with PV Integration". The report presents solutions to operational planning, including balancing operation and generation dispatch, reducing variability and increasing flexibility. Power system case studies from 11 countries complement the theoretical investigations and highlight different approaches to accommodate high penetrations of PV and RES in various types of transmission systems. This IEA PVPS Task 14 report shows a pathway for preparing the future transmission systems along the way towards PV as a major electricity source. The described approach for an enhanced power system operation by optimized utilization of the whole resources of flexibility against the smoothed variability is illustrated in Figure 1.

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

- In May 2015, IEA PVPS Task 14 together with IEA ISGAN Annex 6 (Transmission and Distribution), organized a joint workshop, hosted by the AIT Austrian Institute of Technology, Vienna, Austria.
  Under the title *"The Use of Variable Renewables as Flexible Resources to Support Grid Operation and Power Transmission and Distribution Interaction"*, the workshop covered a broad range of issues: The planned rapid growth of both distributed and large-scale wind and solar power generation will require a "smarter" and more powerful transmission and distribution system, with higher customer involvement and the rise of new market players.
  A key element in this transition is flexibility, both on the demand side and the generation side. Experiences and approaches concerning the use of variable renewables as flexible resources to support grid operation were shared and discussed by experts representing utilities, consulting companies, funding agencies, regulators, research agencies, and international members of the IEA PVPS and IEA ISGAN.
- In December 2015, Task 14 supported the 2015 SolarCanada conference, held in Toronto, Canada by organizing a full conference track under the heading "Technical Transformation"; see the link: http://solarcanadaconference.ca/technical-transformation-track/. This track was designed to educate and support solar industry, utilities, and system operators prepare for a future with more solar on the grid.
  During four sessions over a two day period, the following aspects were collaboratively presented by Task 14 experts and Canadian stakeholders:
  - *Solar Implications for Distribution Grids*: examining how variable renewable energy resources require the adoption of new solutions and strategies which are transforming the ways in which the distribution- and the transmission-networks interact to balance supply and demand and ensure safe and reliable system operation.
  - *Solar Variability, Forecasting, and System Operation*: considering the significant advancement of variable distributed solar generation, and how the interactions between distribution and transmission networks have become more complex with new considerations required for system operation, control and protection.
  - *Smart Inverters and System Benefits:* looking at "smart" inverter functions including reactive power control, voltage, frequency ride-through, advanced two-way control capabilities, storage integration and data streaming, and how smart inverter technology holds the potential to maximize the penetration of solar on the grid while optimizing system benefit and transform the electricity sector.
  - *Smart Grid Integration:* examining the role and technical considerations for solar in grid-modernization and its potential to transform the electricity sector as we know it today by connecting the dots between micro-grids, storage, electric vehicles and the internet.

Task 14 Workshop presentations of both workshops held in 2015 as well as documents from previous events are publicly available for download from the Workshops section of the IEA PVPS website: http://www.iea-pvps.org/index.php?id=212

SUMMARY OF TASK 14 ACTIVITIES PLANNED FOR 2016

Task 14 activities in 2016 will focus on the implementation of the subtasks. Technical research will be done on the following issues:

- The report "Do it Local – Management Summary Local Voltage Support by Distributed Generation" is planned to be published in early 2016.

Fig. 3 - Task 14 Experts at Meeting in Vienna (Photo: IEA PVPS Task 14).

Fig. 4 - Task 14 Technical Transformation Session at SolarCanada 2015 Conference, Toronto, Canada (Photo: IEA PVPS Task 14).

- 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. An overview on international activities in the field of DSO/TSO interfaces is planned.
- Investigation of inverter related requirements for high penetration PV, including interface related issues and communication/control issues.

INDUSTRY INVOLVEMENT

As from the beginning, industry has been directly involved in the development of the concept and work plan 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, also experts from SolarPower Europe (formerly known as EPIA) and CANSIA, The Canadian Solar Industry Association are official members of Task 14 and actively contribute to its activities.

During its whole period, Task 14 actively integrated 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 2015 Task 14 published 2 official reports

- IEA PVPS T14-04:2014 "Power System Operation and Augmentation Planning with PV Integration"
- IEA PVPS T14-05:2015 "Characterization of the Spatio-temporal Variations and Ramp Rates of Solar Radiation and PV" prepared by IEA Task 14 Subtask 1.3

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.

- September, 2015 EU PVSEC (Keynote presentation): "Quantification, Challenges and Outlook of PV integration in the Power System: a Review by the European PV Technology Platform"; P.J. Alet et.al., significant contribution by Task 14 OA Christoph Mayr, AIT Austrian Institute of Technology;
- October 2015 ISGC Conference (invited keynote presentation); "European Grid Codes for DG and ESS Recent developments and future trends"; Task 14 OA R. Bründlinger, AIT Austrian Institute of Technology;
- October 2015 ISGC Conference (invited keynote presentation); "Distribution Grid Integration of Renewables in Germany – Interconnection Requirements and Best Practice Examples"; T. Stetz, Department of Smart Grids and Energy Storage University of Applied Sciences Gießen, Germany;
- November 8, 2015 ISES Solar World Congress 2015 (invited keynote presentation): "High penetration of PV in electricity grids: international context"; Task 14 OA Christoph Mayr, AIT Austrian Institute of Technology.

Presentations of all Task 14 events organised so far are publicly available for download from 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 2016, in order to involve industry, network utilities and other experts in the field of PV integration in the Task 14 work.

At the moment, 2 workshops are planned for 2016:

- Joint workshop between IEA PVPS Task 14 and IEA WIND Task 25 is planned to be held in Fredericia, Denmark in May 2016;
- October 2016: "Global Experiences on High penetration PV Integration", workshop planned as part of the 2016 Singapore International Energy Week (SIEW).

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

MEETING SCHEDULE (2015 AND PLANNED 2016)

2015 Meetings:

- **The 11th Experts' Meeting** was held in Vienna, Austria, May 2015, hosted by AIT and the Austrian Ministry for Transport, Innovation and Technology
- **The 12th Experts' Meeting** was held in Toronto, Canada, December 2015, hosted by CANSIA

2016 Meetings (tentative)

- **The 13th Experts' Meeting** is planned to be held in Fredericia, Denmark, May 2016, hosted by energinet.dk.

TABLE 1 –LIST OF TASK 14 PARTICIPANTS 2015 (INCLUDING OBSERVER)

COUNTRY	PARTICIPANT	ORGANISATION
Australia	Iain McGill	University of NSW
Australia	Glen Platt	CSIRO
Austria	Christoph Mayr	AIT Austrian Institute of Technology
	Roland Bründlinger	AIT Austrian Institute of Technology
Belgium	Pieter Vingerhoets	KU Leuven
	Ioannis-Thomas Theologitis	SolarPower Europe
Canada	Patrick Bateman	CANSIA
China	Wang Yibo	Chinese Academy of Science
Denmark	Kenn H. B. Frederiksen	Kenergy
EC	Arnulf Jàger-Waldau	European Commission
Germany	Martin Braun	Fraunhofer IWES
	Markus Kraiczy	Fraunhofer IWES
	Daniel Premm	SMA Solar Technology AG
	Gunter Arnold	Fraunhofer IWES
	Thomas Stetz	Fraunhofer IWES, until 7/2015 and Mittelhessen University of Applied Sciences, after 8/2015
	Gerd Heilscher	Hochschule Ulm
Israel	Moshe Ohayon	Israel Electrical Company
Italy	Giorgio Graditi	ENEA-Portici Research Centre
	Adriano Iaria	RSE
Japan	Toshihiko Takai	NEDO
	Kazuhiko Ogimoto	The University of Tokyo
	Takashi Oozeki	AIST
Malaysia	Ali Askar Sher Mohamad	SEDA
	Azah Ahmad	SEDA
Portugal	Catarina Calhau	EDP Energias de Portugal
Spain	Vicente Salas	Universidad Carlos III de Madrid
Sweden	Antonis Marinopoulos	ABB Corporate Research
Switzerland	Lionel Perret	Planair SA, Switzerland
	Christoph Bucher	Basler & Hoffmann AG
	Jan Remund	Meteotest
United States	Benjamin Kroposki	National Renewable Energy Laboratory NREL
	Barry Mather	National Renewable Energy Laboratory NREL
Singapore (observer)	Thomas Reindl	SERIS

TASK 15 – ENABLING FRAMEWORK FOR THE ACCELERATION OF BIPV

Fig. 1 - Visit of Task 15 participants at the BIPV Real Life Laboratory in the Netherlands.

Fig. 2 - Task 15 Experts at the Task 15 Kick-Off Meeting in the Netherlands, June 2015.

INTRODUCTION

The built environment is responsible for up to 24 % of greenhouse emissions and accounts for 40 % of the world's total primary energy use. The numbers are increasing each year, due to the rising number of world population, as well as improved standards of living, and will confront us with energy shortage in the future and negative climate changes already in the present. There is ample evidence that the current energy system is not sustainable and that we have to shift to a system based on renewable sources, such as the sun.

Solar PV energy systems, applied in the built environment, offer the possibility of renewable energy closely located to the consumer, solving the challenges of climate change and energy shortage. To facilitate large-scale introduction of these systems, integration in the built environment is necessary, together with the three other key developments, price decrease, efficiency increase and energy storage.

Building Integrated PV (BIPV) systems consist of PV modules that are integrated in the building envelope as part of the building structure, possibly replacing conventional building materials and contributing to the aesthetic quality of the building.

Current BIPV technology has a very small market, but huge potential. To fully grasp this potential, a transition in the built environment has to be realized, in which regulatory barriers, economic barriers, environmental barriers, technical barriers and communicational barriers have to be overcome.

OBJECTIVE

Task 15's objective is to create an enabling framework to accelerate the penetration of BIPV products in the global market of renewables, resulting in an equal playing field for BIPV products, BAPV products and regular building envelope components, respecting mandatory issues, aesthetic issues, reliability and financial issues.

The main thresholds on the track of BIPV roll out cover the knowledge transfer between BIPV stakeholders (from building designers to product manufacturers), a missing link in business approach, an unequal playing field regarding regulatory issues and environmental assessment, as well as a transfer gap between product and application and are reflected in the approach of Task 15.

Task 15 contributes to the ambition of realizing zero energy buildings and built environments. The scope of Task 15 covers both new and existing buildings, different PV technologies, different applications, as well as scale difference from one-family dwellings to large-scale BIPV application in offices and utility buildings.

APPROACH

To reach the objective, an approach based on 6 Subtasks has been developed, focussed on growth from prototypes to large-scale producible and applicable products. The Subtasks with their target audiences are:

- BIPV project database - Designers and architects;
- Transition towards sound business models - Business developers / project managers;
- International harmonization of regulations - BIPV product manufacturers / installers;
- BIPV environmental assessment issues - Policy makers, building environmental assessors;
- Demonstration projects – Researchers, BIPV product developers;
- Dissemination – all outputs from the above mentioned Subtasks.

In this approach the most important process and policy thresholds are identified and breached.

ACTIVITIES OF IEA PVPS TASK 15 IN 2015

SUBTASK A: BIPV Project Database

Subtask contact persons from all 18 countries have been requested to send in 10 BIPV projects that represent interesting cases in their countries. 10 countries have responded at the moment of writing. In total, over 100 projects have been received so far.

The received material looks very promising, but more projects are necessary to develop a full overview and to develop the criteria and parameters for the evaluation.

A questionnaire has been written and sent around for comment. Based on the comments received, the questionnaire shall be updated and will be finalized during the Task 15 Experts Meeting in February 2016.

SUBTASK B: Transition towards Sound BIPV Business Models

Subtask B's objective is to make an in-depth analysis and understanding of the true total economic value of BIPV applications, and derive innovative Business Models that best exploit the full-embedded value of BIPV.

Subtask B is divided in 4 work packages (WP):

WP B1: Analysis of Status Quo

This WP will fully exploit information collected through Subtask A. Based on a selection of existing projects that are most representative of mainstream BIPV solutions/applications, the WP will perform a detailed analysis and description of how economic valuation of the project was realized, of the stakeholders that are economically involved, and of the overarching Business Model that prevails for establishing the financial viability of the solution.

WP B2: Analysis of Boundary Conditions

This WP will analyse the current and forecasted evolution of the boundary conditions determining the financial attractiveness of BIPV solutions. These include in particular, nature and importance of policy support, financial instruments, measures prevailing in terms of self-consumption, etc. This WP is of particular importance as PV – and BIPV – are transitioning from a subsidized, policy driven deployment to a competitive based deployment.

The WP will focus on how this expected transition affects the deployment of BIPV solutions in particular.

WP B3: Development of New Business Models

This is the core WP of the Subtask. It will in particular perform an in-depth analysis on the definition of the true economic value of BIPV, introducing the concepts of "extended economic value" and "patrimonial economic value". It will identify how these new sources of value could possibly be exploited by existing or possible new categories of stakeholders.

It will then analyze how new business models can be derived to fully exploit the "patrimonial economic value"' and the possible need for new ad hoc financial instruments.

Task 15 then formulates key recommendations to policy makers, financial operators and BIPV stakeholders to best support the emergence of innovative business models supporting existing or new BIPV applications.

WP B4: Testing the New Business Models

This WP will, in collaboration with Subtask E, document a selection of test and demonstration projects that illustrate the actual application of a selection of representative innovative Business Models.

SUBTASK C: International Framework of BIPV Specifications

Subtask C's first activities are based on the following definition (based on prEN50583 and European Construction Product Regulation CPR 305/2011):

[Photovoltaic modules are considered to be building-integrated if the PV modules form a construction product which is produced and placed on the market for incorporation in a permanent manner in construction works or parts thereof, and the performance of which has an effect on the performance of the construction works with respect to the basic requirements for construction works.]

This definition will form the basis of continuation of work in this and other Subtasks, and will be expanded for the purpose of Task 15 with aesthetical, economic and environmental parameters.

Within this Subtask, 4 working groups have been established:

Group A: State of the Art

Starting from prEN50583 (2014) and the additional list of requirements from the Japanese delegation, a first list of requirements is created that can then be used as a basis for further improvements.

Group B: Structural Analysis

This group summarizes problems that arise due to the general structure of the prEN50583. Disadvantages of the BIPV definition, the five categories, differences between European and international approaches etc. should be listed and improvements should be suggested.

Group C: Communication

To avoid double work, the aim of this working group is to communicate its efforts to other standardisation groups. Task 15 should be aware of existing standardisation activities as well as be in contact with the most important decision makers and standardisation committees.

Group D: Improvement

This group should find additional needs and requirements for an international BIPV standard that are not listed yet in the basis developed in group A. The improvement should include the listing of multi-functionality issues, including the description of suggested changes in the existing testing procedures of other standards.

SUBTASK D: Environmental Benefits of BIPV

This Substask, coordinated by Cycleco under the direction of the ADEME (French EPA), involves 29 persons from 12 countries. All participants are working for developping a framework enabling the environmental assessment of BIPV.

These experts are mainly from the PV community, and a bridge towards the building industry is being investigated. The first activity, state of the art inventory, has started under the leadership of the Subtask Leader. A first questionnaire to establish the international state of the art was sent to all participants (1st dec. 2015).

The work of Subtask D is split into 4 parts:

- D1: Identification of BIPV related environmental benefits worldwide
- D2: BIPV focused methodology for environmental assessment
- D3: BIPV environmental assessment test cases
- D4: BIPV environmental assessment plug-in for building assessment tools

Fig. 3 - BIPV office façade in Spain with a combination of opaque and semi-transparent amorphous silicon photovoltaic glass modules (Photo: © Onyx).

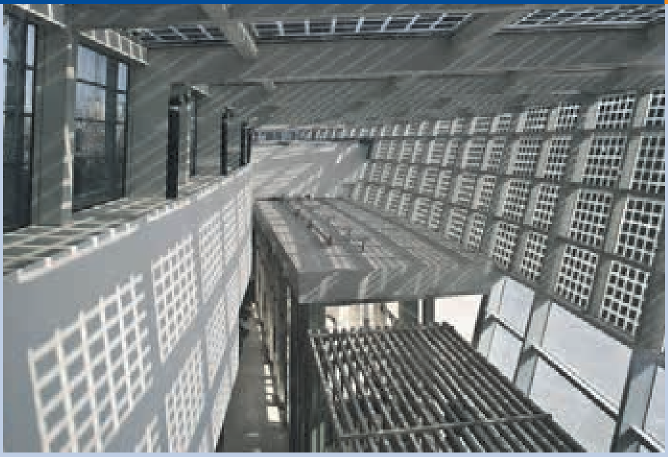


Fig. 4 - Semi-transparent glass photovoltaic modules in the Korean Football Arena entrance lobby.

At present, the University of Applied Sciences Technikum in Vienna (Austria) takes the responsibility of the D2 part, and the coming meeting will enable the selection of the person in charge of the other parts of the Subtask's work.According to the agenda established in the convention agreement between Cycleco (Subtask Leader) and ADEME (IEA PVPS Task 15 Expert France), works on this Subtask are on schedule. Nevertheless, the slight number of contributors should create some delays in the coming months.

SUBTASK E: Demonstration

Out of 63 experts' list contacted, 35 people from 11 countries would like to be involved in Subtask E. Based on an inventory of existing test and demonstration sites, objectives are to identify assessment methods and performance characterization of BIPV solutions to highlight "reference technical solutions" and contribute to dissemination of reliable BIPV solutions. Subtask E is based on a strong contribution from all Subtasks. The first activity in this Subtask, the inventory of existing BIPV testing and demonstration sites, is in progress (Action E1) under the coordination of SEAC (NL). The OFI Institute (AT) is currently finalizing its action choice (Action E2 or E4).

SUBTASK F: Dissemination

No progress to be reported.

TASK 15 ACTIVITIES IN 2015

April 7th 2015: Dutch BIPV stakeholder discussion on T15.
June 22nd – 24th 2015: 1st Task meeting: kick-off, Heerlen, the Netherlands.
September 14th 2015: Task coordination meeting, Hamburg, Germany.
September 15th 2015: EU PVSEC parallel session (jointly with EU PV Technology Platform).
October 6th 2015: Task presentation at the Austrian PV conference, Austria.
November 4th 2015: parallel session at 10th Conference on Advanced Building Skins, Bern, Switzerland.
November 16th 2015: Task presentation at the WCPEC, Busan, South Korea.
November 19th-20th, 2015: Publication at the 13th Asia Pacific Conference on the Built Environment **NEXT GEN TECHNOLOGY** Hong Kong; "Building Integration of Photovoltaic: The Future of Sustainable Building" - Reijenga, Ritzen.

SUMMARY OF TASK 15 ACTIVITIES PLANNED FOR 2016

Task 15 general activity in 2016 focusses on the finalization of the formal participation of the contributing countries through National Participation Plans and a clear distinction in activity responsibility.
The activities planned for the Subtasks are the following:
Finalization of an in-depth questionnaire covering aesthetic, building technological, financial and environmental aspects (subtask A, B and D). This questionnaire will be used for interviewing the main actors of selected BIPV projects in subtask A.

Inventory of the status quo covering regulatory and environmental issues and the current state of BIPV research and development facilities in the contributing countries (Subtasks C, D and E).

Dissemination and outreach activities cover a regular newsletter as well as presenting at national and international sustainable building and PV related conferences, depending on subtask F leadership and country contribution.

PUBLICATIONS AND DELIVERABLES

Subtask A: Publication and application of an elaborate questionnaire for BIPV project analysis and preliminary publication of a selection of analysed projects
Subtask B: Publication of the status quo of applied business models for BIPV application.
Subtask C: Publication of the inventory of applied regulations and mandatory framework of BIPV in the contributing countries.
Subtask D: Publication of the inventory of applied environmental assessment of BIPV in the contributing countries.
Subtask E: Publication of the inventory of existing BIPV research and development facilities in the contributing countries.

MEETING SCHEDULE (2015 AND PLANNED 2016)

The Task 15 Kick-off Meeting was held in Heerlen, the Netherlands, 22-24 June 2015.
The 1st Task 15 Experts Coordination Meeting was held in Hamburg, Germany, 14 September 2015.
The 2nd Task 15 Experts Meeting was held in Sophia Antipolis, France, 2-4 February 2016.
The 3rd Task 15 Experts Coordination Meeting is planned to be held in Munich, Germany, 22 June 2016
The 4th Task 15 Experts Meeting is planned to be held in either Marrakesh, Morocco or Vienna, Austria, 8-10 November 2016.

TABLE 1 – CURRENT LIST OF TASK 15 PARTICIPANTS (INCLUDING OBSERVERS*)

COUNTRY	PARTICIPANT	ORGANISATION
Austria	Hubert Fechner	Univ. As Technikum Vienna, Austrian PV Technology Platform
	Gabriele Eder	OFI, Austrian Research Institute for Chemistry and Technology
	Lukas Maul	University of applied sciences Technikum Vienna
	Dieter Moor	ERTEX Solar GmbH
	Astrid Schneider	AIT - Austrian Institute for Technology
	Philipp Rechberger	ASIC - Austrian Solar Innovation Center
	Gerhard Peharz	Joanneum Research
	Christoph Mayr	AIT - Austrian Institute of Technology
Belgium	Adel El Gammal	Becquerel institute
China	Shengli Wang	IEE (Institute of Electrical Engineering, Chinese Academy of Sciences)
Denmark	Kenn H.B. Frederiksen	Kenergy
France	Simon Boddaert	CSTB (Centre Scientifique et Technique du Bâtiment)
	Renaud Vignal	Arcelor Mittal
	Francoise Burgun	CEA-INES
	Valentine Moreau	Cycleco SAS
	Jérôme Payet	Cycleco SAS
Germany	Claudio Ferrara	Fraunhofer ISE
	Tilmann Kuhn	Fraunhofer ISE
	Wendelin Sprenger	Fraunhofer ISE
	Maria Roos	Fraunhofer IWES
	Norbert Henze	Fraunhofer IWES
	Ingo B. Hagemann	Architekturbüro Hagemann
Greece*	Dimitrios Karamanis	University of Patras
Italy	Francesca Tilli	Gestore dei Servizi Energetici GSE S.P.A.
	Alessandra Scognamiglio	ENEA
	Stefano Avesani	Eurac Research, Institute for Renewable Energy
	Nebosja Jakica	Politecnico di Milano
Japan	Seiji Inoue	AGC Glass Company
Korea	Jun-Tae Kim	Kongju National University

COUNTRY	PARTICIPANT	ORGANISATION
Lithuania*	Juras Ulbikas	Protechnology
Morocco*	Souad LALAMI	IRESEN
Netherlands	Michiel Ritzen	BIHTS / NEBER / Zuyd University of Applied Sciences
	Martje van Horrik	BIHTS / NEBER
	Tjerk Reijenga	BEAR-iD Architects
	Boukje Huijben	TU/e (Technical University Eindhoven)
	Sharon Dolmans	TU/e (Technical University Eindhoven)
	Roland Valckenborg	SEAC
	Chris Geurts	TNO
	Erik Alsema	WE advisors
	Menno van den Donker	SEAC (Solar Energy Application Centre)
	Mariska de Wild-Scholten	Smart Green Scans
	Wilfried van sark	University Utrecht
	RuudDerks	ZigZagSolar
	Olivier Jung	Trespa International B.V.
Norway	Anne Gerd Imenes	Teknova
Spain	Nuria Martin Chivelet	CIEMAT (Research Centre for Energy, Environment and Technology)
	Jonathan Leloux	UPM
	estefania Caamano	Technical University of Madrid
	Maider Machado	Tecnalia Research & Innovation
	Ana Belen Cueli Orradre	CENER
Sweden	David Larsson	Solkompaniet
	Peter Kovacs	SP Technical Research Institute of Sweden
	Bengt Stridh	ABB corporate research / Mälardalen University
	Martin Warneryd	SP Technical Research Institute of Sweden
	Rickard Nygren	White arkitekter
Switzerland	Christof Erban	Meyer Burger AG
	Francesco Frontini	SUPSI

AUSTRALIA

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

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

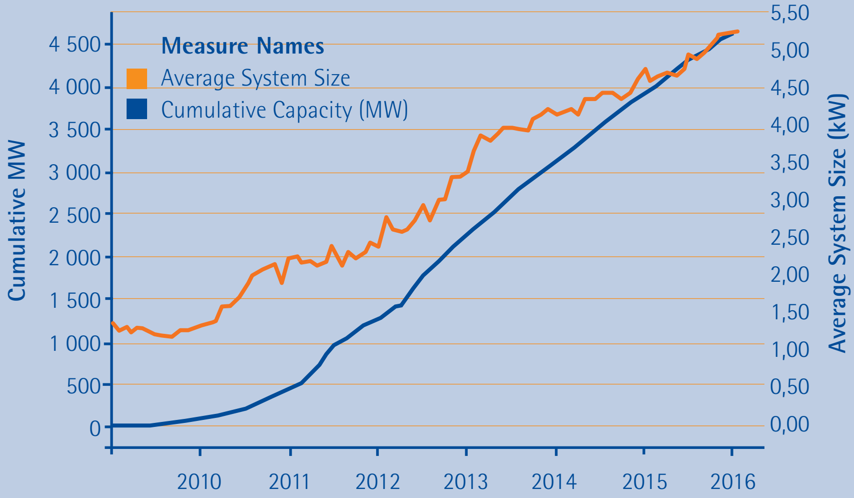


Fig. 1 - Cumulative installed capacity (MW) and average system size (kW) in the Australian residential PV market.

GENERAL FRAMEWORK AND IMPLEMENTATION

Solar power continues to be hugely popular at residential levels in Australia.1,5 million Australian homes are now powered by their own PV system. Residential penetration levels average 18 % of households and reach over 50 % in some urban areas. Market saturation effects are beginning to be observed as residential installation volumes have declined for three years running. Interest in commercial PV systems continues to grow, though not fast enough to offset the decline of residential volumes in 2015.

Deployment of utility-scale PV jumped to record levels in 2015, contributing to a year of growth in the overall market. Installation levels increased from 850 MW commissioned in 2014 to around 935 MWp in 2015. At the end of 2015, installed capacity sat just below the 5,0 GW mark, accounting for 9 % of electricity capacity and 2,5 % of electricity generation. Solar power was the number one source of capacity added to the Australian generation fleet in 2015.

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 slowly continues to build, but may take years to play out. Meanwhile many distribution network operators have singled out PV for punitive requirements such as export-limiting technologies and imposition of demand-tariffs, or have otherwise restricted system sizes, particularly for non-residential systems. Despite this, Australia's High Court blocked one electricity distributor's attempt to apply discriminatory billing upon solar owners.

Australia's PV market remains focussed upon self-consumption, with the majority of the population offered feed-in tariffs worth little more than the wholesale electricity price. Battery suppliers have identified a significant opportunity for sales in Australia, owing to the large differential between the value of solar energy that is self-consumed versus that which is export.

NATIONAL PROGRAMME

The main support for PV at a national level remains the Renewable Energy Target (RET), which undertook an extensive review in 2014 and 2015. Support for large systems is via the Large-scale RET (LRET) which in 2015 was reduced from 41,000 GWh to 33,000 GWh of renewable electricity by 2020. 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 SRES was unaffected by the RET Review.

RESEARCH, DEVELOPMENT & DEMONSTRATION

PV research, development and demonstration are supported at the national, as well as the State and Territory level. In 2015, research grants were available through the Australian Research Council and the Australian Renewable Energy Agency (ARENA). ARENA has supported PhDs scholars and post-doctoral fellows with 18 MAUD committed towards more than 80 projects, the last of which is expected to complete in 2017. To date ARENA has committed 434 MAUD towards Photovoltaic projects, including 17 with the University of NSW, five with the Australian National University, two with the University of

Fig. 2 - The ARENA Solar Flagship Utility Scale Solar Farm, Nyngan NSW. AGL: How we source our energy (Photo: AGL Energy).

Fig. 3 - The ARENA Solar Flagship Utility Scale Solar Farm, Nyngan NSW (Photo: AGL Energy).

Melbourne, and one with the University of Queensland. Major projects supported included:

- Solar Farms at Nyngan, Broken Hill, Moree, Degrussa, Weipa, Doomadgee, Karratha, and many sites in the Northern Territory
- The establishment of the Australia-US Institute for Advanced Photovoltaics

In 2015, in addition to providing funding to mixed-technology projects, the Clean Energy Finance Corporation has added the following PV-specific projects to its investment portfolio:

- 100 MAUD in finance for solar PV and storage projects across Australia which support an electricity retailer to offer Power Purchase Agreements.
- 4,7 MAUD in finance for a large scale solar PV Project in the Northern Territory (Ayers Rock Resort, 1,8 MW).
- 13 MAUD to expand the Uterne power station in the Northern Territory from 1 MW to 4,1 MW in size.
- 15 MAUD in finance for remote renewable solar PV and battery storage in Western Australia (Degrussa, 10,6 MW with 6 MW battery storage).
- 20 MAUD in finance for fringe of grid renewable solar PV in Queensland (Barcaldine, 20 MW).
- In 2015, ARENA and the CEFC also opened complementary large-scale solar programs, worth 100 MAUD and 250 MAUD respectively.

INDUSTRY AND MARKET DEVELOPMENT

Despite the fact that the overall market grew in 2015, installation volumes were substantially lower than expected. Were it not for the three utility-scale installations that arose out of the now-complete Solar Flagships Program (Nyngan (103 MW), Moree (56 MW), and Broken Hill (53 MW)), the overall market would have contracted. The residential PV market contracted 17 %, following a 12 % contraction on the year before. The 10-100 kW market grew by 10 % but not enough to offset the residential contraction.

The growth in commercial PV and the contraction in residential PV means that commercial market now represents 24 % of the non-utility-scale market by volume. Companies like IKEA have installed PV on each of its stores. Hence, average system size in the sub-100 kW segment has climbed to reach 5,3 kW/system by the end of 2015. Module prices increased slightly to around 0,80/Wp in 2015 due to a weakening Australian Dollar; despite this installed prices for small residential systems dropped slightly to 2,40 AUD/Wp.

The trends that were established in 2015 are likely to continue into 2016. The residential PV sector is likely to continue to decline due to the early effects of market saturation and in the absence of any specific stimulus. The commercial PV sector is anticipated to again grow by a modest amount. There are new utility-scale development initiatives from the Australian Renewable Energy Agency (ARENA), Clean Energy Finance Corporation (CEFC), state governments and major electricity providers that will eventually result in a significant volume of projects, though few are likely to be commissioned in 2016. As a result, the overall market is expected to contract in 2016. Meanwhile there is ever-increasing customer interest in on-site storage. Storage solutions from major international players in conjunction with local partners have gone on sale in late 2015 Electricity distribution network operators have also begun trials of storage technology. 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

GENERAL FRAMEWORK AND NATIONAL PROGRAMME

About 75 % of Austria's 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 a significantly rising part of photovoltaics with currently nearly 2 % in 2015. Austria has never produced electricity from nuclear energy and has a strong policy against nuclear. At the climate Conference COP 21 in Paris in December 2015, the Austrian Chancellor also announced the country's intentions to completely eliminate fossil energy use in Austria's electricity system by 2030.

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 1 200 MW in 2020.

Approximately 785 MW of PV power were installed in Austria by the end of 2014. There are no final figures available for 2015 yet, but it is expected that the growth in 2015 declined a little and approximately 925 MW were totally installed in Austria by the end of 2015. With current installation rates, the official market target for 2020 will be reached, at the latest, in 2017.

Austria's support schemes for photovoltaics are manifold; the support per unit was further slightly reduced in 2015. Two support schemes are still 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; the annual cap, which started with 50 MEUR in 2012 is reduced every year by one million. In 2015, an additional 47 MEUR for all "new renewables" became available. Photovoltaic receives 8 MEUR from this amount. 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 2015, the tariff was set at 11,5 EURcent/kWh for PV on buildings (12,5 EURcent/kWh in 2014) and for the first time there was no incentive for PV on the open landscape. As in 2014, an additional 200 EUR subsidy per kWp (or 30 % of total invest cost) was offered.
- About 7 MEUR were dedicated in 2015 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, well-co-ordinated with the feed-in scheme. With 275 EUR per kWp for roof-top systems and 375 EUR per kWp for building integrated systems, the support per kWp was the same as in 2014. This support has led to about 6 000 new PV systems with a total capacity of 36 MWp in 2015. For the first time there was an additional offer for the agricultural sector – systems from 5 kWp to 30 kWp, owned by farmers, got the same incentive per kWp (275/375 EUR) like the other private people, which might have led to approx. 4,4 MWp installed in 2015.

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

The mean system price for private systems went further down to 1 752 EUR/kWp (excluding VAT) for a 5 kW system.

In 2015, support schemes for battery-storage systems in combination with PV systems were offered by several provinces. This scheme is dedicated for small, mainly private systems, the support schemes are very different, typically ranging up to storage capacities of up to a maximum of 10 kWh. Up to now, these initiatives led to a total of a few hundred storage systems.

RESEARCH AND DEVELOPMENT

The National PV Technology Platform, founded in September 2008 and exclusively financed by the participating industry, research organisations and Universities experienced again a very good development in 2015; primarily supported by the Ministry of Transport, Innovation and Technology, this loose platform now acts as a legal body since 2012. The PV Technology Platform brings together about 30 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 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 beside the needed increasing awareness aimed at further improving the frame conditions for manufacturing, research and innovation in Austria with the relevant decision makers.

For many years, the Austrian PV research activities are 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 and, The National Energy Research Programme from the Austrian Climate and Energy Fund, as well as the programme "City of Tomorrow" from the Ministry of Transport, Innovation and Technology which covers quite broad research items on energy technologies including PV. The research budget for PV related projects within the energy research programmes rose substantially until 2013. Whereas in 2007, only 0,7 MEUR were dedicated to photovoltaic research. In 2013, more than 7 MEUR were spent for PV research. However, the data for 2015 shows a decline towards less than 3 MEUR. Further public research funding in the field of PV is given within the initiatives COMET or on an individual project basis.

In 2014, Austria's public expenditures for energy-related research and development amounted to 143 MEUR, increasing the expenditure of 2013 by 15 % and reaching an all-time high. Expenditures for renewable energy technologies were at a total of 32,4 MEUR. Here, solar energy provided 60 % of activities (19,2 MEUR) with its main focus on PV (11,5 MEUR; equal to a share of 8 % of public energy-related research funding).

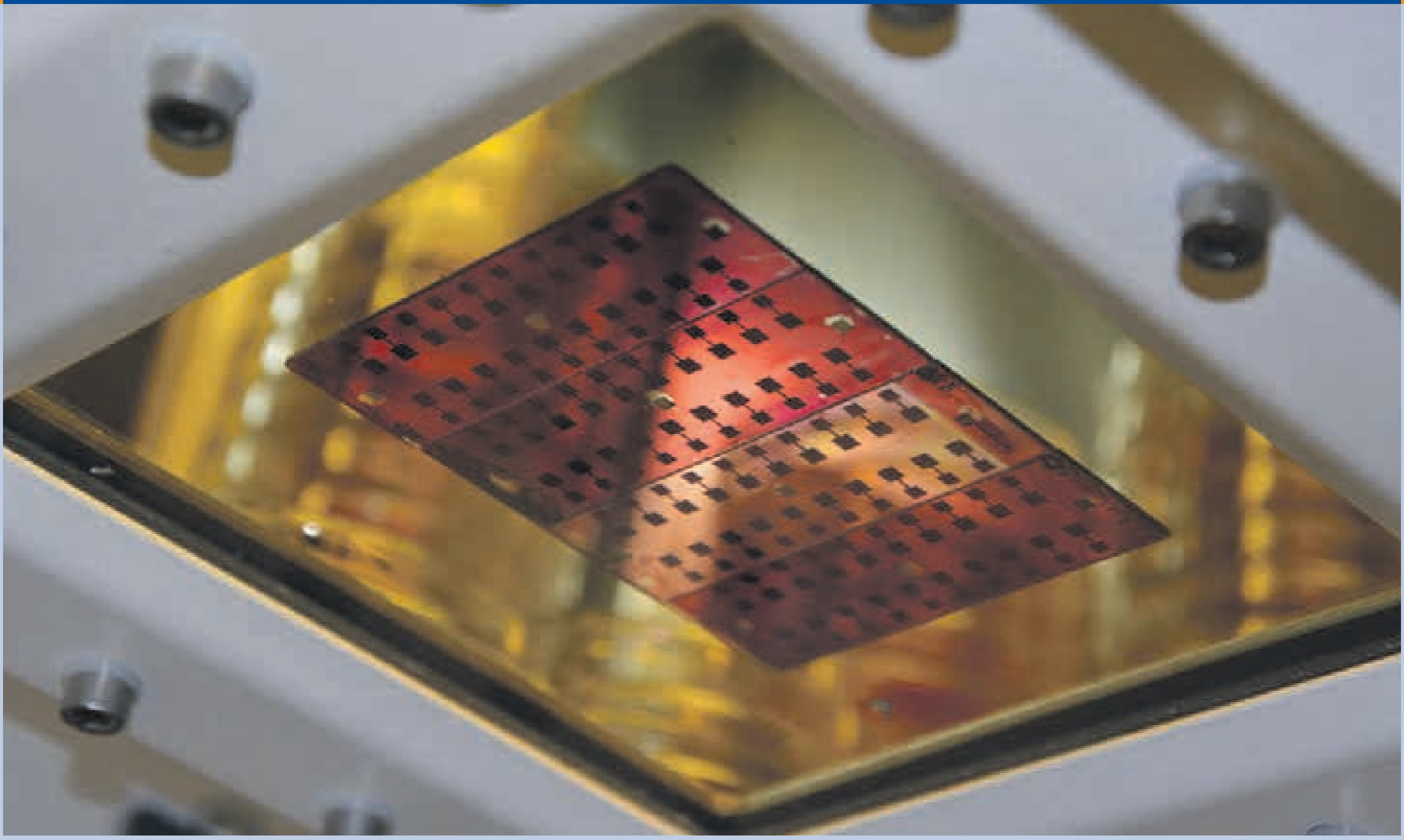


Fig. 1 - Laboratory test devices of inorganic-organic hybrid solar cells prepared at ICTM, TU Graz (Photo: © Astrid Knall, TU Graz).

Within IEA PVPS, Austria is leading the Task 14 on "High Penetration of Photovoltaics in Electricity Networks," as well as actively participating in Task 1,12, 13 and the new Task 15 on "Enabling Framework for the Acceleration of BIPV".

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

"Smart Grid" activities in Austria are more and more focusing on business models for new applications, where PV together with storage, heat pumps, electric-vehicles and other technologies offer a wide spectrum for new activities. PV is seen as an important cornerstone in a new and more and more digital energy world. Moreover, there is a clear tendency of private consumers to achieve a high degree of energy autonomy. PV in combination with storage systems, where both technologies have shown significant cost digression in recent years, offers this opportunity. Out of that trend, discussions about further financing the public grid are emerging.

IMPLEMENTATION & MARKET DEVELOPMENT

As mentioned above, self-consumption is more and more an additional driver of the PV development. However, a self-consumption tax was introduced in 2014, for annual production which exceeds 25 000 kWh; since this is far beyond the typical production by private PV systems, which are dominating the Austrian market traditionally, this tax does not influence the development of private PV storage systems, but has an effect on larger systems in industry as well as small and medium enterprises which are affected by this taxation, self-consumption is mainly seen as the decisive factor for amortisation of larger PV systems in Austria.

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 the form of PV power plants play a minor role. Building integration is an important issue and a cornerstone of the public implementation strategy.

The new Austrian electricity statistic regulation, negotiated and decided at the end of 2015 obliges the network operators from now on to report all new installed wind and PV systems to the regulator at the end of each year. This might be the basis for a national PV register, which could also serve as an important tool to improve the PV power forecasting.

MARKET DEVELOPMENT

The Federal Association Photovoltaic Austria is a non-governmental interest group of the solar energy industry. The association promotes solar PV at the national and international level and acts as an informant and intermediary between business and the political and public sectors. Its focus lies on improving the general conditions for photovoltaic in Austria and on securing suitable framework conditions for stable growth and investment security. Benefiting from its strong public relations experience, PV-Austria builds networks, disseminates key information on the PV industry to the broader public, and organizes press conferences and workshops. By the end of 2015, the association counted 240 companies and persons involved in the PV industry as its members.

The 13th Annual National Photovoltaic Conference took place in Schwaz/Tyrol in 2015. It was again a three-day event, organised by the Technology Platform Photovoltaic and supported by the Ministry of Transport, Innovation and Technology. This strategic conference has been established as THE annual come together of the innovative Austrian PV community, bringing together about 250 PV stakeholders from industry, research and administration.

Many specific conferences and workshops were organised by the association "PV Austria". These renewable energy fairs and congresses are more and more focussing 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. A further 8 courses are planned for 2016. Furthermore, specialized trainings for planners and installers are offered, since Autumn 2015, in the areas of system quality and planning, practical knowledge on standards and guidelines for electrical engineers in practice, optimized self-consumption of PV systems and detailed knowledge of mounting systems.

Larger PV power plants, ranging from several 100 kWp to some MW systems have been successfully installed by the utility "Wien Energie" as "citizen´s solar power plants", meaning that the project is crowdfunded by citizens. They become owner of one or several modules and will receive an annual interest rate. As previous projects have shown, the demand is very high. Usually it only takes some hours until a new power plant is sold out. Part of this success is the relatively high annual interest rate, compared to the currently low market rates.

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. International collaboration is very important.

Storage systems will enable increased energy autonomy and might become a main driver in the sector, currently mainly driven by private consumers.

Changing the energy infrastructure by adapting to fluctuating generation is a major issue. The fruitful smart grids community in Austria, a collaboration between research institutes industry and some national distribution networks operators, has already create significant results from their first demo-sites.

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

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

Smart city projects are well supported by the Ministry of Transport, Innovation and Technology, as well as by the Austrian Climate and Energy Fund. Within the broad range of city relevant research, PV plays more and more a role as 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, as well. All of them include PV as an essential part of the future energy strategy. The importance of proper education for installers and planners of PV systems will increase depending on the market situation; the training is already available and can be extended easily. Meanwhile, at the University of Applied Science Vienna (Technikum-Wien), about 300 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
GREGORY NEUBOURG, APERE ASBL, BRUSSELS

Fig. 1 - The roof of the Belgian pavilion at the Universal Exhibition in Milano was covered with BIPV laminated photovoltaic glass from the AGC Company (either crystalline photovoltaic cells or an organic fill).

GENERAL FRAMEWORK

Belgium reached 3,227 MWp of cumulative installed PV capacity at the end of December 2015, according to the latest figures of the three regional regulators. The country added 88 MWp in 12 months, a similar growth as in the year 2014 or 2008.

Despite this sluggish market, and thanks to an exceptional annual solar radiation (1 049 kWh/kWp in Brussels), the PV electricity production reached 4 % of the total electricity demand in 2015.

In Flanders, the "prosumer fee" of around 85 EUR/KW depending on the Distribution System Operator (DSO) was introduced in July 2015 for all the small PV systems (<10 kW). This fixed fee enables DSOs to charge for the cost of grid use by PV owners, without changing the system of net metering. Big systems (>10 kW) have no net-metering or prosumer fee, they benefit from a self-consumption scheme and from an additional green certificate (GC) 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 65 MWp in 2015, reaching 2,3 GWp. The installation of small systems (<10 kW) was better than in 2014. This segment still represents 51 % of the installed capacity. The big plants (>250 kW) and the commercial segments (10-250 kW) represent respectively 27 % and 22 % of the total installed capacity.

In Wallonia, the Qualiwatt support plan for small systems (≤10 kW) introduced in 2014 has not yet met the success that was foreseen despite the attractive conditions. 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 3 kWp 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 for the equipment (European norms, factory inspection), the installer (RESCERT trainee) and the installation (standard conformity declaration, standard contract) which restores trust for the new investors.

For big systems in Wallonia, a change occurred in the support mechanism in 2015. There is now a system of GC reservation that controls the development of the market. The amount of GC/MWh depends of the system size and varies between 2,4 (156 EUR) if system is smaller than 250 MWp and 1,9 (123,5 EUR) if system is bigger than 750 MWp. This change has strongly impacted the total installation rhythm that went from 375 installations in 2014 to 47 in 2015.
In terms of installed capacity, Wallonia installed 21 MWp in 2015, with a timid recovery of the small systems market, reaching 838 MWp in total.

Brussels is the first Belgian region where the yearly net-metering system that has benefited small systems (< 5 kW) is going to be removed. It will be replaced by a self-consumption scheme at the start

Fig. 2 - In January 2015, IMEC demonstrated a large area industrial crystalline silicon n-PERT solar cell with a record 22 percent efficiency.

of 2018. The green certificates support remains operational and has been increased in the beginning of 2016 for small systems to take into account the removal of the net-metering scheme and to guarantee a 7 year payback time.

In terms of installed capacity, Brussels installed 2 MWp in 2015, reaching 51 MWp.

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 542,1 MW of installed capacity 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 2015, it reached more than 3 GW, which is already more than the double of the objective for 2020.

Since November 2015, and after long negotiations, the national objective of 20 % of renewable energy was translated into regional targets. In 2016, each region will adapt their existing roadmaps to reach these objectives.

RESEARCH AND DEVELOPMENT

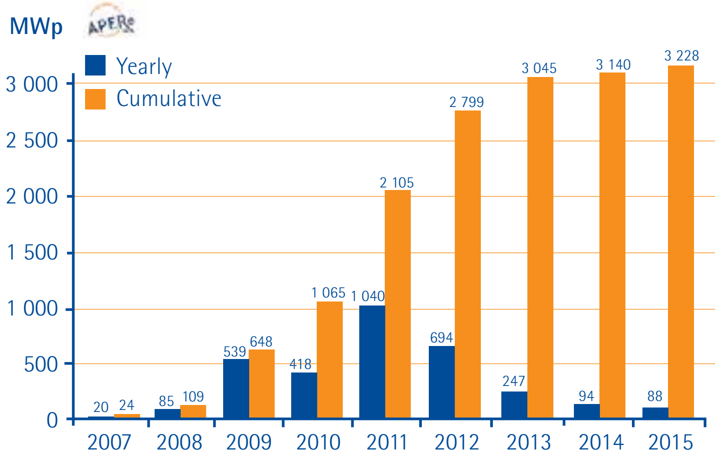
R&D efforts are concentrated on highly efficient crystalline silicon solar-cells, thin film (including Perovskite) and organic solar-cells (for example by IMEC, AGC, etc.). There is also some research on smart PV modules that would embed additional functionalities as micro-inverters (mainly from IMEC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

INDUSTRY

Issol is the last producer of classical modules, but it is not their main activity. With Soltech and Reynaers, they are the three 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	84 844	108 525
2008	539 017	647 542
2009	417 541	1 065 083
2010	1 039 600	2 104 683
2011	694 079	2 798 762
2012	246 648	3 045 410
2013	94 207	3 139 616
2014	88 064	3 227 680

Small-scale projects (< 10 KW) account for 60 % of the installed capacity with more than 361,300 installations which represent approximately 1 household out of 13. The other 40 % include 7 200 large-scale projects.

CANADA

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

YVES POISSANT AND LISA DIGNARD-BAILEY, CANMETENERGY, NATURAL RESOURCES CANADA
PATRICK BATEMAN, CANADIAN SOLAR INDUSTRIES ASSOCIATION (CANSIA)

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 Agency 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.

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 throughout Canada. Most provincial and territorial governments have established policies 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. Others are now beginning to explore the potential of solar PV in greater levels of deployment and at larger scales.

Utility Interconnected PV Systems 2014

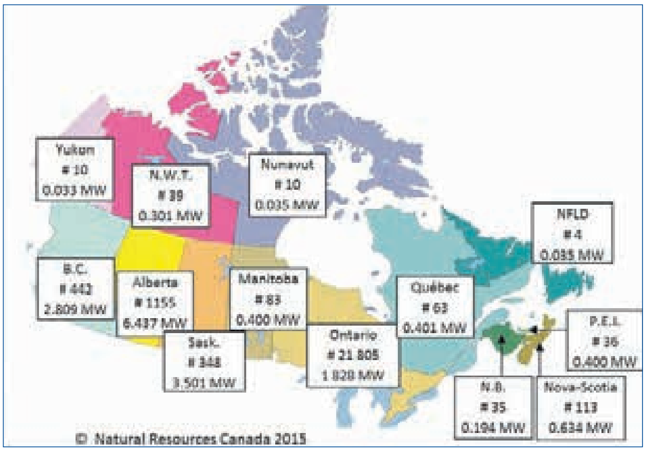


Fig. 1 - Map showing the Canadian provinces, the capacity (in megawatt) and the number of utility interconnected PV Systems in 2014.

The Province of Ontario, Canada's most populous and second largest province, leads the country in photovoltaic (PV) investments. As of September 30th 2015, the cumulative PV installed capacity stood at 1 766 MW_{AC} embedded within the distribution network and 240 MW_{AC} connected directly to the transmission grid for a total of 2 006 MW_{AC}.

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. In 2015, research on the performance, cost and durability of PV systems in the Arctic was identified as a priority to support the clean electricity program in Canadian northern territories.

In December 2015, Canadian and IEA PVPS experts shared the results of their research and demonstration activities at Solar Canada 2015, CanSIA's national annual conference in Toronto. Sessions focused on best practices for managing higher solar PV penetrations in electricity grids, including four panel sessions: Solar Implications for Distribution Grids; Solar Variability, Forecasting, and System Operation; Smart Inverters and System Benefits; and Smart Grid Integration [2].

A new Business-led Network of Centres of Excellence was established in 2014 [3]. 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 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 IEA SHC/EBC 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 [4].

IMPLEMENTATION

Ontario's Long Term Energy Plan and Procurement

The province of Ontario continued its procurements at the residential, commercial and utility-scales. Residential-scale solar (≤ 10 kW) was procured through the microFIT program which has an annual procurement target of 50 MW. Commercial-scale solar (>10 ≤ 500 kW) was procured through the FIT program which has evolved to include a tendering process. For the first time since 2011, the province also re-launched utility-scale procurement by running an RFP for the

Large Renewable Procurement (LRP) program which will competitively contract 140 MW in 2015. The Ministry of Energy of Ontario held a consultation on net-metering and self-consumption (NM/SC) that will align with its "conservation first" policy for small PV systems (under 10 kW) [5]. As of September 30th 2015, the total amount of PV capacity installed and under development in Ontario was approximately 2 483 MW_{AC}. This now represents more than 1,5 % of the electricity mix and 220 $Watts_{DC}$ per capita in the province of Ontario.

Jurisdictional Scan

The Government of Alberta initiated its Climate Leadership consultation in 2015 which gave rise to the announcement in November 2015 that the province will phase out coal-fired generation and triple the proportion of electricity it receives from renewable sources from approximately 10 % today to 30 % in 2030. In 2016, the province will introduce an auction-based approach for procurement of large-scale renewables and renewed regulatory frameworks for self-consumption and community-scale generation.

Saskatchewan also announced a new target in November 2015. By 2030, the proportion of its electricity generation capacity from renewable sources will have doubled to 50 % in 2030. The province also committed to procuring its first utility-scale solar facilities by RFP in 2016 and is also conducting a regulatory review for self-consumption and small-scale generation.

The Yukon Territory initiated a successful micro-generation production incentive program to 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 now offers 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 [6].

The Northwest Territories (NWT) have 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 [7]. In 2015 a total of 55 systems and 650 kW were installed representing 14,9 Watt per capita.

INDUSTRY STATUS

Canada's solar sector has experienced continued significant investments over the last 5 years. Employment in PV-related areas in Canada has grown with a 2014 labour force estimated at over 8 100 compared to 2 700 jobs in 2009. The PV business revenue was estimated at 1 734 M CAD in 2014. This includes 600 M CAD of revenues generated by module manufacturers. The export market accounted for 13 % of manufacturing revenues in 2014.

Seven companies were producing PV modules in 2014, all of which have their facilities located in the province of Ontario with an estimated 778 MW production, largely for the domestic market in Canada. This represents a 23 % growth in production from 2013.

Of these seven manufacturers, five are Canadian companies. Canadian Solar Inc. is one of the top five module producers in the world with a global market share estimated at 7 % in 2014. Its two crystalline silicon PV module manufacturing facilities in Guelph and London, Ontario employed approximately 600 workers and had a maximum total annual production of 432 MW in 2014. The company also has additional PV module production capacity of over 2 000 MW in China.

The balance of system technology manufacturing companies that have development and manufacturing facilities in Canada include Schneider-Electric (Xantrex), Eaton and Sungrow Canada. Other major brands manufacture through OEM contracts with companies such as Celestica, SAE Power and Sanmina.

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, 54 % in 2013 and 52 % in 2014 due to the Ontario incentive programs. PV module prices have gradually declined from 6,18 CAD/Watt in 2004 to 0,85 CAD/Watt in 2014. This represents an average annual price reduction of 22 % over a 10-year period.

FUTURE OUTLOOK

While each Canadian jurisdiction continues to grow rapidly annually, Ontario continues to be the largest solar market in Canada with more than 400 MW_{AC} of new contracts to be awarded in 2016 for residential, commercial and utility-scale facilities. Saskatchewan has also committed to the procurement of 60 MW_{AC} of utility-scale facilities starting in 2016 and the potential for major market growth is contingent on new policy development but anticipated to become significant in 2016.

The Canadian Solar Industry Association (CanSIA) has released a roadmap that presents a vision to 2020 and that identifies key barriers and solutions that industry leaders will address over the next 5 years [8].

REFERENCES

[1] *CanmetENERGY: https://www.nrcan.gc.ca/energy/offices-labs/canmet/5715*

[2] *The expert reports are publicly available, website: http://www.iea-pvps.org under Task 14 research collaboration*

[3] *Refined Manufacturing Acceleration Process – ReMAP $7,7 million for 2014-18: http://www.nce-rce.gc.ca/NetworksCentres-CentresReseaux/BLNCE-RCEE/ReMAP-AAPF_eng.asp*

[4] *International Energy Agency Solar Heating and Cooling – Task 40: http://task40.iea-shc.org/*

[5] *Ontario PV installed power second quarterly 2015 report: http://www.ieso.ca/Documents/Supply/Progress-Report-Contracted-Supply-Q22015.pdf*

[6] *Yukon Micro-Generation Production Incentive Program website: http://www.energy.gov.yk.ca/microgeneration.html*

[7] *Northwest Territories Solar Energy Strategy (2012-2017): http://www.enr.gov.nt.ca/_live/documents/content/Solar_Energy_Strategy_2012-2017.pdf and Presentation by Wade Carpenter, Government of the Northwest Territories at CanSIA Solar Conference December 8, 2015*

[8] *CANSIA Roadmap 2020, December 2014: http://cansia.ca/sites/default/files/cansia_roadmap_2020_final.pdf*

CHINA

PV TECHNOLOGY AND PROSPECTS

WANG SICHENG, ENERGY RESEARCH INSTITUTE, CHINA NATIONAL DEVELOPMENT AND REFORM COMMISSION
XU HONGHUA, INSTITUTE OF ELECTRICAL ENGINEERING, CHINESE ACADEMY OF SCIENCE
LV FANG, INSTITUTE OF ELECTRICAL ENGINEERING, CHINESE ACADEMY OF SCIENCE

Fig. 1 - PV Integrated with Agriculture.

GENERAL FRAMEWORK

On Dec. 22, 2015, the National Development and Reform Commission issued the new Feed-in Tariff of PV for 2016 (NDRC [2015] No. 3044). The details of PV FIT are shown below:

TABLE 1 – THE NEW FITS FOR PV POWER PLANTS AND THE SUBSIDY FOR DISTRIBUTED PV

SOLAR RESOURCES	FIT	DISTRIBUTED PV	
	FIT (Yuan/kWh)	For self-consumed PV (Yuan/kWh)	Excess PV Feed-Back to Grid (Yuan/kWh)
I:	0,80	Retail Price of Grid Electricity +0,42	Wholesale Coal-Fire Tariff + 0,42
II	0,88		
III	0,98		

From Table 1, We can see the FIT reduced for PV power plants which selling all electricity to grid and for self-consumed PV projects, the subsidy level is kept the same as before. To get enough money to support the development of renewable energy, the surcharge level was raised from 1,5 USDcents per kWh to 1,9 USDcents/kWh. By this surcharge, 60-70 BCNY (about 10 BUSD) can be collected every year to subsidy PV, wind and biomass power.

NATIONAL PROGRAM

According to latest roadmap of energy transition, the Chinese government offers three tops: by the year of 2020, the coal consumption in China will reach the top level; by the year 2025, total primary energy consumption will reach the top and by the year 2030, the emission of CO_2 will reach the top and will be decreasing later on. And the targets of energy transition are as follows: by the year of 2020, 15 % of total energy consumption will come from non-fossil fuels, including renewable energy and nuclear energy; by the year 2030, 20 % of total energy consumption will come from non-fossil fuels; by the year 2050, 60 % of total energy consumption and 90 % of electric power will come from renewable energy. To reach these targets, total PV installation must be 150 GW by the year 2020, 400 GW by 2030 and 2 000 GW by 2050. That means, annual average installation should be 20 GW during 2016-2020; annual average installation should be 25 GW during 2021-2030 and annual average installation should be 80 GW during 2031-2050.

Recently, the National Energy Administration (NEA) issued "The 13th Solar Energy National Plan 2016-2020" (draft for comments). The main near targets are: 1) by the year of 2020, PV cumulative installation will be 150 GW, among them, 70 GW is distributed PV, 80 GW is large-scale ground mounted PV and 10 GW of CSP; 2) 65 % of the total PV installation (150 GW) will be installed in the middle and eastern part of China and only 35 % will be installed in the west. From the 13th national plan, within the next 5 years, the distributed PV will grow up sharply, from only nearly 17 % today to 47 % by 2020.

GOVERNMENT SUPPORTED SPECIFIC PROJECTS

During the next 5 years (2016-2020), three government supported specific projects will be carried out: the Leading Runner Plan, Micro-grid Demonstration and PV Poverty Alleviation.


Fig. 2 - Fish-Pool PV and PV on Water Surface.

Leading Runner Plan of PV

This plan is deemed to encourage advanced PV technologies and wan to solve the problem of over-capacity by phasing out the outdated technology and manufacturers. The requirements for the margin of market entry and leading runner specification are shown below:

TABLE 2 – SPECIFICATION REQUIREMENTS FOR PV LEADING RUNNER PLAN

<table>
<tr><th rowspan="2">TYPE</th><th>PV CELLS</th><th>PV MODULES</th><th colspan="2">BASIC REQUIREMENTS</th><th colspan="2">LEADING RUNNER</th><th rowspan="2">DEGREDATION LIMITS</th></tr>
<tr><th>Size of Cells (mm)</th><th>Cell Number in one Module</th><th>15,5 % Efficiency (Wp)</th><th>16 % Efficiency (Wp)</th><th>16,5 % Efficiency (Wp)</th><th>17 % Efficiency (Wp)</th></tr>
<tr><td rowspan="2">Multi-Si</td><td>156*156</td><td>60</td><td>255</td><td>/</td><td>270</td><td>/</td><td rowspan="8">1) Within the first year multi-Si: 2,5 % mono-Si: 3,0 % TF PV: 5,0 %
2) After the first year, annual degradation of all type PV modules should not be higher than 0,7 %;
3) The total degradation within lifetime for all type of PV modules should not be higher than 20 %.</td></tr>
<tr><td>156*156</td><td>72</td><td>305</td><td>/</td><td>325</td><td>/</td></tr>
<tr><td rowspan="2">Mono-Si</td><td>156*156</td><td>60</td><td>/</td><td>260</td><td>/</td><td>275</td></tr>
<tr><td>156*156</td><td>72</td><td>/</td><td>315</td><td>/</td><td>330</td></tr>
<tr><td>a-Si</td><td colspan="2" rowspan="4">All Thin-Film (TF)</td><td colspan="2">Effciency ≥ 8 %</td><td colspan="2">Effciency ≥ 12 %</td></tr>
<tr><td>CIGS</td><td colspan="2">Effciency ≥ 11 %</td><td colspan="2">Effciency ≥ 13 %</td></tr>
<tr><td>CdTe</td><td colspan="2">Effciency ≥ 11 %</td><td colspan="2">Effciency ≥ 13 %</td></tr>
<tr><td>Other TF</td><td colspan="2">Effciency ≥ 10 %</td><td colspan="2">Effciency ≥ 12 %</td></tr>
<tr><td>HCPV</td><td colspan="2">500 concentrating times</td><td colspan="2">Effciency ≥ 28 %</td><td colspan="2">Effciency ≥ 30 %</td><td>1) Within the first year, the power degradation should not be higher than 2,0 %;
2) After the first year, the annual degradation of all type PV modules should not be higher than 0,5 %;
3) The total degradation within lifetime for all type of PV modules should not be higher than 10 %.</td></tr>
<tr><td>DC/AC Inverter</td><td colspan="2">Grid-connected Inverters</td><td colspan="2">Effciency ≥ 96 % with transformers;
Effciency ≥ 98 % without transformers.</td><td colspan="2"></td><td></td></tr>
</table>


Fig. 3 - PV Integrated with Greenhouses.

Micro-Grid Demonstration

On July 13th, NEA (National Energy Administration) issued the "Guideline for Promoting RE Micro-grid Demonstrations" (NEA (2015) No.265), plan to build 30-50 RE Micro-grid demonstration projects in China, include grid-connected micro-grid and off-grid stand-along micro-grid projects:

Off-Grid Isolated Micro-Grid:

- Micro-Grid for Islands
- Micro-Grid for Remote Villages

Grid-connected Micro-Grid:

- Grid-friendly Micro-Grid
- Self-Balanced Micro-Grid
- Service-Type Micro-Grid

The purposes of the demonstration is as follows:

- Going forward to reach high-penetration of Distributed RE (>50 %);
- To make fluctuant RE power become grid-friendly dispatchable power sources;
- To start a new market for energy storage;
- Institutional Innovation and hoping to have independent distributors of power supply.

PV Poverty Alleviation

On December 24, 2015, NEA issued the document of "Speed Up Energy Construction at Poor Regions to Push Forward Poverty Alleviation" NEA [2015]452. The main issues are:

1) A total of 15 GW will be installed in next 5 years, 3 GW per year on average;
2) The regions for PV Poverty Alleviation should have good solar resources, the annual yield should be higher than 1 100 hours;
3) PV Poverty Alleviation will focus on 15 provinces, 451 poor counties with 35,700 registered poor villages;
4) By the year 2020, an average 3 000 Yuan income per year should be provided to the registered 2 million poor families and the benefits should last 20 years;
5) The Poverty Alleviation Project is to install 3 KW of PV for each poor family. 70 % of capital cost will be subsidized by central and local governments. This project is to provide a money source to the poor families.

INDUSTRY AND MARKET DEVELOPMENT

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

In 2015, total PV grade poly-silicon produced WAS about 165 000 Tons. China now is the largest producer in poly-Si in the world (shared 48,5 % in total world production), but still needs to import about 100 000 Tons from other countries. The situation of poly-Si production in China is shown below:

TABLE 3 – DOMESTIC DEMAND AND PRODUCTION OF POLY-SI (2011-2015)

YEAR	2011	2012	2013	2014	2015
World (Ton)	240 000	235 000	246 000	302 000	340 000
China (Ton)	84 000	71 000	84 600	136 000	165 000
Share (%)	35,00	30,21	34,39	45,03	48,53

Fig. 4 - Technicians are installing PV system for a rural house in Guzhang county, Jiangxi province.

Fig. 5 - A villager is checking PV system on his own house roof.

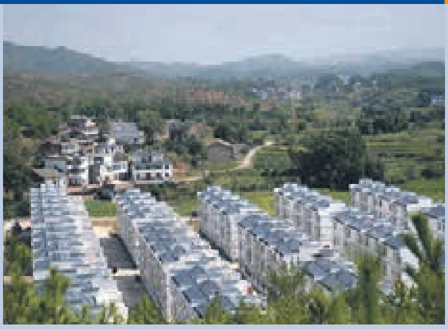


Fig. 6 - The new look of the whole village, almost every house has an installed PV system.

In recent years, the cost of poly-silicon used in PV has been reduced significantly. Today, the cost of poly-Si is only about 11 USD/kg and the spot price is about 15 USD per kg.

China is the largest producer of PV modules since 2007, the situation is shown in Table 4 below:

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

YEAR	2007	2008	2009	2010	2011	2012	2013	2014	2015
PV Production (MW)	1 340	2 714	4 990	12 437	22 798	25 214	25 610	35 000	41 000
Dem. PV Market (MW)	20	40	160	500	2 700	3 560	10 680	10 640	15 000
Share of Export (%)	98,51	98,53	96,79	95,98	88,16	85,88	58,30	69,60	63,41

China's PV installation in 2015 is shown in Table 5:

TABLE 5 – DOMESTIC PV INSTALLATION BY SECTORS IN 2015

2015 DOMESTIC PV MARKET BY SECTORS				
No.	MARKET SECTOR	ANNU.INS. (MWp)	CUMM. INS. (MWp)	SHARE (%)
1	Rural Electrification	10	180	0,41
2	Communication & Industry	5	85	0,20
3	PV Products	5	85	0,20
4	Distributed and Building PV	1 390	6 060	13,92
5	Ground Mounted LS-PV	13 740	37 120	85,27
	Total	15 150	43 530	100,00

During 2011-2015, 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 6 – PRICE REDUCTION OF PV DURING THE LAST 5 YEARS

YEAR	2011	2012	2013	2014	2015	2016 (E)
Cummulative (GWp)	3,50	7,06	17,74	28,38	43,38	63,00
Module Price (CNY/Wp)	9,00	4,50	4,00	3,80	3,50	3,30
System Price (CNY/Wp)	17,50	10,00	9,00	8,00	7,00	6,50
PV Tariff (CNY/kWh)	1,15	1,00	0,9-1,0			0,8-0,98

COPPER ALLIANCE

THE COPPER ALLIANCE'S ACTIVITIES

FERNANDO NUNO, PROJECT MANAGER, EUROPEAN COPPER INSTITUTE

Fig. 1 – Copper busbars.

Fig. 2 - Electrical board.

Copper Alliance is supported by 43 industry members, all of whom are highly active in various areas of the complete copper production chain. Through its market development program, Copper Alliance promotes copper applications to multiple target audiences. Its policy, advocacy, education and partnership initiatives are designed to translate copper's excellent technical properties into user benefits and added-value. Considering the strong linkages between carbon reductions and copper use, Copper Alliance aims to accelerate the energy transition through its Leonardo ENERGY initiative.

SUSTAINABLE ENERGY

Leonardo ENERGY (LE) actively supports a low carbon economy by facilitating knowledge and technology transfer, and promoting good practices in both engineering and policy making. LE runs innovative and targeted campaigns on a broad portfolio of copper-intensive technologies. They are designed to contribute significantly to energy sustainability in key areas such as building automation and controls, high efficiency motor systems, industrial demand side management, etc.

Since copper is the material that integrates many diverse solutions in electricity systems, LE develops and executes strategic initiatives in the field of renewable energy such as:

- Analysis of how to improve the inherent flexibility of the electricity system and enhance its ability to cope with variable electricity production in preparation for near 100 % renewable electricity;
- Promotion of industrial demand side management (facilitating the integration of massive renewables in the grid);
- Capacity building and knowledge transfer on best practices on renewables through application notes, webinars and e-learning programs;
- Review of scenarios for near 100 % renewable electricity systems and infrastructure requirements at system level.

PV RELATED ACTIVITIES

Copper Alliance supports PV development through various streams:

- In-depth market intelligence reports;
- Regular and active involvement in standardization activities at IEC level;
- Advocacy on new business models for PV. As an example, Copper Alliance supports the design of economically sustainable incentive schemes for PV through the grid parity monitor (www.leonardo-energy.org/photovoltaic-grid-parity-monitor), which also contributes to improving public acceptance.
- Training engineers and policy makers on facilitating, designing, installing and operating PV systems.

COPPER ALLIANCE INVOLVEMENT IN IEA PVPS ACTIVITIES

Copper Alliance actively participates in the IEA PVPS ExCo meetings. Moreover, it contributes to Task 1 reports, such as the analysis of self-consumption regimes around the world. In addition to the publication of IEA PVPS reports and summaries on the Leonardo ENERGY website, Copper Alliance successfully held two PV webinars, reaching an audience of about 600 energy professionals.

ABOUT COPPER ALLIANCE

Headquartered in New York, NY, USA, the organization has divisions in Asia, Europe and Africa, Latin America, and North America. It incorporates 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, Copper Alliance has built up a comprehensive resource of approximately 500 program partners from all over the world.

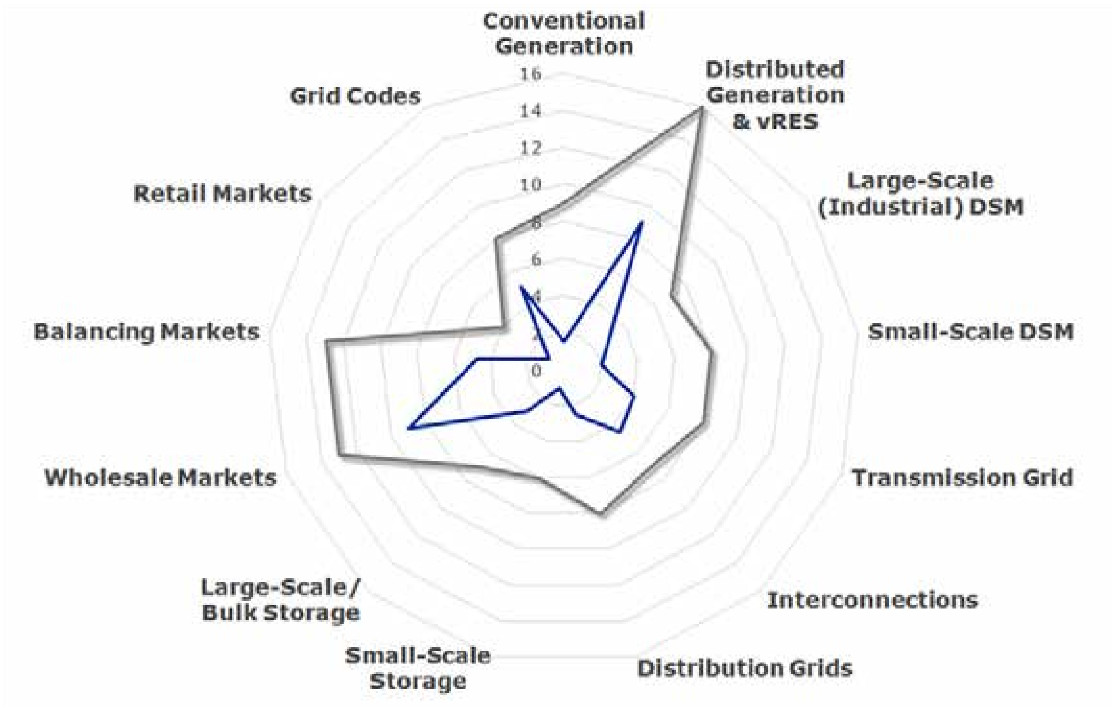


Fig. 3 - Flexibility tracker tool for analysis and benchmark of different countries (http://j.mp/flexroadmap).

DENMARK

PV TECHNOLOGY STATUS AND PROSPECTS
FLEMMING KRISTENSEN, ENERGIMIDT LTD., DENMARK
PETER AHM, PA ENERGY LTD., DENMARK

Fig. 1 - Car park with a 152 kWp PV system from the town hall in Fredensborg. Developed by Solar Park.

Fig. 2 - Gudhjem public swimming hall, Bornholm. Crowd founded by the local inhabitants.

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 of 2015 about 45 % 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 2015, PV proved periodically capable of providing about 15 % 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 a number of projects supported mainly by the Danish Energy Authority's EUDP programme, and via the Public Service Obligation (PSO) of Danish transmission system operator, Energinet.dk, a fully government owned body, i.e. the ForskVE programme targeting R&D&D in the field of green electricity producing technologies.

Net-metering for privately owned and institutional PV systems was established mid 1998 for a pilot-period of four years. In late 2002 the net-metering scheme was extended another four years up to the end of 2006. Net-metering has proved to be a cheap, easy to administrate and effective way of stimulating the deployment of PV in Denmark; however the relative short time window of the arrangement was found to prevent it from reaching its full potential. During the political negotiations in the fall of 2005, the net-metering for privately owned PV systems was consequently made permanent, and net-metering - during 2012, at a level of approx. 0,30 EUR/kWh primarily because of various taxes – combined with dropping PV system prices proved during 2012 to be able to stimulate PV deployment seriously, as the installed grid connected capacity during 2012 grew from about 13 MW to approx. 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 the 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. A standard FIT for both wind and PV is set at 0,60 DKK/kWh (8,05 EURcents) for the first 10 years and 0,40 DKK/kWh (5,37 EURcents) the following 10 years. A quota system in lots of 20 MW for different targets groups has been established and increased FIT for 10 years can be applied for in this context; the increased FIT will be reduced year by year until it is equal to the standard FIT.

Fig. 3 - Sunset over a 2,38 MW PV park in Kollund. Developed by Sveigaard, Herning.

Fig. 4 - Roof integrated PV system by Storløkke holiday centre in Bornholm. A part of the PV Island Bornholm R&D project. Developed by Nielsen El, Rønne.

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, and a dispute during 2014 between the European Commission and the government about the compliance of the 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 2015, about 183 MW installed capacity was added leading to a total installed capacity of around 783,1 MW by end of 2015; two large scale ground mounted systems alone accounted for about 110 MW. 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 main potential for deployment of PVs in Denmark has been identified as building applied or integrated systems. However, during 2015, a couple of ground based centralised PV systems in the range of 50 to 60 MW have been commissioned.

The Danish Energy Agency commissioned a revision of the national PV Strategy in 2015; the revision which will be carried out in consultation with a broad range of stakeholders is expected to be completed primo 2016.

In late 2015, the Danish Energy Agency forecasted PV to reach 1,75 GW by 2020 (5 % of power consumption) and more than 3 GW by 2025 (8 % of power consumption); the figures, which were made public early 2016, were part of a revised general energy sector forecast.

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, and network codes are under revision to accommodate a high penetration of inverter-based decentral generation, as well as to conform to the EU wide harmonisation under development in Entso-E/EC.

INDUSTRY AND MARKET DEVELOPMENT

A Danish PV industrial association (Dansk Solcelle Forening) was established in 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 for private households coming from PV by 2020, but is now revising this target, even though being hampered in the process by the regulatory uncertainties. The association plays a key role in the previously mentioned revision of the national PV Strategy.

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 significant PV relevant battery manufacturing in Denmark at present, although a Li-Ion battery manufacturer has shown interest in the PV market. A few companies develop and produce power electronics for PVs, mainly for stand-alone systems for the remote-professional market sector such as telecoms, navigational aids, vaccine refrigeration and telemetry.

A number of companies are acting as PV system integrators, designing and supplying PV systems to the 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 2015 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 183 MW on the domestic market is estimated at around 265 MEUR and combined with exports the estimate is around 300 MEUR.

The cumulative installed PV capacity in Denmark (including Greenland) has been estimated at a bit more than 800 MW by the end of 2015.

FUTURE OUTLOOK

The new liberal minority government, which came into power in June 2015, has announced the intention to reduce the annual government funds, which until now have been set at 135 MEUR and allocated to R&D into energy and renewables. How this reduction will affect the PV sector is not yet clear.

The future market development for PV in Denmark will strongly depend on the impact of the revised net-metering scheme, including the caps mentioned above, following the settlement between the European Commission and the government to be reached before the end of 2016. The emerging market sector of PV installations for own consumption is growing, however, there is little firm data on this new submarket.

EUROPEAN COMMISSION

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

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

THE EUROPEAN ENERGY POLICY FRAMEWORK

The Energy Union framework strategy launched in February 2015 set out the strategic vision to bring about the transition to a low-carbon, secure and competitive economy in the European Union [1]. The Energy Union consists of five interrelated dimensions: security of energy supply; internal energy markets; energy efficiency; decarbonisation of the energy mix; and research and innovation in the energy field. These dimensions were described elsewhere [2].

The Energy Union strategy places consumers at the core of the EU energy policy, encouraging them to take full ownership of the energy transition. As the emerging self-consumption model opens new opportunities for energy consumers, the European Commission provided insights and identified best practices on renewable energy self-consumption in the EU [3].

More recently, the first *State of the Energy Union* reported on progress over the year 2015 and identified key issues requiring specific attention in 2016 [4]. Progress made, the way forward and policy conclusions are presented for each of the five dimensions. With the *State of the Energy Union* it is remarked how the implementation of the Energy Union strategy and the accomplishment of the energy transition requires strategic planning. However, only around a third of Member States (MSs) currently have comprehensive energy and climate strategies in place beyond 2020, including national indicative targets for greenhouse gas emissions, renewables and energy efficiency. This is a matter of concern in view of the necessity to create a predictable framework for investments in areas which often require long-term planning. Integrated national energy and climate plans, addressing all five dimensions of the Energy Union, are necessary tools to have more strategic planning.

DEPLOYMENT

In 2014, about 7 GW of new photovoltaic (PV) capacity was installed in the European Union, bringing the cumulative PV capacity to about 86 GW. Following the annual newly installed capacity maximum reached in 2011, with more than 22,5 GW installed that year, a shrinking market was recorded for the third year in a row. The EU global market share was lower than 18 % in 2014, while it represented about 74 % of the global market in 2011. The cumulated PV capacity installed in the EU countries with more than 1 GW at the end of 2014 is reported in Fig. 1. The European market might shrink for different reasons (phasing out of support schemes, restricted access to credit, introduction of caps, and retroactive changes). The solar electricity production is estimated at about 85 TWh, with Germany and Italy together accounting for more than 65 % of the whole solar electricity production. 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. In this respect, Europe represents today the most advanced and innovative system worldwide to demonstrate the integration of photovoltaics into the energy sector.

RESEARCH AND DEMONSTRATION PROGRAMME

Horizon 2020, the EU framework programme for research and innovation for the period 2014-2020, is structured along three strategic objectives: "Excellent science", "Industrial leadership", and "Societal challenges" [6]. With a budget of about 30 BEUR, the third objective -Societal challenges- focuses on six key areas: 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. In particular, the specific goal 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, covering the Work Programme (WP) for the period 2014-2015, was published in December 2013. Amongst the others, this Call addressed 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 concerned technology development, whereas technology demonstration and supply-side market readiness were addressed in LCE 3. The following PV specific challenges were comprised within the LCE 2 topic: 1. Developing next generation high performance PV cells and modules (for the year 2014); and 2. Developing very low-cost PV cells and modules (for the year 2015). The PV specific challenges under LCE 3 concerned: 1. Accelerating the development of the EU Inorganic Thin-Film (TF) industry (for the year 2014); and 2. PV integrated in the built environment (for the year 2015). Evaluations for these specific challenges are now concluded; two projects have been granted under the 2014 LCE 2 challenge, one under the 2015 LCE 2 challenge, and one more under the 2015 LCE 3 challenge.
A new Call for "Competitive low-carbon energy" has been published within the Energy Challenge, covering the WP for the period 2016-2017 (publication date: 13 October 2015). The Call comprises six PV specific challenges, divided into five "topics": LCE 7 (Developing the next generation technologies of renewable electricity and heating/cooling), LCE 9 (Increasing the competitiveness of the EU PV manufacturing industry; opening date: 27/05/2016; submission deadline: 8/09/2016), LCE 10 (Reducing the cost of PV electricity; opening date: 26/05/2017, deadline: 7/09/2017), LCE 21 (Market uptake of renewable energy technologies; opening date: 30/09/2015, deadline: 5/01/2017), LCE 37 (Support to the energy stakeholders to contribute to the SET-Plan; opened on 30/09/2015, deadline: 05/04/2016).
The PV specific challenges under LCE 7 concern: 1. Developing next-generation increased efficiency high-performance crystalline silicon c-Si PV cells and modules (for the year 2016; opened on 30/09/2015, deadline: 16/02/2016); 2. Developing next-generation

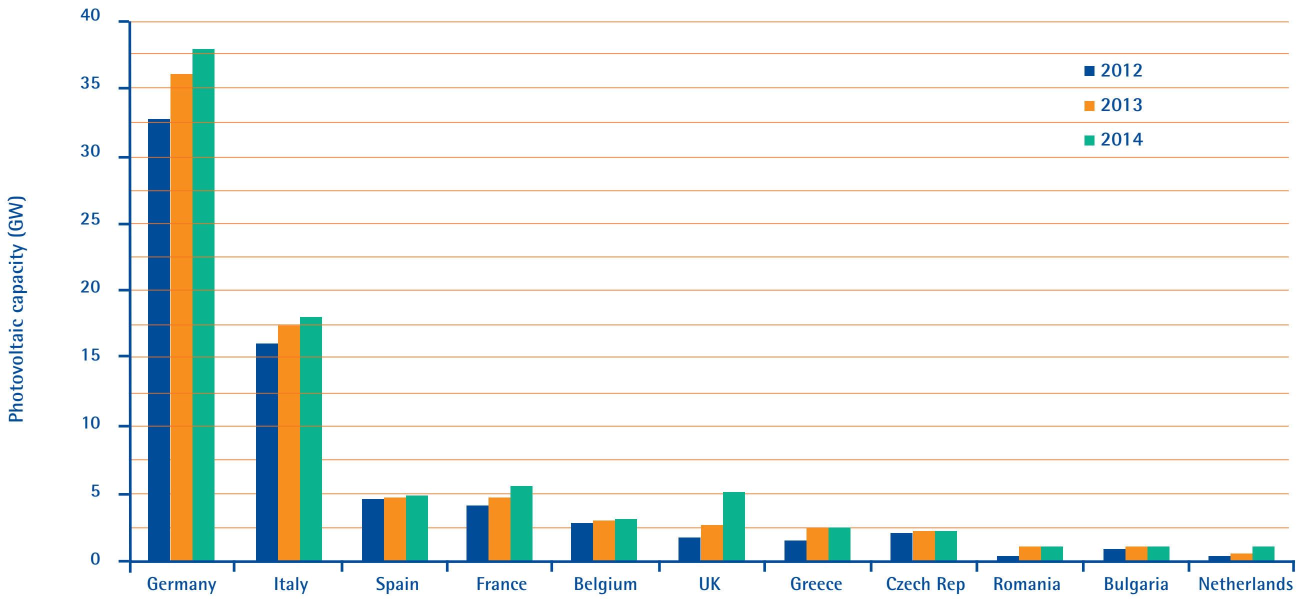


Fig. 1 - Cumulated installed photovoltaic capacity in some EU countries [5].

increased-efficiency high-performance perovskite PV cells and products (for the year 2017; opening date: 16/09/2016, deadline: 5/01/2017).

Furthermore, complementary activities in the field of PV are supported under a variety of topics within the Horizon 2020 WP; e.g., LCE 1 and LCE 6 (New Knowledge and Technologies) in the 2014/15 and 2016/17 WP for the Energy Challenge, respectively, or the topic NMBP 19-2016 (Advanced Materials Solutions and Architectures for High Efficiency Solar Energy Harvesting), included in the 2016/17 WP for 'Leadership in Enabling and Industrial Technologies – Nanotechnologies, Advanced Materials, Biotechnology and Advanced Manufacturing and Processing'.

SET-PLAN ACTIONS AND INITIATIVES

Towards the European Technology and Innovation Platform on Photovoltaics

The Communication "Towards an Integrated Strategic Energy Technology (SET) Plan: Accelerating the European Energy System Transformation" [7] lists 10 key actions, addressing the R&I and competitiveness priorities of the 5th pillar of the Energy Union. These key actions, formulated on the basis of the SET Plan Integrated Roadmap [2,8], are essential to develop and integrate innovative technologies and system solutions that will accelerate the transition to a low-carbon economy. The SET Plan governance needs to be adapted to ensure, through structured and targeted exchanges on common priorities and commitments, the cooperation of all stakeholders to deliver on the key actions and hence to achieve the objectives of the Energy Union.

One of the main novelties of the SET Plan governance is the establishment of European Technology and Innovation Platforms (ETIPs), structures gathering all the relevant stakeholders, with arrangements for cooperative discussions with MSs / Associated Countries (ACs) and the Commission services. The main role of ETIPs is to provide strategic advice to MS/ACs and the EC on all issues relevant to progressing their R&I efforts, building on consensus among the stakeholders. The ETIPs are foreseen to be a continuation of the European Technology Platforms (ETPs) and European Industry Initiatives (EIIs) in a single platform, with the freedom of self-organisation. Accordingly, the Solar European Industry Initiative (SEII) [2] is going to evolve towards the ETIP PV.

Strategic Targets in Photovoltaic Solar Energy

In view of progressing the implementation of the actions contained in the SET-Plan Communication, and specifically the actions concerned with the priority "Number 1 in Renewable Energy" [7], a series of Issues Papers for different areas of the energy sector (including PV) have been issued, jointly prepared by the services of the European Commission and discussed with the representatives of EU MSs and countries part of the SET Plan. The Issues Papers basically propose strategic targets to stakeholders. For PV, the overarching goals are to re-build EU technological leadership in the sector by pursuing high-performance PV technologies and their integration in the EU energy system; and to bring down the levelised cost of electricity from PV rapidly and sustainably.

The input from, and positions of, stakeholders for each area addressed by the Issues Papers have been used to come to an agreement on targets in a dedicated meeting of the SET Plan Steering Group with a representation of key stakeholders. As for PV, the agreement has followed consultations with the European Photovoltaic Technology Platform (PVTP), the European Construction Technology Platform (ECTP), the EERA Joint Programme on Photovoltaics (EERA JP-PV), and the European Platform of Universities in Energy Research & Education

(EUA-EPUE), as well as a public consultation via the SETIS website [9]. This agreement takes into consideration the responding Input Papers from the stakeholders, public comments available on the SETIS website and discussions held in the SET-Plan Steering Group meeting of 9 December 2015.

The agreed strategic targets in PV solar energy are here reported:
1. Major advances in efficiency of established technologies (c-Si and TFs) and new concepts:

- Increase PV module efficiency by at least 20 % by 2020 compared to 2015 levels;
- Increase PV module efficiency by at least 35 % by 2030 compared to 2015, including the introduction of novel PV technologies.

2. Reduction of the cost of key technologies:

- Reduce turn-key system costs by at least 20 % by 2020 as compared to 2015;
- Reduce turn-key system costs by at least 50 % by 2030 compared to 2015 with the introduction of novel, potentially very-high-efficiency PV technologies manufactured at large scale.

3. Further enhancement of lifetime, quality and sustainability:

- Increase module lifetime to a guaranteed power output time (at 80 % of initial power) to 30 years by 2020 and 35 years by 2025;
- Minimize life-cycle environmental impact along the whole value chain of PV electricity generation, increase recyclability of module components.

4. Enabling mass realisation of "(near) Zero Energy Buildings" by Building-Integrated PV (BIPV):

- Establish structural collaborative innovation efforts between the PV sector and key sectors from the building industry;
- Develop BIPV elements, which at least include thermal insulation and water protection, to entirely replace roofs or facades and reduce their additional cost by 50 % by 2020, and by 75 % by 2030 compared to 2015 levels, including with flexibility in the production process.

5. Major advances in manufacturing and installation:

- Increase large scale manufacturing concepts and capabilities by demonstrating PV production capabilities of at least 20 m^2 per minute by 2020;
- Develop PV module and system design concepts that enable fast and highly automated installation, to reduce the installation costs of both ground-mounted arrays and building renovation, by 2020.

The stakeholders have agreed to develop, within 6 months, a detailed implementation plan for the delivery of these targets, to determine joint and/or coordinated actions; to identify the ways in which the EU and national research and innovation programmes could most usefully contribute; to identify the contributions of the private sector, research organizations, and universities; and to identify all issues of a technological, socio-economic, regulatory or other nature that may be of relevance in achieving the targets. The stakeholders intend to use the ETIP PV as the main vehicle for discussions on the implementation plan.

REFERENCES

[1] A Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy, COM(2015)80, Brussels, 25.2.2015

[2] P. Menna, F. Belloni, Support to research, development and demonstration activities on photovoltaics at European Union level, IEA PVPS Annual Report 2014, pp 54-56.

[3] Best practices on renewable energy self-consumption, SWD (2015) 141 final, Brussels 15.7.2015

[4] State of the Energy Union 2015, COM(2015) 572 final.

[5] For the years 2012 and 2013, the source is Photovoltaic Barometer, Eurobserver-Systèmes Solaires (April 2014). For the year 2014, the source is Global Market Outlook For Solar Power / 2015 – 2019 (SolarPower Europe, Mid 2015).

[6] REGULATION (EU) No 1291/2013 of 11 December 2013 establishing Horizon 2020 - the Framework Programme for Research and Innovation (2014-2020), OJ L 347/104 (20.12.2013).

[7] Towards an Integrated Strategic Energy Technology (SET) Plan: Accelerating the European Energy System Transformation, COM (2015) 6317 final.

[8] Towards an Integrated Roadmap: Research & Innovation Challenges and Needs of the EU Energy System, JRC/SETIS, http://setis.ec.europa.eu/set-plan-implementation/towards-integrated-roadmap-and-action-plan.

[9] Strategic Energy Technologies Information System (SETIS), https://setis.ec.europa.eu

FINLAND

PV TECHNOLOGY STATUS AND PROSPECTS

KARIN WIKMAN, PROGRAMME MANAGER, TEKES, THE FINNISH FUNDING AGENCY
JERO AHOLA, PROFESSOR, LUT, LAPPEENRANTA UNIVERSITY OF TECHNOLOGY

Fig. 1 - Wall-mounted solar PV panels at LUT (Photo: Lappeenranta University of Technology www.lut.fi).

Fig. 2 - Suvilahti Solar PV plant in Helsinki (Photo: Helen Oy www.helen.fi).

GENERAL FRAMEWORK AND IMPLEMENTATION

A long-term objective of Finland is to be a carbon-neutral society. This challenge is particularly great in the energy sector. Approximately 80 % of all greenhouse gas emissions in Finland come from energy production and consumption, when transport energy use is included. At the energy policy level, the National Climate and Energy Strategy is updated by each government. The latest update was released in 2013, and the work for the next one is in progress.

NATIONAL PROGRAMME

Currently, there are no specific objectives nor a national programme for photovoltaic power generation in Finland. Instead, solar PV is considered an energy technology among others that can be used to enhance the energy efficiency of buildings by producing electricity for self-consumption. To support PV installations, the Ministry of Employment and the Economy has granted investment subsidies to renewable energy production. The support is only intended for companies, communities and public organizations, and it will be provisioned based on applications. Thus far, the subsidy level has been 30 % of the total project costs. Agricultural companies are also eligible to apply an investment subsidy of 35 % for PV installations from the Agency of Rural Affairs. Individual persons are able to get a tax credit for the work cost component of the PV system installation. The sum is 45 % of the total work cost including taxes. The tax credit can only be applied when the PV installation is implemented as a retrofit.

R&D

In Finland, the R&D activities on solar PV are spread out over a wide array of universities. Academic applied research related to solar systems, grid integration, power electronics and condition monitoring are conducted at Aalto University, Lappeenranta University of Technology and Tampere University of Technology as well as at Metropolia, Satakunta and Turku Universities of Applied Sciences. There is also active research on silicon solar cells at Aalto University, on high-efficiency multi-junction solar cells based on III-V semiconductors at Tampere University of Technology, and on roll-to-roll printing or coating processes for photovoltaics at VTT Technical Research Centre of Finland. In addition, there are research groups working on dye-sensitized solar cell (DSSC), organic photovoltaic (OPV) and atomic layer deposition (ALD) technologies at Aalto University and the Universities of Helsinki and Jyväskylä.
The research work in universities is mainly funded by the Academy of Finland and Tekes – the Finnish Funding Agency for Innovation. Tekes also finances company-driven development and demonstration projects. The largest R&D company in the field of solar PV is ABB. There are no specific budget lines or allocations or programs for solar energy R&D&I in Finland, but PV is funded as part of open energy research programmes. Over the last few years, the average public spending on PV has been approx. 3 MEUR per annum. The Academy of Finland is financing basic research with an estimated annual contribution of approx. 0,5 MEUR, while Tekes is funding applied research, innovation and demonstrations with approx. 2,5 MEUR per annum.

INDUSTRY AND MARKET DEVELOPMENT

For a long time, the PV market in Finland has been dominated by small off-grid systems. There are more than half a million holiday homes in Finland, a significant proportion of which are powered by an off-grid PV system capable of providing energy for lighting, refrigeration and consumer electronics. The amount of off-grid PV capacity in Finland is estimated to be approx. 10 MWp. Since 2010, the number of grid-connected PV systems has gradually increased. Presently, the market of grid-connected systems outnumbers the market of off-grid systems. The grid-connected PV systems are mainly roof-mounted installations on public and commercial premises and in private dwellings. By the end of 2015, the installed grid-connected PV capacity was estimated to be approximately 10 MWp.

FRANCE

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

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

GENERAL FRAMEWORK AND IMPLEMENTATION

In 2015, the French government took several new measures in favour of the photovoltaic sector, enacted the Energy Transition Act for Green Growth and hosted the United Nations on Climate Change Conference (COP21).

The new measures raised the 2020 National target volume of PV installations from the current 5 400 MW to 8 000 MW, increased by 10 % the T4 feed-in tariff for PV roofs with simplified integration, and increased the target volumes of the two on-going calls for tenders to 240 MW and 1 100 MW respectively.

In early 2015, the Energy Regulatory Commission (CRE) launched two calls for tenders, one for rooftop systems (100 kW to 250 kW) for a total volume of 120 MW, the target volume being later doubled to 240 MW (3 × 80 MW), and the other for the installation of 50 MW of photovoltaic plants (> 100 kW) with storage in non-interconnected territories (ZNI). At the end of the year, the Ministry of Environment, Energy and Sea released the results of the CRE3 call for tenders with a total power of 1 100 MW and also published a calendar of new calls for tenders totalling 4 350 MW between 2016 and 2019. All these measures were well received by the solar industry.

The Energy Transition Act for Green Growth was passed by the French Parliament in August 2015. For the Minister for Environment the law 'embodies a great ambition to make France an exemplary nation in terms of reducing its greenhouse gas emissions, diversifying its energy model and increasing the deployment of renewable energy sources'. The law's main objectives include GHG reduction (- 40 % by 2030 compared to 1990 levels), energy efficiency (reducing demand by 50 % in 2050 compared to 2012 levels), the diversification of energy supply through a reduced consumption of nuclear and fossil fuels and an accelerated deployment of renewables (32 % of the final energy consumption in 2030 and 40 % of the electricity production). The law creates a new support mechanism for renewables above 0,5 MW (starting 1 January 2017), in which electrical energy will be sold directly on the electricity market and will benefit from a premium (based on the difference between the market price and a reference tariff). The multi-year energy plan (PPE), still unpublished, will set out the specific financial conditions under which the objectives will be achieved.

The UN Conference on Climate Change (COP21) took place in Paris in December 2015 attracting 20 000 delegates. The leaders of the 195 countries in attendance adopted the Paris Agreement to limit average global warming to well below 2 °C before the end of the century. As one of the major side events of COP21, India and France launched an International Solar Alliance to boost solar energy in developing countries.

From a national perspective, the French Agency ADEME has conducted a prospective study entitled, A *100% Renewable Electricity Mix? - Analyses and Optimisations*. The study identifies the technical measures to be implemented (strengthening electricity grids, load shedding and storage) for a growth policy in renewable electricity generation.

By the end of 2015, the PV industry had added 879 MW of grid-connected PV systems bringing the French cumulative capacity to 6 549 MW.

NATIONAL AND REGIONAL PROGRAMMES

The French photovoltaic sector development is historically driven by a national policy of feed-in tariffs. Alternatively, PV systems above 100 kW can apply to calls for tenders.

Feed-in Tariffs

Feed-in tariffs aim at promoting building-integrated photovoltaic systems (Table 1). They are guaranteed over a period of 20 years and paid for by electricity consumers.

In 2015, the Ministry of Environment decided on a 10 % increase of the T4 tariff in order to boost simplified building-integration (ISB) systems.

TABLE 1 – PV FEED-IN TARIFFS FOR THE 4TH QUARTER OF 2015 (EUR/kWh)

TARIFF CATEGORY AND PV SYSTEM TYPE	POWER OF PV INSTALLATION (W)	TARIFF Q4 2015 (EUR/kWh)	2015 ANNUAL VARIATION (%)	VARIATION SINCE MARCH 2011 (%)
T1 – Full building-integration (IAB)	P ≤ 9 kW	0,2539	- 5,9 %	- 44,8 %
T4 - Simplified building-integration (ISB)	P ≤ 36 kW 36 kW < P ≤ 100 kW	0,1440 0,1368	+ 4,8 % + 4,8 %	- 52,6 % - 52,5 %
T5 – Other installations	P < 12 MW	0,0612	-10 %	- 49,0 %

NOTE 1: In 2013, T2 and T3 tariffs were included into T1 and T4 categories. NOTE 2: Increase of T4 tariff in 2015.
Source: CRE, Ministry of Environment, Energy and Sea.

National Calls for Tenders for PV Systems above 100 kW

Table 2 provides a summary of all national calls for tenders launched by the French Energy Regulatory Commission (CRE) under the supervision of the Ministry of Environment. There are three types of calls for tenders:

1. The first relates to the construction and operation of photovoltaic installations **between 100 kW and 250 kW** which have to comply with the rules governing simplified building integration (ISB). In March 2015, the CRE launched a third series of calls with a target volume of 120 MW over three phases of 40 MW each. In July 2015, a volume of 120 MW was added to the call for agricultural buildings.
2. The second type of calls for tenders relates to the construction and operation of photovoltaic installations **above 250 kW and up to 12 MW**. Applications are PV on buildings, PV carports, ground-mounted PV power plants on fixed structures or with solar trackers, 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 2015, the initial 400 MW target volume of the third CRE call launched in November 2014 was almost tripled, which led to the selection by the Ministry of 253 projects for a total power of over 1 100 MW. There was a 15 % to 23 % fall in the average electricity selling prices compared to those listed in the previous CRE2 selection (Table 2).
3. The third type of national calls refers to **non-interconnected insular territories** (ZNI) i.e. Corsica and the French overseas departments. In May 2015, the CRE issued a call to install 50 MW of PV plants **(> 100 kW) with storage**. The target volume is equally divided between installations on buildings and ground-mounted plants (submission deadline 20 November 2015).

At the end of 2015, the calls for tenders for systems above 100 kW resulted in the selection of 1 822 PV installations with a total power of 2 279 MW (Table 2).

In November 2015, the Ministry of Environment issued the 2016-2019 provisional calendar of national calls for tenders for systems above 100 kW, providing for the installation of 4 350 MW, of which 1 350 MW will be installed on buildings and 3 000 MW will be ground-mounted (Table 3).

Regional and Local Initiatives

In recent years France's regional, departmental and municipal authorities have set up several photovoltaic promotion policies. The regions of Alsace, Aquitaine, Guadeloupe, Languedoc-Roussillon, Pays de la Loire and Poitou-Charentes have issued calls for proposals for photovoltaic self-consumption projects.

At a local level, a number of municipalities are implementing their Climate-Energy Plan. For example, Paris is currently implementing several eco-district projects. A notable low energy building situated in the 15th arrondissement in Paris, was inaugurated by the French President in November 2015. The building houses the new headquarters of the French Ministry of Defence and features an 820 kW BIPV rooftop with specially designed zinc coloured c-Si PV modules similar to zinc roofs in Paris (Figure 2).

To help collectivities in their PV development strategies, ADEME has published *Photovoltaics and Territorial Collectivities*, a guide with case-studies on the economic, societal and environmental benefits of PV systems at local level.

RESEARCH AND DEVELOPMENT

In France, PV research, development and innovation (RDI) activities cover the full spectrum of topics and involve most of the industrial and public research laboratories working in the sector. RDI projects are funded by national public agencies ADEME, ANR and Bpifrance. These organisations are in charge of managing the government programme called *Investments for the Future* (PIA) and the *Single Interministerial Fund* (FUI). Regional councils can also provide additional financial support for collaborative projects. All projects are funded through subsidies and/or repayable advances.

The RDI strategy 2014-2020 of the French Environment and Energy Management Agency (ADEME) is to call for research projects that accompany the energy and environmental transition. Calls for proposals cover the topics of innovative component processes, PV building integration technologies, network integration of renewables, smart electrical systems, etc. ADEME manages 13 RDI projects whose funding comes either from PIA or from its own budget. Three new projects under private-public partnerships were selected in 2015: smart module with micro-inverter, bifacial cells and new cell architecture.

In July 2015, the French National Research Agency (ANR) published a list of six new basic PV research projects on perovskites, nanowires and a new type of transparent electrodes as defined under the topic 'Clean, Secure and Efficient Energy', one of the nine societal challenges of the National Strategic Agenda.

INES, the National Solar Energy Institute, is the main organisation in charge of RDI and training on solar energy. Its PV activity covers crystalline silicon (from feedstock to cells), organic materials, PV modules, PV components and systems, as well as storage, building applications and solar powered mobility.

IPVF, the *Institut Photovoltaïque d'Île-de-France* (IPVF) brings together several public research teams and industry laboratories in order to carry out further research into thin film materials, processes and machinery, and to develop advanced concepts for high efficiency cells and modules.

Other public research teams from the CNRS (National Organisation for Scientific Research) and from universities together with engineering schools contribute to national and transnational RDI

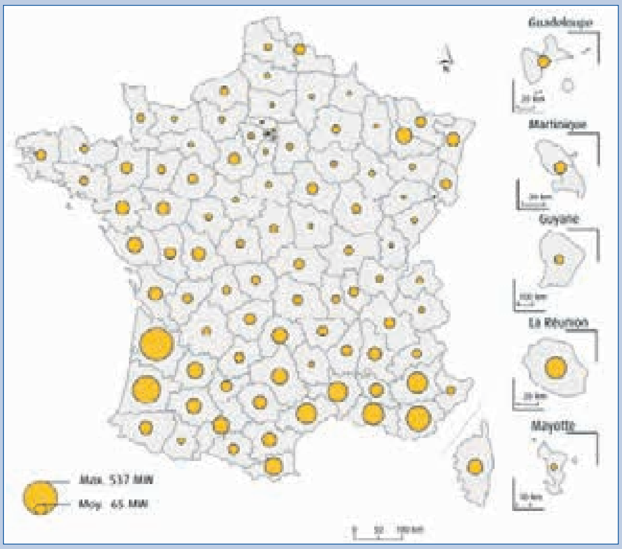


Fig. 1 – Grid-connected cumulative installed PV capacity in the French departments at the end of 2015: 6,5 GW and 365 000 PV installations (source: SOeS).

Fig. 2 – 820 kW BIPV rooftop with specially designed zinc coloured c-Si PV modules similar to zinc roofs in Paris (Photo: ANMA, ©R. Nicolas-Nelson/ Armée de l'Air).

TABLE 2 – SUMMARY OF CALL FOR TENDERS FOR PV SYSTEMS ABOVE 100 kW

CALL TYPE		TARGET VOLUME (MW)	ACHIEVED VOLUME (MW)	NUMBER OF INSTALLATIONS	AVERAGE SELLING PRICE (EUR/MWh)
1 – "Simplified" calls 100 kW to 250 kW **Simplified building integration**	**First (2011-07) and second series of calls (2013-03)**	360 MW	**279**	**1 343**	212* (1st series) 162* (2nd series)
	Third series of calls 3 phases (launched 2015-03) 1st phase Results to be published in 2016	3 × 40 doubled to 3 × 80	n/a	n/a	n/a
2 – 'Ordinary' calls 250 kW to 12 MW **Large roof, PV carport, Ground-mounted plant, CPV...**	**CRE1 (2011-09)** **CRE2 (2013-03)**	950	**900**	**226**	213* (CRE1) 142* (CRE2)
	CRE3 (2014-11) Results published in 2015-12	400 almost tripled to 1 100 MW	**1 100** (Applications: 2 200 MW)	**253**	Large roof: 129 (-18 %**) PV carport: 124 (-15 %**) Ground-mounted: 82 (-23 %**)
3 – PV plants > 100 kW with storage for ZNI* **	**ZNI 1 (2015-05)** Results to be published in 2016	50	n/a	n/a	n/a
Total (not incl. 3rd series and ZNI calls)		2 410 MW	**2 279 MW**	**1 822** installations	

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

*** Compared to preceding call.*

**** ZNI: non-interconnected territories (Corsica and French overseas departments).*

Source: CRE and Ministry of Environment, Energy and Sea.

TABLE 3 – PROVISIONAL CALENDAR OF CALLS FOR TENDERS 2016-2019 (MW)

APPLICATION	2016	2017	2018	2019	TOTAL
Rooftop	2 calls × 150	3 × 150	3 × 150	1 × 150	1 350
Ground-mounted	1 call × 500	2 × 500	2 × 500	1 × 500	3 000
Total	800	1 450	1 450	650	4 350

Source: Ministry of Environment, Energy and Sea.

Fig. 3 – 230 MW PV plant, near Bordeaux, mounted on fixed structures with an east-west orientation (Photo: Neoen, Clemessy).

programmes, including the European Horizon 2020 programme and the Solar-ERA-Net network. French experts participate in the various Tasks of IEA PVPS among which, the new Task 15 "Enabling Framework for the Acceleration of BIPV".

The 5th Photovoltaic National Days (JNPV), organised near Paris by the CNRS and the Federation of PV Research Labs (FedPV) from 1 to 4 December 2015, offered PV researchers the opportunity to present and discuss their work.

INDUSTRY AND MARKET DEVELOPMENT

The *Journal du Photovoltaïque* (May 2015) provides an overview of about 250 stakeholders showing that all professions are represented in the French photovoltaic value chain from manufacturing materials, ingots/cells/modules, production equipment and a variety of components and products all the way to system planning and implementation. Photovoltaic modules are produced by nine manufacturers with a total production capacity of 800 MW.

During 2015, an estimated volume of 879 MW (939 MW in 2014, 651 MW in 2013) was grid-connected representing some 16 865 PV installations (source: SOeS, Observation and Statistics Office, Feb. 2016). PV systems up to 9 kW contributed 9 % of annual installed photovoltaic power and systems between 9 kW and 100 kW 16 %. PV systems above 100 kW all resulting from calls for tenders contributed 75 %. The 230 MW Cestas PV plant installed near Bordeaux, contributed 26 % of annual power. The plant is mounted on fixed structures with an east-west orientation (Figure 3).

At the end of 2015, the cumulative grid-connected PV power capacity in France was estimated at 6 549 MW with some 364 830 PV installations (Table 4). Figure 1 shows the distribution of PV installations in the French departments. Building-integrated systems amounted to 62 % of capacity while ground-mounted PV plants stood at 38 % (source: Observ'ER and ADEME).

TABLE 4 – GRID-CONNECTED PV CAPACITY AT THE END OF DECEMBER 2015 (PROVISIONAL)

POWER CATEGORY	CUMULATIVE POWER AT THE END OF 2015 (%, MW)	CUMULATIVE NUMBER OF PV ISNTALLATIONS AT THE END OF 2015
Up to 9 kW (T1 FiT)	16 %	91 %
From 9 kW to 100 kW (T4 FiT)	19 %	7,2 %
Above 100 kW (calls for tenders)	65 %	1,8 %
Total (provisional)	**6 549 MW**	**364 830 installations**

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

GERMANY

PHOTOVOLTAIC BUSINESS IN GERMANY – STATUS AND PROSPECTS

KLAUS PRUME, CHRISTOPH HÜNNEKES, PROJEKTTRÄGER JÜLICH (PTJ), FORSCHUNGSZENTRUM JÜLICH GMBH

GENERAL FRAMEWORK AND IMPLEMENTATION

The "Energiewende", the transformation of the energy system, is a core task for Germany's environmental and economic policy. Overall objective is an environmental friendly, reliable and economically feasible energy supply. Furthermore, it was decided in 2011 to terminate the production of nuclear power until 2022. Therefore, the Federal Ministry for Economic Affairs and Energy (BMWi) defined an energy agenda comprising 10 key projects to approach this goal of the energy transition 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. 32,5 % of the gross electricity consumption of Germany in 2015. This is already close to the first target of the German Energy Concept [2] to reach 35 % in 2020 (long term target: 80 % in 2050).

Photovoltaic (PV) is a major part of this development driven by the Renewable Energy Sources Act (EEG) [3] on the one hand and a noticeable decrease of system prices on the other hand. A capacity of 1,5 GW PV power has been newly installed in Germany in 2015 (see Figure 2). This results into a total installed PV capacity of 39,7 GW connected to the electricity grid. Subsequently, PV contributed 38,5 TWh (approx. 6 %) to the annual gross electricity generation of 647,1 TWh [4]. The total amount of electricity generated by grid connected PV systems increased by 6 % in comparison to the previous year [5].

Fig. 1 - Test façade for various building integrated PV systems (Photo: Maria Roos, Fraunhofer IWES, Kassel).

NATIONAL PROGRAMME

The responsibility for all energy related activities are concentrated within the Federal Ministry for Economic Affairs and Energy (BMWi). 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. In order to stimulate competition, additional amendments to the EEG have been introduced from August 1st 2014 on. The most important change for PV is that new 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 small PV systems, the FiT depends mainly on the system size. 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 2,4 – 2,6 GW. No further reduction of the FiT was executed from October 2015 on since the installed capacity dropped below this range in the last two years. Details on the development of the FiT can be found in [6]. Table 1 shows the development of the FiT for small rooftop systems (< 10 kW) installed since 2001 [7]. 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.

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*	2016*
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	12,31

** adjusted by a flexible monthly degression rate between 0 – 2,8 % throughout the year*

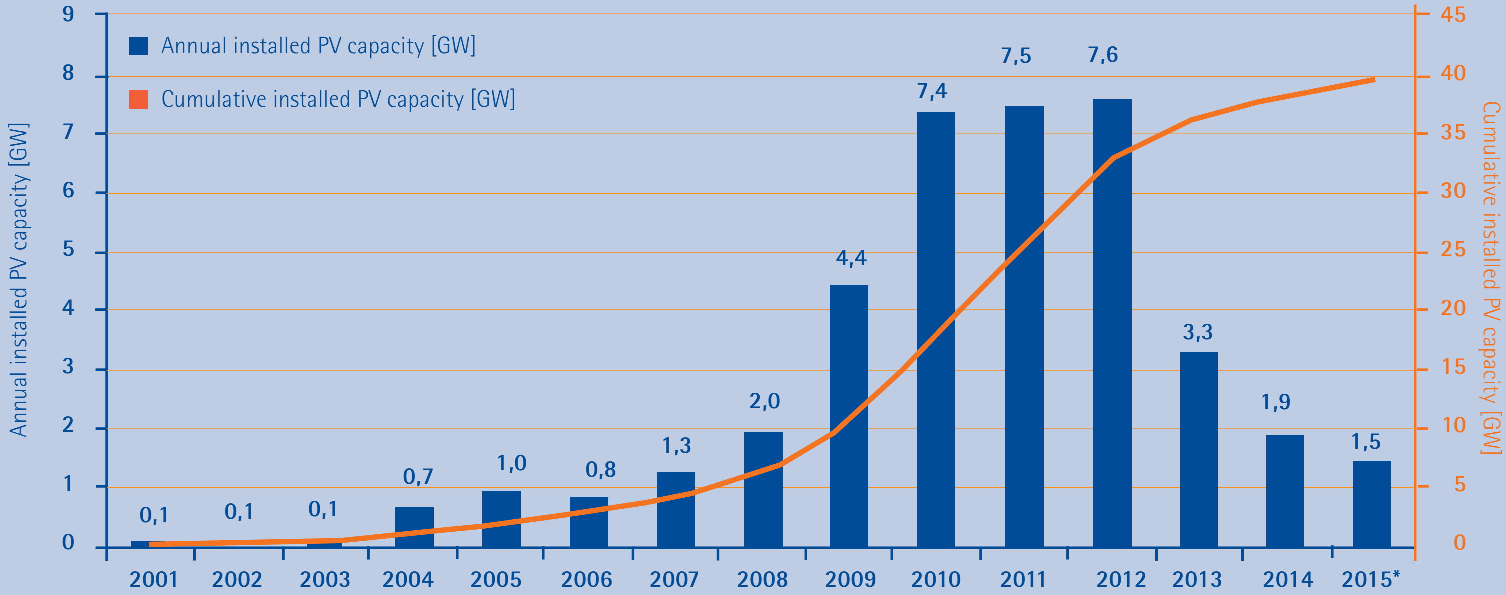


*Fig. 2 - Development of grid connected PV capacity in Germany, *first estimate as of February 2016.*

In 2015, within the "market integration model" three pilot auctions have taken place for ground-mounted photovoltaic installations, enabling initial experience to be gathered with the new promotion instrument in the field of renewable energies. The aim of the pilot auctions for ground-mounted PV installations is to achieve the expansion targets for renewables in a cost-efficient manner. The pilot auction has ensured that new ground-mounted PV installations are being built while maintaining a high level of public acceptance and stakeholder diversity. The three calls covered a capacity of 500 MW altogether and were characterized by a high degree of competition. The proposed capacity was significantly over-subscribed and the price level was reduced from call to call (9,17 EURct/kWh -> 8,49 EURct/kWh -> 8,00 EURct/kWh) which shows a good efficiency of the process. Moreover, investments in PV installations are getting attractive even without financial support by a Feed-in-Tariff. A PV rooftop system in the range of 10 – 100 kW cost about 1 300 EUR/kW in 2015 [8]. The Levelized Costs of Energy (LCOE) for such a PV system are around 0,13 EUR/kWh whereas the average electricity price for a private household is around 0,28 EUR/kWh [9].

In addition to the above mentioned support scheme for renewable energies a 25 MEUR market stimulation programme has been introduced to boost the installation of local stationary storage systems in conjunction with small PV systems (< 30 kWp). [10] Within the framework of this storage support programme around 20 000 decentralized local storage systems were funded by the end of 2015. A continuation of the programme is planned for 2016.

RESEARCH AND DEVELOPMENT

Research and Development (R&D) is conducted under the 6th Programme on Energy Research "Research for an Environmental Friendly, Reliable and Economically Feasible Energy Supply" [11] 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 programme. Concerning PV, the call addresses six focal points which are all connected to applied research:

- Silicon wafer technology,
- Thin-film technologies, especially based on 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 PV (CPV) and
- Cross-cutting issues such as Building Integrated PV (BIPV), recycling or research on the ecological impact of PV systems.

In 2015 the BMWi support for R&D projects on PV amounted to about 59,68 MEUR shared by 262 projects in total. That year, 106 (2014: 90) new grants were contracted. The funding for these projects amounts to 84,2 (66,9) MEUR in total.

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

Funding Activities of the BMBF

From 2013 to 2015, the BMBF funded PV projects under the programme "Material Research for the Energy Transition" aiming for the support of long-term R&D which is complementary to the BMWi funding. From September 2015 on, the BMBF relaunched its energy related funding under the "Kopernikus" initiative. Under this scheme cooperative research on four central topics of the "Energiewende" will be addressed: storage of excess renewable energy, development of flexible grids, adaption of industrial processes to fluctuating energy supply and the interaction of conventional and renewable energies.

"R&D for Photovoltaics" – a Joint Initiative of BMWi and BMBF

To support the momentum stimulated by the Innovation Alliance PV of 2010, a new joint initiative of BMWi and BMBF has been launched in 2013. The aim of this 3 year programme "R&D for Photovoltaics" 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.

A mid-term evaluation of the running 12 joint projects which are funded by the ministries BMWi (8 projects, 43 MEUR) and BMBF (4 projects, 6 MEUR) [13] will take place in early 2016. Already now, first results show a significant impact: SolarWorld presented a 22 % record cell efficiency using industrial standard materials and processes only.

INDUSTRY AND MARKET DEVELOPMENT

The German PV industry manufacturers as well as equipment suppliers are slowly gaining ground. SolarWorld is shifting its whole production processes towards the highly efficient PERC (passivated emitter rear contact) technology. At the same time, material and equipment suppliers experienced a significant upturn in 2015. Holding a share of 50 % [14] of the world market of PV process technologies, equipment suppliers could maintain an excellent position. However, competition with foreign suppliers is becoming more intense.

Together with a strong research community and a high number of system installers, a workforce of approximately 40 000 to 50 000 people are employed in the PV industry [15].

REFERENCES

[1] 10-point energy agenda of the Federal Ministry for Economic Affairs and Energy, see http://www.bmwi.de/English/Redaktion/Pdf/10-punkte-energie-agenda,property=pdf,bereich=bmwi2012,sprache=en,rwb=true.pdf

[2] Energy Concept for an Environmentally Sound, Reliable and Affordable Energy Supply, see http://www.germany.info/contentblob/3043402/Daten/3903429/BMUBMWi_Energy_Concept_DD.pdf

[3] Renewable Energy Sources Act (EEG 2014), see http://www.bmwi.de/BMWi/Redaktion/PDF/G/gesetz-fuer-den-ausbau-erneuerbarer-energien,property=pdf,bereich=bmwi2012,sprache=de,rwb=true.pdf

[4] Gross energy production and consumption in Germany in 2015, see http://www.ag-energiebilanzen.de/index.php?article_id=29&fileName=quartalsbericht_q4_2015_18122015.pdf

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

[6] Feed-in-Tariffs for 2015/2016 can be found at www.bundesnetzagentur.de

[7] The amended Feed-in-Tariff (FiT) programme went into effect on April 1, 2012. For PV system installations up to 10 kW capacity, the new FiT from January 1st, 2016 will be 12,31 € ct / kWh. For roof top installations up to 40 kW capacity, the new FiT will be 11,97 € ct / kWh, up to 100 kW the FiT is 10,71 € ct / kWh (all without direct marketing of the electricity). Systems above 500 kW require direct marketing of electricity. No reimbursement is paid for installations greater than 10 MW. A monthly degression rate is fixed quarterly depending on the installed capacity of the last 12 month in relation to the aimed corridor between 2,4 – 2,6 GW.

[8] Fraunhofer study on facts of PV in Germany: https://www.ise.fraunhofer.de/de/veroeffentlichungen/veroeffentlichungen-pdf-dateien/studien-und-konzeptpapiere/aktuelle-fakten-zur-photovoltaik-in-deutschland.pdf

[9] Average electricity price for a private household in Germany: https://www.bdew.de/internet.nsf/id/DC9ABD3F297604DC1257F42002E5075/$file/160122%20BDEW%20zum%20Strompreis%20der%20Haushalte%20Anhang.pdf

[10] Market stimulation programme 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

[11] The 6th Energy Research Programme of the Federal Government, see http://www.bmwi.de/English/Redaktion/Pdf/6th-energy-research-programme-of-the-federal-government,property=pdf,bereich=bmwi,sprache=en,rwb=true.pdf

[12] Research project database (in German), see http://foerderportal.bund.de

[13] F&E Photovoltaik: https://www.solarstromforschung.de/

[14] VDMA - German Engineering Federation: http://pv.vdma.org/article/-/articleview/11180819

[15] Germany Trade and Invest – for PV see http://www.gtai.de/GTAI/Content/EN/Invest/_SharedDocs/Downloads/GTAI/Industry-overviews/the-photovoltaic-market-in-germany-en.pdf

ISRAEL

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS: AN UPDATE

GIDEON FRIEDMANN, TECHNOLOGIES & RENEWABLE ENERGY SECTION MANAGER
MINISTRY OF NATIONAL INFRASTRUCTURE, ENERGY & WATER RESOURCES

GENERAL

In preparation for the 2015 Paris Agreement on Greenhouse Gas Emissions Reductions, the Israeli government set a new target of 17 % Renewable Energy electricity production (in energy terms) to be reached by 2030, with interim targets of 13 % in 2025 and 10 % in 2020. In addition, a 17 % energy efficiency improvement target was set. There is no potential for hydropower generation in Israel, whereas in most of Europe this is a significant part of the clean energy. In light of the dramatic decrease in the cost of PV systems in recent years, it is now expected that more than 50 % of the renewable energy in Israel will come from the PV sector.

Approximately 780 MW of PV systems were installed by the end of 2015, of which 200 MW were connected in 2015. Conventional large scale capacity is close to 16,000 MW. Two large scale plants were connected this year, Halutziot with 55 MW and Ketura Solar with 40 MW. The capacity factor in Israel for PV is considerably higher than in Europe and stands around 19 % for actual production on an annual average. The overall electricity production from renewables in 2015 was close to 3 %.

Government support to renewable energy (RE) is given in the form of guaranteed Feed-in-Tariff (FiT) for 20 years. FiTs vary by project nature, size and other parameters. FiTs have decreased considerably over the last few years, and are expected to continue their decline. In order to reduce the costs of RE installations, Israel is now trying a new bidding system for the FiT in large PV projects. Under this system, a quota and price are set by the Public Utilities Commission. If the quota is not filled, the price rises a notch, and so forth, until all the quota is filled. Current starting price for this FiT bidding system is 0,27 ILS per KWh (0,07 USDcents). The first bidding process is now in progress. A price of 0,32 ILS (0,08 USDcents) was set in another large project. Other bidding processes are also expected soon.

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 – part of which was used for the above described bidding system. In addition, there is a quota of 180 MW, which is expected to be converted from CSP to PV. Other than these, essentially all previous PV quotas have been assigned to projects. It is expected that significant quotas (hundreds of MW) will be released in the next 2 years in order to achieve the interim goal of 10 % RE production by 2020, and in consideration with the fact that PV is currently the most readily available RE in Israel.

2015 has seen a dramatic decline in the electricity cost in Israel (around 15 %). This is mainly due to the removal of temporary costs which were associated with the gas supply crisis in 2012, and due to the steep decline in the price of coal, which is used to produce almost 50 % of the electricity in Israel. Thus the competition to renewable energy has become tougher. However, it is still clear that PV systems are close to grid parity. For example, the estimated cost, **without** externalities, of an open cycle gas turbine in Israel is about 0,25 ILS per KWh, which is just a fraction lower than the 0,27 ILS per KWh mentioned above for PV. In fact, there is a tariff that is available to RE manufacturers, which PV entrepreneurs ought to consider. This tariff is the recognized conventional electricity generation tariff + a premium for emissions reduction (currently 0,26 + 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. An example for this uncertainty was seen last year with the steep decline of electricity generation costs.

GOVERNMENT POLICY CONSIDERATIONS

Review of the current policies continues. Our 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.

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. Currently around 50 MW of this quota has been used, and with the decline of the FiT, it is becoming more popular.
- 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.

Fig. 1 - First generation BiFacial PV system installed by SolAround, with white background to increase the contribution of the back side of the PV panel. Overall efficiency of SolAround BiFacial panels is expected to be between 25-28 %.

Fig. 2 - Solatics PV Integrated Membrane installation, using the "Direct Attachment" method.

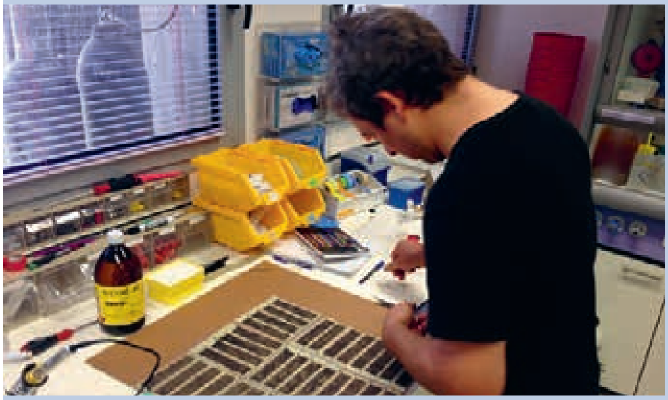


Fig. 3 - Lab testing of small scale SolarPaint coated units. SolarPaint develops a flexible net coated with its proprietary paint, that will produce electricity from the sun.

RESEARCH AND DEVELOPMENT

The Ministry of National Infrastructure, Energy and Water Resources supports R&D under 3 main programs, which are operated by the Chief Scientist Office at the Ministry:

- 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.

To facilitate higher penetration of PV systems, high priority research topics include improved efficiency of PV systems, and storage.
Among the current companies supported are:

- **Solaraound** develops high-power high-efficiency bifacial p-Si PERT solar cells that allow significantly lower LCOE, compared with most industry leaders, who use costly n-Si wafers and processes. SolAround novel technology allows the implementation of bifacial high front and back efficiency cells using the lower cost p Si, fitting 85 %-90 % of the production lines worldwide and avoiding the costly move to n-Si. The company's technology for a highly controllable boron doping of the p+ layer, allows retaining for the first time in p-Si, a very high bulk lifetime of the minority carriers, in combination with low surface recombination losses through the high-temperature fabrication stages. SolAround plans to launch in 1,5 years its bifacial PERT p-type cell with 21 % front efficiency and 25 %-28 % equivalent efficiency, in a production cost close to that of a standard cell. The company has already produced, certified and launched in Germany industrial high-power high-end bifacial cells and modules of its 1st generation.
  In collaboration with the Lev Academic Center in Jerusalem (JCT), SolAround develops a novel simulation model for the prediction of the energy collection characteristics and generation by bifacial PV modules and systems.
- **Solatics** develops PV Integrated Membrane (PVIM) technology which allows lower cost solar PV installation on water reservoirs, landfill, brownfield sites and even flat-roof applications, where standard solar PV systems cannot be installed.
  Designed to improve the overall architecture and assembly of the crystalline silicon solar panels, Solatics' technology allows the use of crystalline silicon (c-Si) solar cells at a much lower cost per installed Watt. Targeting large-scale commercial customers such as electric utilities, water companies, waste companies and landfill owners, Solatics offering includes reduced system cost, easier and faster installation, larger capacity and higher yield per acre, reduced BOS (Balance of system) costs, integrated-racking solar design and overall lower installed cost in comparison with standards glass-metal solar panels. Using its "Direct Attachment" method, Solatics also solves waterproofing issues, static load limitations, un-stable ground and drifting problems, surface penetration and wind related phenomena.
- **SolarPaint** develops a paint formulation and an electrode netting that upon simple installation and application will become an economic, aesthetic and efficient solar harvesting system. The first product that the company is developing is a light and flexible 1 m x 1,6 m netting of electrodes simply trimmable by scissors to adjust to the desirable form, to be used for the external coverage of walls and roofs. The netting will be sold painted with the solar paint which the company is developing, coated with a colorful protective topcoat and complete with standard electrical connectors, ready for simple installation. The developed paint contains a combination of an active material and other materials acting as stabilizers, binders and fillers in the finished solar cell. The cell itself is built such that in reaction to solar radiation the electrons in the active material undergo excitation. The electronic properties of the active material and the electrode netting facilitate charge separation and efficient conduction of charges to produce an electric current. The chemical processes used in their synthesis are simple and enable attractive pricing and widespread use.

ITALY

PV TECHNOLOGY STATUS AND PERSPECTIVES

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

GENERAL FRAMEWORK AND IMPLEMENTATION

In 2015, the Italian PV sector continued to grow, but in a different way than in the past. After the conclusion in 2013 of the feed-in incentive programme named "Conto Energia", the sector changed approach trying to capture new opportunities in distributed generation.

First estimates for 2015 show the total new PV capacity installed of almost 300 MW, thus underlining a reduced growth compared to 2014 (424 MW). The residential segment of small size plants performed better thanks to tax deductions; medium and large plants did not grow as expected despite the possibility to be installed with a specific grid configuration in order to be recognized Sistemi Efficienti di Utenza (SEU, see "National Programme" below).

A marginal sector which is growing slowly but constantly is the PV off-grid one for domestic and non-domestic applications that reached about 14 MW.

On the whole, it can be estimated that a total cumulative capacity of almost 19 GW was reached at the end of 2015. Thus, after the Feed-In Tariff (FiT) era, Italy can be considered a mature market (although with a different trend related to new installations) with a positive public perception towards PV technology.

More encouraging statistics are those of PV energy production that in 2015 reached 25,2 TWh, almost 13 % more than 2014. This represents 8,5 % of the total Italian electricity consumption and 9 % of total gross production. More specifically, during June 2015, also thanks to weak demand, PV plants covered 13 % of demand, while in a few midday hours of the same month the power delivered by PV plants and wind turbines exceeded demand.

The contribution of "new renewables" (solar, wind and geothermal) reached about 17 % of all energy production, a share that rose to around 33 % including hydroelectric source. PV represented about 55 % of total energy production from new renewable sources.

NATIONAL PROGRAMME

The strong growth of the PV sector in Italy was achieved thanks to massive financial support in the period 2005-2013. After the end of FiT programme in 2013, two kind of mechanism remain valid in 2015; the first deals with the value of energy delivered to the grid (given the real time self-consumption allowed for all PV system sizes) and the second relates to tax breaks and white certificates.

The schemes of the first group are:

- net billing system, so-called "Scambio Sul Posto" (SSP), valid initially for existing plants with a capacity below 200 kW and extended from 2015 to new plants up to 500 kW; under SSP provision, electricity fed into the grid is remunerated through an "energy quota" (based on market prices) and a "service quota" (depending on some grid services costs);
- electricity sales, indirectly by entering into a "Ritiro Dedicato" (RID), through which GSE retires the electricity according to a dedicated withdrawal agreement, or directly, through sales of electricity on the power exchange or to a wholesaler.

Fig. 1 - Detail of BIPV monocrystalline modules in the 5 kWp PV plant in Verona (Photo: GSE Gestore dei Servizi Energetici - www.gse.it).

Regarding the second mechanism, tax breaks have been extended through 2015 and white certificates are still available; both provisions apply for 2016, too.

Moreover, an additional mechanism, the so-called "Sistemi Efficienti di Utenza" (SEU) configuration, is becoming widespread (especially among existing plants). This configuration consists of generation systems in which one or more power production plants operated by a single producer are connected through a private transmission line to a single end user and are entitled to obtain a significant reduction on the electricity bill.

The experience so far has outlined that SSP plus tax breaks are the most effective mechanisms in boosting new PV installations, especially in the residential sector, while the SEU can boost the installation of medium and large plants.

RESEARCH, DEVELOPMENT AND DEMONSTRATION

In Italy, research, development and demonstration activities in the field of PV technology are mainly led by ENEA (the Italian Agency for New Technology, Energy and Sustainable Economic Development) and RSE (a research company owned by GSE). Additional contributions on the PV devices and systems are also provided by several universities, CNR (the National Council for Scientific Research) and few private company's laboratories.

ENEA is the most relevant research organization operating in PV in Italy. Most of its activity is on materials, solar cells as well as on PV systems. The most relevant topics of research and development on materials and devices concern crystalline and microcrystalline silicon cells, amorphous-crystalline silicon heterojunction cells, CZTS single junction and CZTS/silicon tandem cells, Perovskite single junction and Perovskite-silicon tandem cells and micromorph tandem cell. Moreover, ENEA is focused on innovative approach for the architectural integration of PV elements in buildings and concentrators technologies. Regarding PV systems ENEA is developing

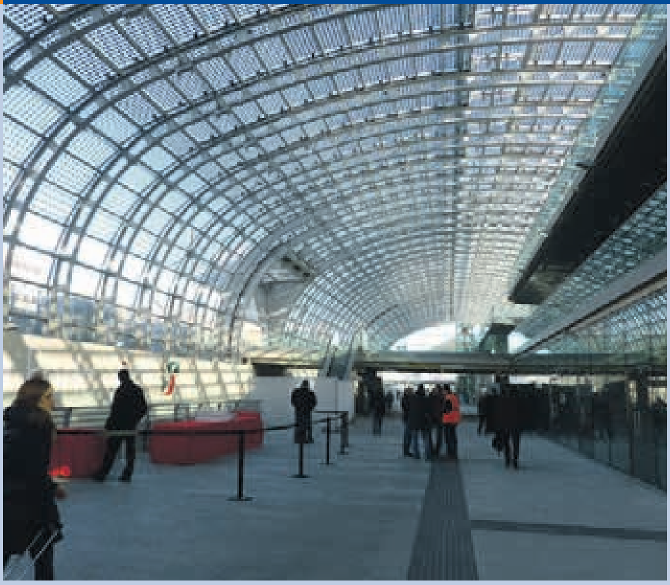


Fig. 2 - BIPV plant in Torino, 553 kWp, monocrystalline modules (Photo: ENERGYGLASS, www.energyglass.eu; Information: GSE Gestore dei Servizi Energetici – Atlasole www.gse.it).

Fig. 3 - Li-Ion Energy storage system (16 kWh) for 14 kWp grid connected PV plant on Lampedusa island (Photo: ENEA, www.enea.it).

devices, software, modelling, smart grid concepts and strategies for optimum plant integration in the electrical grid in order to address value services for users and distributors taking also into account the emerging technologies of energy storage and management. In this context, ENEA during 2015 has installed and is testing grid-connected PV plants equipped with different storage technologies on Lampedusa Island.

RSE 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 frame of the Italian electric system research programme RdS (Ricerca di Sistema) and European projects. In this field, RSE is involved in the design of new optics, in outdoor and indoor concentrating module characterization and in the development of advanced solar tracking control. Within the frame of the new H2020 program, RSE is involved in the project CPVMatch, on the development of a four-junction solar cell for better spectral matching by using frontier multi-junction technology, for the development of new mirrors for high concentration and new sensors to be integrated in the CPV modules for more accurate sun tracking. 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 communities in remote areas (i.e. small islands of Mediterranean Sea).

INDUSTRY AND MARKET DEVELOPMENT

Domestic production of PV cells and modules is still in a difficult period, with a gap between actual output and production capacity. After the end of FiT scheme, the sector became independent on financial support and therefore many producers, mostly those with speculative aims, were forced to abandon the market because of price reduction.

For power conditioning systems, domestic production capacity puts Italy among the top manufacturers worldwide.

Besides, at the end of 2015, new solutions on energy storage were announced: hybrid storage systems to be used in micro-grids, in electrification of rural areas and in balancing services in the field of on and off-grid applications.

Taking into account the Italian manufacturing assets and the size of the annual national market, expected for the next years around a few hundred MW, internationalization is obliged path for the Italian PV industry given the ratio between the production capacity and the stable domestic market. Thanks also to the know-how acquired during the boom years, Italian PV companies are repositioning in foreign markets, providing interesting developments for the future growth of this technology. In particular, companies producing inverters are ahead in the process as EPC contractors and system integrators, while more difficulties are encountered by module manufacturers. For the above mentioned reasons, none of module producers became an important international player.

Moreover, the high level of PV plant capacity built in the past helped the growth of companies providing operation and maintenance activities. Large Italian companies, in the past EPC contractors and system integrators, are now more and more focused on large size plant management and maintenance services; while significant merge and acquisition processes are ongoing in this sector in Italy, also in the frame of EU, representing an important market.

JAPAN

PV TECHNOLOGY STATUS AND PROSPECTS

HIROYUKI YAMADA, NEW ENERGY AND INDUSTRIAL TECHNOLOGY DEVELOPMENT ORGANIZATION (NEDO)
OSAMU IKKI, RTS CORPORATION

Fig. 1 - Floating PV Power Plant (INFINI Hyogo Daikyu Power Plant) (Inami Town, Hyogo Prefecture). Multicrystalline silicon PV module: 250 W x 6 846 modules (by INFINI) 1,7 MW.

GENERAL FRAMEWORK

Based on the "Fourth Strategic Energy Plan" approved by the cabinet in 2014, the Ministry of Economy, Trade and Industry (METI) formulated Japan's "Long-term Energy Supply-demand Outlook" in July 2015. The national government decided the Energy Mix for FY 2030 desirable for Japan. The Plan strategically shows the direction of energy which Japan should depend on in the future, focusing on key issues such as reduction of power generation cost and greenhouse gas emissions, improvement of energy self-sufficiency ratio and the ratio of baseload power sources. In the Outlook's energy mix, it is estimated that the total power generation amount in FY 2030 will be approximately 1 065 TWh. Under this estimate, target ratios of power sources were set as follows: 22 to 24 % by renewable energy; 20 to 22 % by nuclear power; 26 % by coal; 3 % by oil and 27 % by LNG. The total ratio of fossil fuels amounts to 56 %. The target ratio of renewable energy exceeds that of nuclear power, which represents that renewable energy will become one of the mainstream power sources in the future. Breakdown ratios of renewable energy are as follows: 7,0 % by PV; 1,7 % by wind; 1,0 to 1,1 % by geothermal; 8,8 to 9,2 % by hydro and 3,7 to 4,6 % by biomass. 7,0 % by PV corresponds to 64 GW of power generation capacity. Except for hydro power generation, PV power generation is positioned the highest among other sources of renewable energy.

Regarding the installed capacity of PV systems, a total of 81,7 GW (as of the end of August 2015) of PV systems have been approved under the Feed-in Tariff (FIT) program which took effect in July 2012, of which 22,2 GW started operation. Annual PV installed capacity in 2015 is expected to have increased year for year to the level of 9 to 10 GW, a similar level to that of 2014. Rapid growth of PV installations brought about some issues such as an increase in the nation's financial burden, limit of connection to the grids, necessity for output curtailment and so on. Having faced these issues, METI decided to drastically review the scheme to introduce PV and other sources of renewable energy. METI held meetings of councils and subcommittees to discuss the revision of the Act on Special Measures Concerning Procurement of Renewable Energy Sourced Electricity by Electric Utilities (Renewable Energy Act) in 2016 and the final proposal for the report on the reform of the FIT program was compiled, based on the following five pillars: 1) measures to address projects which have not started operation; 2) promotion of long-term stable power generation; 3) cost-efficient introduction; 4) accelerated introduction of power sources with longer lead time such as geothermal and wind power generation which requires a long time for development; and 5) expanded introduction of taking advantage of the electricity system reform. This proposal shows measures to address various current issues and includes revision proposals aimed to create a sustainable market toward the future. The Renewable Energy Act is scheduled to be revised in 2016.

Furthermore, in December 2015, METI started working on the formulation of the "Innovative Strategy for Energy", designed to efficiently promote system reforms of electricity and gas markets and the Energy Mix for FY 2030 while securing consistency.

NATIONAL PROGRAM

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

METI is taking initiative in supporting introduction of PV systems under the FIT program.
In FY 2015, 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) 27 JPY/kWh (excl. tax) for PV systems with a capacity of 10 kW or more for the period of 20 years and 2) 35 JPY/kWh for PV systems with a capacity of below 10 kW (33 JPY/kWh for PV systems which are not required to be equipped with devices to respond to output curtailment) for the period of 10 years. Under the FIT program, as of the end of August 2015, total capacity of approved PV systems with a capacity of below 10 kW, between 10 kW and below 1 MW and 1 MW and more are 4,1 GW, 34,4 GW and 43,2 GW, respectively, amounting to 81,7 GW in total. However, since it takes time for many PV projects to start operation after they have obtained approval due to the issues of permission and electric grids, only 22,2 GW of PV systems started operation under the FIT program and 6 778 MW of PV systems out of them started operation between January and August 2015, a 23,6 % increase compared to the same period of the previous year.

In order to respond to a large number of applications for facility approval by renewable energy projects dominated by PV projects, various amendments were made related to the FIT program in 2015. Highlights of the amendments are as follows: 1) It is impossible to change the manufacturer or the type of PV modules after the facility is approved, and amendments which lower the conversion efficiency are not permitted; 2) It is impossible to increase the approved output capacity; 3) FIT will be fixed at the time when the grid connection contract is signed; 4) Documents which indicate the securing of land and facilities must be submitted within 270 days from the next day of received date of grid connection application to utility company; 5) Grid connection is not possible in case the details of the project site are not the same as those described in the notification documents on facility approval; 6) In case the project capacity is increased after the start of operation, the increased capacity is subject to a newly applied FIT; 7) It is possible that the approval may be revoked in case cost for grid connection by the project owner is not paid within one month after the signing of the grid connection contract; 8) The status of obtaining various permissions must be reported and 9) Information on facility approval must be disclosed to local governments. With these amendments of the FIT program, it has become difficult to easily obtain a facility approval for the FIT program. Furthermore, discussions on the major revision of the FIT program accompanied by the revision of the law also started, in order to drastically change the program, including the resolution to the previously-approved projects which have not started operation for a long time. Under this revision, rules have been discussed that all the projects including previously-approved ones will be obliged to newly obtain "project approval" and that they will not be able to be connected unless they meet the new criteria.

METI established the "Working Group on Grid Connection of Renewable Energy" in 2014 under the New and Renewable Energy Subcommittee operated under the Advisory Committee for Natural Resources and Energy. The Working Group estimates and reports possible grid connection capacity of each of the electric utilities except for those who have sufficient open capacity of grid connection. For the projects which exceed this possible grid connection capacity, electric utilities are able to conduct unlimited output curtailment. In reality, there has been a delay in the restart of nuclear power plants and not all the renewable energy projects which had applied for grid connection contracts started operation; grid-connected capacity of PV systems has not reached the possible grid connection capacity. However, in a remote island in the service area of the Kyushu Electric Power Company which has a small grid connection capacity, Japan's first output curtailment was conducted in May 2015.

(2) METI's budget related to dissemination of PV power generation

After the enforcement of the FIT program, the focus of METI's budget has shifted from supporting introduction with subsidy to establishing the environment toward a large-scale dissemination of renewable energy including responses to grid restriction and subsidy for storage batteries to adjust the grid. 3,5 BJPY was allocated as the FY 2014 supplementary budget to "Subsidy for measures for off-grid renewable energy power generation systems, etc.," which is designed to subsidize renewable energy-based power generation systems for self-consumption, instead of selling the entire generated electricity. Also, large-scale budget items were included in the FY 2014 supplementary budget as part of measures for electric grids. 74,4 BJPY was allocated to "Emergency responses to suspension of grid connection of renewable energy," 13,0 BJPY to "Subsidy for projects to support introduction of lithium ion batteries for stationary installation," and 6,5 BJPY for "Project for improving technologies to deal with surplus power generated by renewable energy power generation systems."

Also, 45,6 BJPY has been allocated to "Subsidy for projects to implement the Feed-in Tariff (FIT) program for renewable energy" as a budget item to compensate the amount of reduced surcharge of entities who are eligible for the reduction of surcharge payment.

As a support project for renewable energy-based power generation facilities in the areas damaged by the Great East Japan Earthquake, "Subsidy for projects to promote introduction of renewable energy power generation systems, etc. as part of restoration measures" was implemented from FY 2011 to FY 2015 (total budget: 31,6 BJPY)." 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. In FY 2015, 21 PV systems with a total output of approximately 132 MW were selected. Under the similar framework, "Subsidy to support restoration through promoting introduction of renewable energy-based power generation facilities, etc." was implemented, applicable to three disaster-stricken prefectures of Iwate, Miyagi and Fukushima with the budget of 3,7 BJPY in FY 2015. In FY 2014, 70 PV systems with a total output of approximately 45 MW were selected.

(3) Efforts by other ministries and local governments related to dissemination of PV power generation

Under the "Project to promote introduction of renewable energy and advanced facilities, etc. in public facilities" (former "Green New Deal Fund"), the **Ministry of the Environment (MoE)** has been supporting introduction of renewable energy, storage batteries, etc. in disaster prevention facilities, evacuation facilities and public facilities which should retain the function in case of disaster, while promoting support for introduction of advanced facilities toward enhancing measures against global warming at waste disposal facilities. In FY 2015, the budget of 19,0 BJPY was allocated. In addition, in FY 2015, 5,3 BJPY was allocated to the "Project to create advanced 'low-carbon, recycling and harmony with nature' local communities (Green Plan Partnership project)," approximately 1,4 BJPY for the "Project to promote creation of low-carbon communities in remote islands," 1,0 BJPY for the "Project to promote establishment of independent and distributed low-carbon energy society," 4,6 BJPY for the "Project to establish a fund to promote investment in low-carbon in local communities," approximately 2,2 BJPY for the "Project to subsidize interest for

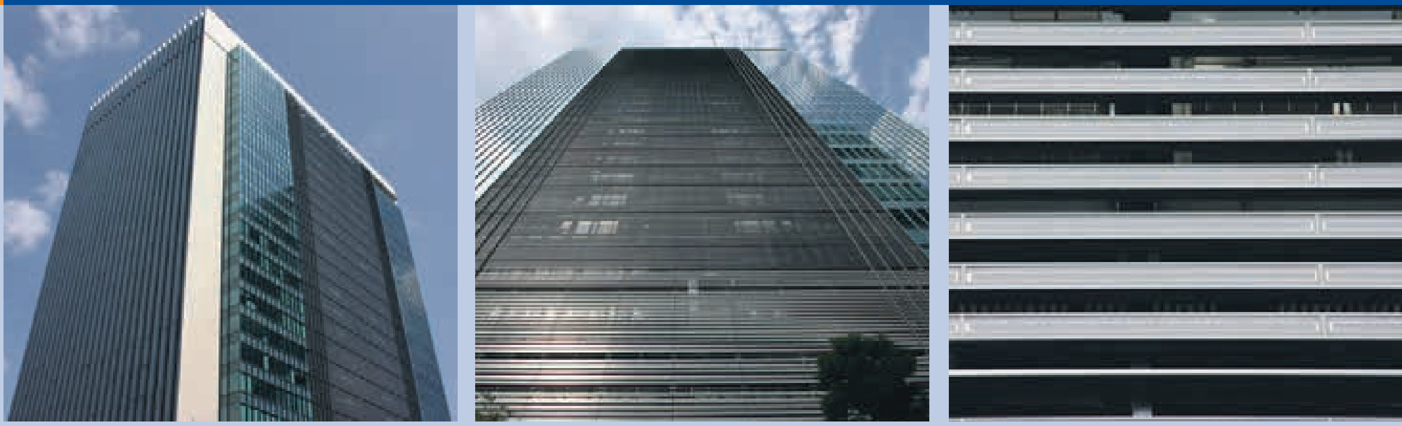


Fig. 2 - Office building "Ochanomizu Sola City" (Chiyoda Ward, Tokyo). Single crystalline silicon PV module: 150 kW.

expansion of the environmental finance," 1,8 BJPY for the "Eco lease business promotion project," 7,3 BJPY for the "Project to support establishment of social system to improve low-carbon value," and so on.

The **Ministry of Land, Infrastructure, Transport and Tourism (MLIT)** obliged the buildings to conform to the energy conservation standards, in response to the enactment of the "Act on Improvement of Energy Consumption Performance of Buildings," the revised "Act Concerning the Rational Use of Energy (Energy Saving Act)" and so on. Compared to the past, standard values were largely increased and they became obligatory. Therefore, for buildings with an area above a certain level, construction cannot be started in case annual energy consumption exceeds the standard value. Discussions are underway in a direction where not only the fact that introduction of PV systems and other renewable energy-based power generation facilities makes it easier to achieve the standard value but also a special case for floor-area ratio (FAR) which eases the FAR should be included. Moreover, approximately 400 MJPY was allocated in FY 2015 to cover the expenses of survey to promote improvement of infrastructure through public-private partnership (PPP) designed to support discussion to establish a project to improve infrastructure such as revitalization of local communities and improvement of disaster prevention conducted by local governments. Also, in the FY 2014 supplementary budget, 93,5 BJPY was allocated to conduct the Eco Point program and to support projects toward establishment and improvement of energy-saving houses and buildings, whereas approximately 8,2 BJPY was allocated to efforts such as enhancement of disaster prevention functions of governmental facilities which work as disaster prevention bases. MLIT is also conducting the Eco Point program to establish and improve energy-saving houses and buildings and supporting leading projects of houses and buildings aiming to conserve energy and reduce CO_2 emissions.

The **Ministry of Agriculture, Forestry and Fisheries (MAFF)** is implementing a subsidy program to introduce PV systems at facilities for agriculture, forestry and fisheries, in order to promote introduction of renewable energy into these industries. MAFF 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. MAFF allocated 100 MJPY in the FY 2014 supplementary budget and 1 BJPY in the FY 2015 budget for this project.

The **Ministry of Education, Culture, Sports, Science and Technology (MEXT)** has been promoting establishment and improvement of environment-friendly school facilities in order to promote environmental measures at educational facilities. According to the result of survey on the installation status of renewable energy-based power generation systems at public school facilities as of April 1, 2015, PV systems are installed at 8 617 schools (including 7 371 elementary and junior high schools), achieving the installation ratio of 24,6 %. Among the renewable energy-based power generation systems installed at public elementary and junior high schools, 3 711 schools are equipped with the systems which have the function to continue operation even in case of blackout. This represents 44,5 % of schools which are equipped with PV systems.

In order to strengthen efforts for local production and local consumption of energy, local governments and municipalities are working on expanding dissemination of renewable energy. Some of them took initiative in the establishment of PPS (Power Producer and Supplier) across the nation to sell the generated electricity to public facilities and businesses. They have established a framework to support dissemination of renewable energy which can complement the national government's review of its policy on renewable energy, through the support program to introduce PV systems for universities, shopping districts and community development, selection and announcement of suitable sites for PV power plants, demonstration project on energy storage technology, as well as project to establish a fund through public-private partnership (PPP) for dissemination of renewable energy.

R&D, D

R&D

The New Energy and Industrial Technology Development Organization (NEDO) completed two programs at the end of FY 2014 (March 2015): "R&D for High Performance PV Generation System for the Future (FY 2010 to FY 2014)" and "R&D on Innovative Solar Cells (FY 2008 to FY 2014)". Post-evaluation of these projects was conducted and R&D of PV system technologies are underway in the demonstrative program mentioned below.

As for R&D for PV system technologies, NEDO started "Development of high performance and reliable PV modules to reduce levelized cost of energy" (FY 2015 to FY 2019) in FY 2015 based on the NEDO PV Challenges, a new guidance for technology development that was formulated in September 2014. Four technological development topics were determined following the NEDO PV Challenges aiming to achieve power generation cost of 14 JPY/kWh by 2020 and 7 JPY/kWh by

Fig. 3 - Fukushima Airport Mega-Solar Power Plant (Sukagawa City, Fukushima Prefecture, etc.). Total: 1,2 MW (500 kW, 200 kW, 500 kW), 30 types of PV modules including tracking system and various types of mounting structures.

2030 with a total of 19 R&D topics, and three trends survey projects were selected from public offering in June 2015 and started activities. Eight topics mainly proposed by businesses for practical technologies were selected under "R&D for silicon solar cells employing advanced complex technologies and high performance CIS solar cells." Two research topics were on ultra-high performance III-V compound PV modules and low-cost perovskite solar cells under "R&D for solar cells with innovative new structures", conducted by industry-university consortiums. Under "Technological development of common platform for PV cell/ module", four topics including high-efficiency crystalline silicon with pilot mass-production line and high performance CIS solar cells. Five research topics including performance measurement technology for solar cells and reliability measurement technology, output evaluation technology of PV power generation, etc. were selected for the "Development for common platform."

As for R&D conducted by MEXT, MEXT promotes "FUTURE-PV Innovation Projects (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 conduct research activities by the end of FY 2016 (March 2017). MEXT also conducts two basic R&D programs through 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". Most of the research projects under both programs were terminated as scheduled.

Demonstration

In the area of PV-related demonstration research, a program promoted by NEDO titled "Leading technological development for commercialization of organic PV (FY 2012 to FY 2014)" was finished at the end of FY 2014 (March 2015). In FY 2015, NEDO promoted three demonstration projects following the above mentioned "NEDO PV Challenges." Under "Demonstration project for diversifying PV applications (FY 2013 to FY 2016)" aiming at extension of PV installation areas, development and demonstration of installation technologies for building walls, agricultural applications, slopes and water surfaces, etc. and validation of power generation performance in these sites were conducted. Development and demonstration of solar thermal/ PV hybrid modules and systems as added value technologies applying functions other than power generation or adding new applications have been conducted. For the "Technological development for improvement of system performance and operation and maintenance (O&M) (FY 2014 to FY 2018)" and the "Development of PV recycling technologies (FY 2014 to FY 2018)", NEDO solicited new proposals for research topics. Under these projects, development and demonstration have been conducted on technologies to improve the power generation amount by highly-functioned BOS, technologies to reduce BOS cost including installation cost and recycling process technologies of PV modules.

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 demonstration projects on smart communities are conducted home and abroad and 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 2015:

- 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 (finished in March 2015), Technology demonstration on electricity supply system utilizing EVs and PHVs in Osaka Business Park, Osaka City, Osaka Prefecture, Demonstration of energy management for the integrated fish processing site in Onagawa Town, Miyagi Prefecture, Technology demonstration aiming at establishing a local 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;
- Smart Community Demonstration Project: Lyon, France (FY 2011 to FY 2015), Gongqing City, Jiangxi Province, China (FY 2011 to FY 2015), Malaga, Spain (FY 2011 to FY 2015), Java Industrial Park, Indonesia (FY 2012 to FY 2017), Manchester, UK (FY 2014 to FY 2016), Speyer, Germany, (FY 2015 to FY 2017);
- Japan - U.S. Smart Grid Collaborative Demonstration Project (FY 2010 to FY 2014, completed): New Mexico, USA;
- Demonstration Project for World-leading Remote Island Smart Grid (FY 2011 to FY 2016): Maui Island, Hawaii, USA;
- Model Project for a Microgrid System Using Large-scale PV Power Generation and Related Technologies (FY 2012 to FY 2015): Neemrana Industrial Park, Rajasthan, India;
- Demonstration for Hybrid Solar Inverter & Battery System with Monitoring and Control (FY 2015 to FY 2016): Oshawa, Ontario, Canada.

Furthermore, demonstration projects on large-capacity storage systems were started by electric utilities as part of support programs by METI and MoE, aiming to expand possible grid connection capacity of renewable energy and control the grid.

INDUSTRY STATUS AND MARKET DEVELOPMENT

Many of the Japanese PV cell/module and system manufacturers are doing business in accordance with their estimates that their shipment volume will remain at the same level as, or decrease, from the previous fiscal year, due to the impacts of the revision of the FIT program, etc. After the sluggish sales in the first half of FY 2015 (April to September 2015), a sign of recovery has emerged in the second half of FY 2015. However, the situation remains difficult for these manufacturers due to the reduction of average prices and other factors. Among Chinese manufacturers doing business in Japan, some achieved year-to-year increase in shipment, approaching closely to the shipment of Japanese manufacturers. They forecast that the Japanese PV market for MW-scale PV power plants will shrink and are shifting back to the residential, building and facility PV markets. The manufacturers are differentiating themselves from others through introduction of high-efficiency and high-output products, product lineup with HEMS and storage batteries, as well as extension of warranty for output and devices.

In the components and manufacturing equipment industry, efforts have continued to reduce cost and improve performances of PV cells, modules and systems.

In the PV inverter industry, companies reported their good business performances one after another, reflecting the growth of the PV markets both in Japan and abroad. Japanese manufacturers are enhancing activities for their future growth, including enhancement of production capacity of products for overseas markets, launch of hybrid inverters equipped with lithium ion batteries, production of string inverters for MW-scale PV power plants, and enhancement of maintenance service, taking advantage of the offices across Japan.

In the supporting structure industry, in addition to domestic manufacturers, an increasing number of non-Japanese manufacturers are entering the Japanese market thanks to the rapid increase of demand due to the increase in installations of industrial PV systems. Some Japanese manufacturers are enhancing their production capacity of supporting structures and brackets, while others are conducting sales activities in preparation of doing business in emerging markets in the future, in line with the establishment of their overseas production bases. With the growing installations, installation locations are getting more diverse, and development of new products and manufacturing processes have been advanced.

In the storage battery industry, a number of new products were launched one after another, with long life, large capacity and high reliability as storage systems for residential applications. Home builders launched smart houses, which are equipped with PV systems and storage batteries as standard equipment. Also, efforts on zero energy houses (ZEH) which realize self-consumption from their own generated electricity have advanced. Storage systems for cutting peak power and balancing the generated power are on sale for businesses.

In the housing industry, efforts for dissemination of ZEH have been accelerated mainly by major prefabricated housing manufacturers, beyond the movements to secure energy-saving performances of newly-built buildings to meet the obligation to conform to energy conservation standards. Due to the fact that PV power generation is approaching "grid parity" and that the public awareness of disaster prevention is improving, there is a sign of trend shifting from selling the entire generated electricity to the self-consumption business model. Overall, the residential PV market has stabilized and both established and newly-entered businesses in this market have shown their intention to return to and focus on this market segment.

In the EPC sector, installation of small- to large-scale PV systems continues to increase under the FIT program, and the market is brisk. A great number of announcements were made on the start of operation and construction plans of large-scale PV projects with a capacity of several dozens of MW. Trading of so-called "middle solar" PV projects with a capacity of up to 1 MW is also accelerated.

In the area of PV business support service, companies are increasingly differentiating themselves from their competitors through improving operation and maintenance (O&M) service. With the steady growth of the PV installed capacity in Japan, major EPC companies, distributors, as well as businesses in the security, electronic device and telecommunications industry are entering this business sector.

In the area of PV power generation business, announcements on the start of operation of PV projects have been made one after another. Large-scale PV projects with a capacity of several dozens of MW to over 100 MW have started generating power in Japan. Major PV system manufacturers are also actively engaged in a large number of projects, which is contributing to the expansion of sales of PV systems. New business models emerged, including the power sales business with leased PV systems and resale of MW-scale PV projects; contributing to broadening the scope of the PV power generation business.

In the finance industry, financial institutions are actively investing in PV projects, along with the revitalization of the domestic PV system business, mainly with MW-scale PV projects. They are supporting the expansion of PV system installations in a variety of formats such as establishment of project finance and investment funds, sale of insurance products, preliminary rating of trust beneficiary right, establishment of funds to acquire the power generation business, establishment of the infrastructure fund market, issuance of green bonds and syndicated loans by regional banks.

REPUBLIC OF KOREA

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

DONGGUN LIM, KOREA NATIONAL UNIVERSITY OF TRANSPORTATION

Fig. 1 - Bicycle lane covered with solar panels, Sejong-si, Korea.

GENERAL FRAMEWORK AND IMPLEMENTATION

The Korea government set its 4th basic plan for new and renewable energy (NRE) in 2014 which is the domestic/international resource development and the long-term (2014-2035) basic plan for the New and Renewable Energy NRE. Visions and targets of the new basic plan are as follows. (1) By 2035, provide 11,0 % of the primary energy supply with NRE. (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 the NRE supply will account for 4,9 % in 2014, 12,9 % in 2025 and 14,1 % in 2035. (3) Focus on making the 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.

In Korea, FIT was terminated at the end of 2011. The Renewable Portfolio Standard (RPS) replaced the FIT scheme from 2012. Under the RPS scheme, Korea's PV installation marked a tremendous jump to 1,011 GW in 2015. At the end of 2015, the total installed capacity was 3,493 GW.

NATIONAL PROGRAMME

Korea has been making an effort to increase the renewable energy portion of the "national energy mix". The new goal was announced in 2014. In the target scenario, the Korea's renewable energy share of primary energy supply will account for 11 % in 2035. That is the same as the target of the first energy plan which was announced in 2008. Currently, the renewable energy is estimated to account for 3,6 % of total primary energy consumption.

(1) RPS Programme

The Renewable Portfolio Standard (RPS) is a system that enforces power producers to supply a certain amount of the total power generation by NRE. The RPS replaced the FIT Scheme from 2012. In Korea, 14 obligators (electricity utility companies with electricity generation capacity of exceeding the 500 MW) are required to supply 10 % of their electricity from New and Renewable Energy (NRE) sources by 2024, starting from 2 % in 2012. PV has its own set-aside amount in the RPS of total 1,5 GW by 2015. The PV set-aside requirement plan was shortened by one year in order to support the local PV industry. In 2015, the record-breaking 924 MW was installed under this program. In a cumulative amount, about 68 % of the total PV installations in Korea were made under RPS scheme, while a total of 500 MW (about 14 %) was installed under FIT programme which ended in 2011. The RPS is expected to be the major driving force for PV installations in the next few years in Korea, with improved details such as boosting the small scale installations (less than 100 kW) by adjusting the REC and multipliers, and unifying the PV and non-PV markets.

Fig. 2 - 3 MW roof mounted PV system at LG Electronics, Gumi-si, Gyunsangbuk-do, Korea (Photo: Solar Today).

(2) Home Subsidy Programme

This programme was launched in 2004 that merged the existing 100 000 solar-roof installation programme. Although the 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 general, detached and apartment houses can benefit from this programme. The Government provides 60 % of the initial PV system cost for single-family and private multi-family houses, and 100 % for public multi-family rent houses. The maximum PV capacity allowed for 3 kW. In 2015, 21 MW was installed under this programme.

(3) Building Subsidy Programme

The Government supports up to 50 % of installation cost for PV systems (below 50 kW) in buildings excluding homes. 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 diffuse into the market. Various grid-connected PV systems were installed in schools, public facilities, welfare facilities as well as universities. In 2015, 6 MW was installed under this programme.

(4) Regional Deployment Subsidy Programme

In an effort to improve the energy supply & demand condition and to promote the development of regional economies by supplying region-specific PV system that are friendly to the environment, the government has been promoting a regional deployment subsidy programme designed to support various projects carried out by local governments. The government supports up to 50 % of the installation cost for NRE (including PV) systems owned and operated by local authorities. In 2015, 14 MW was installed under this programme.

(5) Convergence and Integration Subsidy Programme for NRE

This is a new NRE subsidy program launched in 2013. A consortium led by either local authority or public enterprise with NRE manufacturing companies and private companies can apply for this subsidy programme. This programme 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 programme. In 2015, 5 MW was installed under this programme.

(6) Public Building Obligation Programme

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 % (in 2014) of their total expected energy usage from newly installed NRE resource systems. Public institutions include state administrative bodies, local autonomous entities, and state-run companies. The building energy obligation share will increase up to 30 % by 2020. In 2015, 33 MW was installed under this programme.

TABLE 1 - OBLIGATION SHARE FOR PUBLIC BUILDING OBLIGATION PROGRAMME

YEAR	2011~2012	2013	2014	2015
OBLIGATION SHARE (%)	10	11	12	15

YEAR	2016	2017	2018	2019	2020~
OBLIGATION SHARE (%)	18	21	24	27	30

(6) PV Rental Programme

This is a new NRE subsidy programme launched in 2013. The PV rental programme will fully begin since 2014. Household owners who used more than 350 kWh of electricity can apply for this programme. Owners pay a PV system rental fee (maximum monthly 70 000 KRW which is on the average less than 80 % of the electricity bill) for a minimum of 7 years and can use the PV system with no initial investment and no maintenance cost for the rental period. PV rental companies recover the investment by earning a PV rental fee and selling REP Renewable Energy Point (REP) having no multiplier. In 2015, 8 MW was installed under this programme.

R&D, D

A total of eight Korean ministries were involved in planning and managing the national PV R&D projects. In 2013, 86,9 % of total PV R&D budget was managed by the Ministry of Trade, Industry and Energy (MOTIE) and the Ministry of Science, ICT and Future Planning (MSIP) (112,0 BKRW by MOTIE and 73,3 BKRW by MSIP), and the rest was managed by six other government entities including the Small and Medium Business Administration (16,4 BKRW) and the Ministry of Education (7,5 BKRW). The Korea Institute of Energy Technology Evaluation and Planning (KETEP) controls the biggest portion of the MOTIE-led national PV R&D budget and managed a total of 430 BKRW for the period of 2008~2013. About 60 BKRW will be invested in PV R&D through KETEP in 2014. For the short-term commercialization, so many projects have been implemented with the subjects of polycrystalline Si, Si ingot, crystalline silicon solar cell, CIGS thin film solar cell, PV module, and PV system. For long-term and innovative goals, many projects have been implemented in the area of quantum dot, organic, and perovskite solar cells.

Fig. 3 - 5 MW PV power plant at Amsa Arisu Water Filtration Center, Seoul, Korea (Photo: Hankook-Ilbo).

INDUSTRY AND MARKET DEVELOPMENT

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

TABLE 2 – CAPACITY OF PV PRODUCTION CHAIN IN 2015

POLY-SI (TON)	Ingot (GW)	Wafers (GW)	Cells (GW)	Modules (GW)
93 000	3,350	2,830	3,645	4,490

Production of Feedstock and Wafer: OCI achieved its total production capacity of poly-silicon feedstock up to 52 000 ton. Woongjin Energy is operating a 1 GW silicon ingot capacity plant. Nexolon has a capacity of 1,75 GW in silicon wafers.

Production of Photovoltaic Cells and Modules: Hanwha Q CELLS Korea built 1,5 GW of photovoltaic cell plant and 500 MW of module plant in province of Chungcheongbuk-do. LG Electronics has a capacity of 900 MW and 1 GW in the c-Si solar cells and modules, respectively. Hyundai Heavy Industry has a capacity of 600 MW and 600 MW in the c-Si solar cells and modules, respectively. Shinsung Solar Energy has a capacity of 420 MW and 150 MW in the c-Si solar cells and modules, respectively.

Since the installation of 276 MW in 2008, the PV market remained stagnant in Korea over the three years that followed (installation of 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, 230 MW in 2012, 531 MW in 2013 and 926 MW in 2014, respectively, were installed due mainly to the newly introduced RPS scheme with mandated PV requirement. The RPS scheme was again the main driver for PV installation in 2015, and a remarkable size of 1,011 GW was recorded. At the end of 2015, the total installed PV capacity was about 3,493 GW, among them the PV installations that were made under the RPS scheme accounted for 68 % of the total cumulative amount.

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

GENERAL FRAMEWORK AND IMPLEMENTATION

The grid-connected PV market in Malaysia is largely driven by the implementation of the feed-in tariff (FiT) mechanism by the Sustainable Energy Development Authority Malaysia ("the Authority"). 2015 marked the fourth year of FiT implementation in Malaysia; the FiT is framed under the Renewable Energy (RE) Act 2011 [Act 725] whilst the establishment of the Authority is under the SEDA Act 2011 [Act 726]. Aside from the Authority, 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 save for the state of Sarawak. The FiT portfolio covers five types of renewable resources connected to the grid; they are biomass, biogas, small hydro, PV, and geothermal. Of these five renewable resources, PV continuously ranked as the renewable resource with the fastest take up rate. Despite a steep degression rate for PV compared to the other renewable resources, the PV market continued to outpace the other renewable resources due to the ease of project implementation. As of end of December 2015, the Authority approved a total of 7 268 applications (324,79 MW) for PV and these applications constituted 97,8 % of the total applications approved under the FiT mechanism.

Degression Rates: Since the FiT was implemented on 1 December 2011, degression rates for PV have been revised on annual basis to reflect a reasonable return on investment in PV projects. On 29 December 2015, new degression rates were gazetted and this review took into consideration the global pricing dynamics of PV and the weakening of the Malaysian Ringgit (MYR) against major currencies such as the US Dollar. The degression rates for installed PV capacities of up to 1 MW remained unchanged. However, the degression rates for installed PV capacities greater than 1 MW and up to 30 MW were revised from 20 % to 15 %. Additionally, the degression rate for bonus criteria for use of PV as installation in building or building structures (i.e. retrofitted application) was revised from 20 % to 10 % but the degression rates of use of PV as building materials (i.e. BIPV application) remained at 20 %, and use of locally manufactured or assembled PV modules and inverters remained at 0 %.

Way Forward: The FiT mechanism is funded by consumers who contributed an additional amount of 1,6 % on their electricity bills [1] to the RE Fund. This totals to approximately only MYR 633 million per annum; the amount is miniscule compared with many countries implementing the FiT mechanism. This matter is exacerbated as the Malaysian Government subsidizes the electricity tariff in the country. Due to the constraint in the RE Fund; PV under the FiT is projectedto conclude releasing further quota post 2017. In order to sustain the PV industry and to grow the PV market in the country, thePrime Minister of Malaysia announced in the Budget 2016 the implementation of Net Energy Metering by the Authority with the quota capacity of 100 MW per year commencing 2016 (23 October 2015).

Fig. 1 - A PV farm of 1,764 MW in Kedah, Malaysia by Leaf Energy Sdn Bhd.

NATIONAL PROGRAMME & MARKET DEVELOPMENT

The market development for grid-connected PV systems hinges mainly on the FiT mechanism. In 2015 alone, a total of 2 770 applications for PV were approved with a total capacity of 72,50 MW. The breakdown of approved applications is as follows: individuals (2 479 applications 20,39 MW), community (184 applications 4,51 MW), and non-individuals (107 applications 47,60 MW). As of 31 December 2015, a cumulative total of 221,33 MW of PV projects were operational of which the 46,05 MW were for the individuals, 0,97 MW were for the community and 174,31 MW were for the non-individual PV projects. This translated to 4 827 individuals, 58 communities, and 285 non-individuals feed-in approval holders. The installed PV capacity in 2015 alone was 61,3 MW; 17,05 MW from individuals, 0,97 MW from communities, and 43,28 MW from non-individuals. More information on PV quota, FiT rates and operational capacity can be accessed via www.seda.gov.my.

In the state of Sarawak, the cumulative installed PV capacity in 2015 was 2,747 MW of which 2,489 MW was off-grid and 0,258 MW was grid-connected PV systems. In 2015 alone, there were no grid-connected PV systems installed whereas there were 1,657 MW of off-grid PV systems installed. Although FiT is not extended to the state of Sarawak, net energy metering mechanism is implemented at utility level (source: Sarawak Energy Berhad).

[1] domestic consumers with not more than 300 kWh per month electricity are exempted from contribution to the RE Fund.

INDUSTRY DEVELOPMENT

On the PV manufacturing front, Malaysia remains a significant PV producer (after China and Taiwan). In 2015, the total metallurgical grade silicon (MGS) and polysilicon manufacturing nameplate capacity remained at 53,4 tonnes with employment of 840. For wafer, solar cells and PV modules manufacturing, the total estimated nameplate capacity was 9 430 MW with employment of 13 149. Figure 2 shows the major PV manufacturing statistics in Malaysia classified under 4 categories for 2015 and 2016 (estimate): Metallurgical and Poly Silicon, Wafer, Solar Cells, and PV Modules.

METAL SI & POLY SI		2015		2016 (ESTIMATE)	
No.	**Company Name**	**Capacity (kilo ton)**	**Employment**	**Capacity (kilo ton)**	**Employment**
1	Elpion Si (Metal Si)	33,4	160	33,4	160
2	Tokuyama (Poly-Si)	20,0	680	20,0	680
	Total	**53,4**	**840**	**53,4**	**840**
WAFER		**2015**		**2016 (ESTIMATE)**	
No.	**Company Name**	**Capacity (MW)**	**Employment**	**Capacity (MW)**	**Employment**
1	Sun Edison (P-type mono)	1 000	650	NA	NA
2	Comtec (Ingot, N-type mono)	205	320	278	434
	Total	**1 205**	**970**	**278**	**434**
CELL		**2015**		**2016 (ESTIMATE)**	
No.	**Company Name**	**Capacity (MW)**	**Employment**	**Capacity (MW)**	**Employment**
1	AUO-SunPower (N-type Mono-Si)	750	1 694	800	1 664
2	Hanwha Q-Cells (P-type Multi-Si)	1 700	1 106	NA	NA
3	TS Solartech (Multi-Si)	210	200	700	500
4	First Solar Tetrasun (N-type Mono-Si)	100	100	100	100
5	Jinko Solar (Multi-Si)	500	536	500	536
6	JA Solar (Multi-Si)	NA	NA	400	700
	Total	**3 260**	**3 636**	**2 100**	**2 800**
MODULE		**2015**		**2016 (ESTIMATE)**	
No.	**Company Name**	**Capacity (MW)**	**Employment**	**Capacity (MW)**	**Employment**
1	First Solar (CdTe thin film)	2 400	3 900	2 400	3 900
2	Flextronics (OEM for Si)	1 100	1 500	1 500	2 000
3	Panasonic (HIT N-type Mono Si)	300	1 200	425	1 250
4	MSR (Mono & Multi-Si)	85	130	85	130
5	Solartif (Multi-Si)	10	NA	NA	NA
6	PV HiTech (Multi-Si)	5	15	5	15
7	Endau XT (Mono & Multi-Si)	75	NA	NA	NA
8	Hanwha Q-Cells	1 600	774	NA	NA
9	Jinko Solar (Multi-Si)	450	914	450	914
10	Nanopac (Thin Film)	Not operational		12	30
11	Promelight (Mono & Multi-Si)	40	106	150	200
	Total	**6 065**	**8 539**	**5 015**	**8 409**

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

Within the PV industry, there were 118 PV service providers active in the market in 2015. The list of these registered PV service providers for 2016 can be found in www.seda.gov.my.

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 main R&D areas of Malaysian universities and research institutions.

<table>
<tr><th colspan="5">NATIONAL UNIVERSITY OF MALAYSIA (UKM)</th></tr>
<tr><th>PV Cell</th><th>PV Module</th><th>BOS</th><th>PV System</th><th>Others</th></tr>
<tr><td>• Bifacial C-Si Cell
• Junction formation optimization of C-Si Cell
• Surface texturisation of C-Si Cell
• CdS/CdTe Cell
• $CdCl_2$ Treatment
• Indoline-based dye for DSSC</td><td>• Bifacial module
• PV-thermal panels with bifacial solar cell
• Thermal analysis of semi-transparent PV</td><td>• Optimization of inverter
• Optimization of MPPT controller</td><td>• Hybrid PV systems design
• Performance study of PV/T collector</td><td>• Solar radiation monitoring
• Solar radiation, solar energy, meteorological variables prediction</td></tr>
<tr><th colspan="5">UNIVERSITY OF MALAYA (UM)</th></tr>
<tr><th colspan="2">PV Cell</th><th colspan="3">BOS</th></tr>
<tr><td colspan="2">• Nanostructured TiO_2-Ge thin film
• Multilayer Si/Ge thin-film</td><td colspan="3">• SEPIC converter for MPPT
• 6-phase induction motor drive
• Active power filter for harmonic compensation
• Transformerless inverter/converter
• Multilever inverter/converter
• Temperature sensor for PV inverter</td></tr>
<tr><th colspan="5">UNIVERSITY OF SCIENCE, MALAYSIA (USM)</th></tr>
<tr><th colspan="5">PV Cell</th></tr>
<tr><td colspan="5">• Highly doped N-type porous Si
• Nano-texturing of C-Si Cell
• CdS/CIGS cell on PET substrate
• ITO/ZnO and other thin film on PET substrate
• Flexible substrate for electronic devices at low temperature of 70°C and atmospheric temperature</td></tr>
<tr><th colspan="5">UNIVERSITI TEKNOLOGI MALAYSIA (UTM)</th></tr>
<tr><th colspan="3">BOS</th><th colspan="2">PV System</th></tr>
<tr><td colspan="3">• Selective harmonics elimination with PWM for inverter
• Bidirectional inverter/converter</td><td colspan="2">• PV system simulator/MPPT/ Energy recovery scheme during partial shading condition</td></tr>
<tr><th colspan="5">UNIVERSITI PUTRA MALAYSIA (UPM)</th></tr>
<tr><th>PV Cell</th><th colspan="2">BOS</th><th colspan="2">Others</th></tr>
<tr><td>• CIS thin film
• SnSe thin film</td><td colspan="2">• Cascade voltage doubler for voltage multiplication</td><td colspan="2">• Solar radiation prediction</td></tr>
</table>

<table>
<tr><th colspan="2">UNIVERSITI TEKNOLOGI MARA (UITM)</th></tr>
<tr><td colspan="2">PV System</td></tr>
<tr><td colspan="2">• Grid-connected/stand-alone PV system sizing optimization
• GCPV system output prediction</td></tr>
<tr><th colspan="2">TECHNICAL UNIVERSITY OF MALAYSIA (UTEM)</th></tr>
<tr><td colspan="2">PV System</td></tr>
<tr><td colspan="2">• Energy recovery scheme during partial shading condition</td></tr>
<tr><th colspan="2">UNIVERSITI MALAYSIA PERLIS (UNIMAP)</th></tr>
<tr><td colspan="2">PV Cell</td></tr>
<tr><td colspan="2">• Natural anthocyanins compound as photovoltaic sensitizer</td></tr>
<tr><th colspan="2">MULTIMEDIA UNIVERSITY (MMU)</th></tr>
<tr><td colspan="2">PV System</td></tr>
<tr><td colspan="2">• Performance analysis of PV/T system</td></tr>
<tr><th colspan="2">UNIVERSITI TUNKU ABDUL RAHMAN (UTAR)</th></tr>
<tr><td>PV Cell</td><td>BOS</td></tr>
<tr><td>• Non-imaging concentrator
• Non-imaging focusing technology
• Synthesis of TiO2 for DSSC</td><td>• Sun tracking system
• Polymer electrolyte for lithium rechargeable battery</td></tr>
<tr><th colspan="2">UNIVERSITI MALAYSIA PAHANG (UMP)</th></tr>
<tr><td>PV Cell</td><td>PV System</td></tr>
<tr><td>• TiO2 nanostructure
• Electrospinning of TiO2 and SnO2 nanoflowers/nanowires
• Perovskite solar cells</td><td>• Estimation of solar radiation</td></tr>
<tr><th colspan="2">UNIVERSITI TEKNOLOGI PETRONAS (UTP)</th></tr>
<tr><td>PV Cell</td><td>PV System</td></tr>
<tr><td>• Optimization/Synthesis of TiO2 aggregates
• Flexible DSC</td><td>• Estimation of solar radiation</td></tr>
<tr><th colspan="2">SIRIM BERHAD</th></tr>
<tr><td colspan="2">Others</td></tr>
<tr><td colspan="2">• Fabrication of solar simulator</td></tr>
<tr><th colspan="2">MIMOS BERHAD</th></tr>
<tr><td>PV Cell</td><td>BOS</td></tr>
<tr><td>• PV Device</td><td>• Solar tracking apparatus</td></tr>
</table>

Fig. 3 - Main Solar PV Researches by Local Universities and Research Institute (Source: Malaysian Industry-Government Group for High Technology).

MEXICO

PV TECHNOLOGY: STATUS AND PROSPECTS IN MEXICO

JAIME AGREDANO, JORGE M. HUACUZ
ELECTRICAL RESEARCH INSTITUTE

GENERAL FRAMEWORK AND IMPLEMENTATION

The legislative process for the Constitutional Energy Reform in Mexico was concluded in December of 2015, with the approval by Congress of the Law for Energy Transition (LET). This is one of the nine new laws enacted since the Mexican energy reform process began in 2013. Jointly with the also new Law for the Electricity Industry (LEI), the LET sets the legal framework for the massive deployment in Mexico of PV, along with other renewables. This legal framework includes, among other things, the implementation of a system of Clean Energy Certificates to be issued by the Energy Regulatory Commission (CRE) as a means of certifying the amount of electricity produced from clean energy sources by the electric companies established in Mexico after the unbundling of the state electricity monopoly, CFE. Also included in the legal framework is a mechanism for long-term auctions of clean electricity, clean power and clean energy certificates. Strategy and planning instruments, such as the Transition Strategy to promote the use of cleaner technologies and fuels, the National Program for Sustainable Energy Use, and the Special Program for Energy Transition, have been established with the purpose of assuring that the national goal previously set in the General Law for Climate Change, of reaching 35 percent of electricity produced from clean energy by 2024, will be met.

NATIONAL PROGRAMME

Albeit no specific national PV program has been instrumented in this country, an increasing number of utility-scale PV projects have been permitted and are at different stages of development. To date, CRE has awarded generation permits for grid-connected PV totaling 7,285 MW in capacity. According to the recently released National Electric System Development Program, which derives from the Electricity Reform Act of 2013, solar energy will reach 2,103 MW by the year 2029. It is assumed that all this capacity will be reached with photovoltaic systems, as no indications of concentrating solar power projects for Mexico could be found in the projections.

R&D, D

It is still too early to report progress made by the team of universities, private firms and research centers clustered in the recently created Center of Innovation for Solar Energy (CEMIE-SOL). Current PV projects approved within this initiative are mostly in their initial stages.

INDUSTRY AND MARKET DEVELOPMENT

The installation of PV-powered micro-grids in remote rural communities continues as part of the government's rural electrification programs. The total number of installations, mostly of 50 kWp capacity each, has reached 2,5 MW.

Local PV module assembly capacity has grown to around 1 GW with the recent inauguration of a 500 MWp facility near Mexico City. Other smaller manufacturing facilities have been installed in central and south Mexico to supply PV modules for the national markets, while other companies previously installed near the Mexico-US border continue their production for the export market.

Fig. 1 - 70 kW PV System in a Fruit Packing Plant, Colima MX (Photo: Conermex).

Financing, historically one of the main barriers for the introduction of renewable energy in Mexico, is now slowly appearing. FIDE, a not-for-profit electricity savings organization focusing on electricity consumers of the domestic, and small and micro enterprises sectors, reports having financed close to 1 000 roof top PV projects for a total close to 12 MUSD. These are small projects of less than 4 KW each for domestic users and less than 8 kW each for enterprises. Estimates of the National Solar Energy Society (ANES), Mexican Chapter of the International Solar Energy Society (ISES) indicated that 103 MW were installed during 2015. The market segmentation shows that between 8 000 and 10 000 rooftop PV systems, with a total capacity of 50 MW, were installed in 2015; with 1 MW for street lighting, 3 MW for SHS and water pumping and 49 MW in centralized PV parks. In early 2016, a 22 MW PV plant is going to be put on line. This plant is part of a project for installing 400 MW to be completed in the coming years. According to CRE data, close to 3 GW of utility scale PV projects already permitted are at different stages of development; 600 MW are expected to come on line during 2016. The down side of the developing Mexican PV market is that a 15 % import duty has been imposed on PV modules, which is currently been fought against on legal grounds by a number of project developers.

THE NETHERLANDS

PV TECHNOLOGY STATUS AND PROSPECTS 2015

OTTO BERNSEN, RVO, ENERGY INNOVATION

Fig. 1 - TU-e family car "Stella" winning the category cruiser car in the Solar World Challenge in Australia for the second consecutive year (Photo: news TU-e).

GENERAL FRAMEWORK

The Dutch PV market shows a sturdy yearly growth and there are early indicators that especially the rooftop market will exceed the nearly 300 MW installed capacity in 2014 to approx. 450 MW in 2015. However, the Dutch market has not yet reached its full potential for acceleration in the larger systems segments. After breaching the 1 GW number of total installed capacity last year, the sunny expectations have been tempered by the inability to reach a breakthrough in larger applications (up to and over15 kWp) supported by the SDE plus scheme. Some larger systems have been realised but since renewable energy sources have to compete in the Netherlands with each other on price in the SDE plus scheme, solar has been largely pushed out by other cheaper alternatives. The National Action Plan Solar (NAZ) however foresees a growth of installed capacity in 2023 of 10 GW instead of the earlier projected 4 GW in 2020. This amounts to approximately 15 % of the total renewable energy production and 7 % of the total electricity demand in 2030. For now, the domestic markets relies on the several hundred Megawatts installed each year while the market is gradually diversifying into different sizes, different types of panels and different applications.

The definition of the traditional category of PV as a device generating only electricity might need some revision in the future. The main reason for this is that after the initial pioneering phase of PV technologies it is now not only widely accepted as a viable alternative but also increasingly integrated and seen as part of an energy system. This can be in combination with the different functions of an energy system such as storage, as in the case of artificial photosynthesis which converts sunlight into fuels, or with the additional functions of BIPV, such as active cooling/heating, insulation, shading, waterproof and aesthetics. Artificial photosynthesis and luminescent solar concentrator (LSC) are in the early stages of development.

The major drivers of the domestic rooftop market stay the same in 2015 for the Netherlands; lower prices, the net metering scheme which is guaranteed until 2020, the various tax reduction schemes, the quality of the installation, the low interest rates which turn solar into a viable alternative for saving money and the mandatory energy label (EPC) for houses on the market. The Netherlands offer an innovative domestic market with many niche markets and specialised products.

The international consolidation in the solar industry also continues with new players entering and old ones adjusting. The core group of equipment manufactures led by Tempress, Eurotron, Levitech and VDL maintained their position while chemical multinational DSM continues to be a worldwide market leader, specifically in encapsulation of solar cells.

The national effort is led by the Top Consortium for Knowledge and Innovation (TKI) for Solar which in 2016 has merged together with the TKIs for smart grids and the built environment under the flag of Urban Energy (see http://topsectorenergie.nl/urban-energy/). The TKI Urban Energy is a public –private partnership and its goal is to further accelerate the development and application of solar power in the Netherlands and to ensure that the added value to the Dutch economy is maximized.

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 various tax incentives, the SDE plus scheme (which is a feed-in subsidy for larger solar systems up and above 15 kWp) and the net metering scheme for households and smaller systems. A tax reduction scheme exists for local energy cooperatives with members living nearby and similar postal codes, the so-called "postcoderoos". Apart from these instruments, the so-called Green Deals can still be closed concerning public-private partnerships that contribute to the 2020 energy goals. The innovation is driven by the TKI Urban Energy (Top consortium for Knowledge and Innovation) and fundamental research is mainly executed by NWO (the Dutch National Science Foundation) and their institutes, such as DIFFER, which focuses specifically on fusion and solar fuels.

A new instrument was introduced in 2015, the renewable energy R&D instrument (http://www.rvo.nl/subsidies-regelingen/topsector-energieregelingen-tse/subsidieregelingen/hernieuwbare-energie). Its main goal is to reach the climate goal of 16 % renewable energy in 2023 in a cost effective way by means of innovative projects that lead to cheaper renewable energy production with new products.

These national programmes are complemented by many regional programmes executed by provinces and cities targeting also specific niches, such as schools, sport clubs or the replacement of asbestos roofs with solar. An example is the largest solar park of 6 MWp in the Netherlands on the island of Ameland for which construction started in 2015.

Fig. 2 - Tulipps Solar lightweight thin-film BIPV with founder and CEO Paul Stassen (Photo: RVO.nl).

RESEARCH AND DEVELOPMENT ACTIVITIES

In 2015, approximately 26 MEUR public funding for solar was allocated to R&D projects. More data is gathered from all Dutch research efforts and shall be presented later this year.

The solar program lines of the TKI IDEEGO (now Urban Energy) on applied research consisted of:

- Solar technologies (PV)
- Multifunctional building parts containing PV (BIPV).

The key research partnerships in these two focus areas are:

- SEAC (Solar Energy Application Centre; an initiative of ECN, TU-e, TNO and University of Utrecht) for systems & applications;
- Silicon Competence Centre (ECN, FOM-Amolf, TUD-Dimes and Tempress, Levitech en Eurotron) for wafer-based silicon PV technologies;
- Solliance (TNO, ECN, TU/e, Holst Centre, IMEC and FZ Jülich and DSM, VDL, DyeSol, Rexroth, Nano-C, SolarTek) for thin-film technologies.

Several academies have bachelor and master courses on solar technologies. A test site is based at the expertise centre NEBER of Hogeschool Zuyd for large scale applications and especially renovation projects http://international.zuyd.nl/research/centres-of-expertise/neber.

Scientific research into solar technologies, production and applications is regionally dispersed in the Netherlands over various universities including Utrecht, Leiden, Amsterdam, Delft, Nijmegen, Groningen, Eindhoven and at AMOLF in various groups like Nanoscale Solar Cells, Photonic Materials and Hybrid solar Cells, see their website http://www.amolf.nl/research/nanoscale-solar-cells/.

INDUSTRY STATUS

In 2015, only a few companies have been producing solar cells or modules in the Netherlands. Trina Solar has taken over Solland Solar with a capacity of 200 MWp a year and Hyet Solar produces amorphous silicon cells for demonstration and is developing niche markets. There are however new innovative initiatives, such as Orange Solar producing tailor made modules, Solarus in Venlo producing solar collectors and Exasun in Rijswijk which produces the first back contact solar cells (15 Mwp per year) with plans for expansion. Tulipps Solar is ready for the production of lightweight panels (see Figure 2).

The manufacturing industry of machinery led by Tempress, Eurotron, Levitech and VDL has maintained their market position notwithstanding the continuing international consolidation in the industry. From the chemical industry multinational DSM is a worldwide market leader specifically in encapsulation of solar cells with dedicated antireflective coating.

Worthwhile mentioning are also four very specific niche markets in the Netherlands apart from the solar crystalline solar cells that are still dominant in the solar market, namely: the high quality solar cells for the European space programs ESA and CPV applications, the innovative experiments by TNO with solar cells in pavement called Solar Road, the combination of LED lighting and PV in green houses and last but not least the combination of amorphous solar cells on industrial foils covering large surfaces; for example, waste dumps.

The installation of solar has led to the creation of 10 000 jobs in the building and installation sector (source: Nationaal Solar Trendrapport 2015).

In Figure 3, an overview is given of the module prices since 2013. It seems to stabilize on an average price of 1,06 EUR/Wp. About 50 % of the panels are imported from Asia. Over 90 % of this market consists of roof top systems.

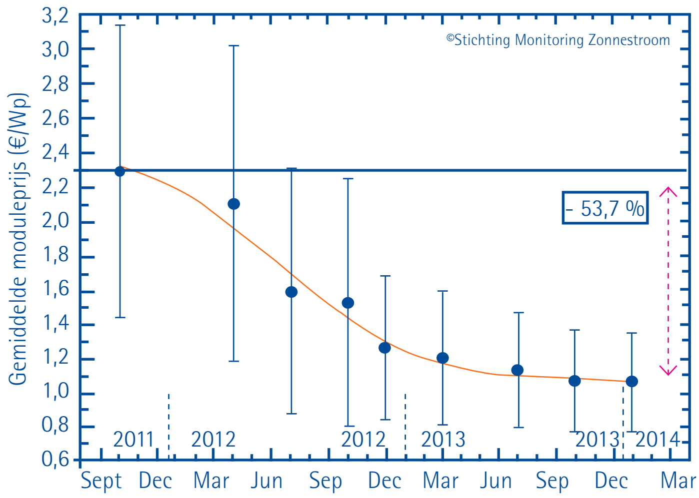


Fig. 3 - Average module prices on the Dutch solar market (Source: Stichting Monitoring Zonnestroom).

All parties in the Dutch Solar sector can be found for match-making activities on the mobile App Dutch solar sector. The App is available for IOS (iPhone and iPad), see http://sectorapp.tkisolarenergy.nl/.

Fig. 4 - Design LSC in solar screen SONOB along highway by Heijmans (Source: Heijmans Bv. http://www.heijmans.nl/nl/solar-noise-barriers-sonob/).

DEMONSTRATION PROJECTS

The phase of demonstration projects of PV modules is still very much alive in the Netherlands and covers new markets segments like infrastructure, green houses, floating systems, BIPV and more efficient thin film and crystalline cells. A good example is the field test for Luminescent Solar Concentrators (LSC) in noise barriers along highways by a consortium led by Heijmans (Sonob-project, See Figure 4).

IMPLEMENTATION AND MARKET DEVELOPMENT

An important incentive for households is net metering for own consumption. This net metering scheme is guaranteed until 2020 but there is much public debate on the prolongation of this incentive and the socialization of external costs. The amount of installations is rising fast and also an argument exists that net metering obstructs a business case for local storage systems.

There is a specific report for the SDE plus scheme containing larger systems but the main message here is that there exists a large discrepancy between the solar systems expected and realized (see figure 13 in Report on Renewable Energy 2014. http://english.rvo.nl/sites/default/files/2015/09/Renewable%20energy%20report%202014_0.pdf

As mentioned before, in previous years the registration of roof mounted solar panels in the Netherlands is not complete and the installation of smart meters is only at its initial stage. Therefore, the estimation of the total amount installed capacity each year is not accurate and there might exist an error margin of 10 % and probably more. The official figures are published by the CBS in May after which adjustments can still be made. Given this situation and the positive early indicators in the sector (with thanks to Solar Solutions, Solar Magazine and Polder PV) for the rooftop segment and some large scale systems realised on industrial roofs, a first estimation of 450 MW is given here and the official figures over the year 2015 will be presented in May 2015 by the CBS. To reach the set goals however, the domestic Dutch market will have to speed up to a growth of around 1 GW a year.

Dutch Installed capacity yearly and accumulated MWp

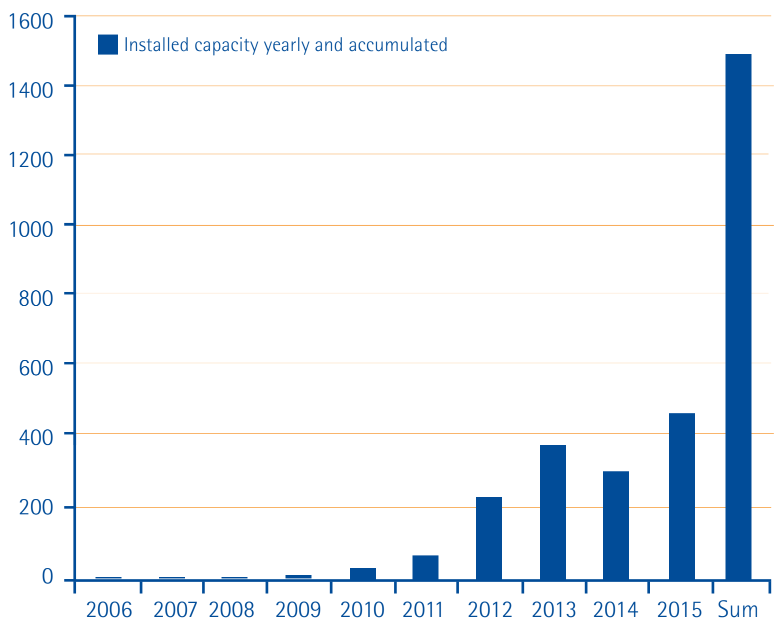


Fig. 5 - Preliminary estimation for installed capacity in 2015 MWp. (Source: CBS Statline contains only figures until year 2014. 2015 is not published yet).

NORWAY

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

BJØRN THORUD, THE RESEARCH COUNCIL OF NORWAY

Fig. 1 - 127 kWp of screen-printed glass with integrated PV cells installed in 2015 at Solsmaragden, in Drammen, Norway (Photo: Fusen AS).

GENERAL FRAMEWORK

Hydropower is the main source of electricity generation in Norway, covering 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, 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.

2015 was the fourth 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 28,4 TWh/year before 2020. The total power production in Norway in 2014 was 144,8 TWh, whereas only 128,6 TWh was consumed in Norway. By the end of Q4 2015, 570 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.

NATIONAL PROGRAMME

Currently, Norway has no defined goals when it comes to implementation of PV technology. The el-certificate market is technology neutral and thus the intention is to support all new types renewable power generation. The entrance fee for the participation in the el-certificate market is minimum NOK 15 000 NOK, and this amount is generally too high for owners of small PV systems. Larger PV systems could benefit from the el-certificate market, but the regulations for PV in this market has yet to come in place. In a hearing, NVE suggested that PV could be included in the el-certificate market if the PV plant was set up as the same way as an ordinary power station. Thus, one would have to apply for a concession for electricity sales and pay for grid services to the TSO. Self-consumption would not be eligible for el-certificates. However, during the negotiations for the state budget at the end of 2015, the Parliament asked the Government to revise the regulations so that self-consumption would be eligible for el-certificates. As of the beginning of 2016, there are no regulations in place and therefore el-certificates have not been credited to any PV-plant.

Since the el-certificate market has proven to be "unsuited" for small scale power generation, such as PV, Enova has made an exception for privately owned PV systems below 15 kWp. These systems are eligible for a support of 10 000 NOK plus 1 250 NOK/kWp. This support scheme was introduced in January 2015 and during the first year of operation a total of support of 1,18 MNOK has been given, resulting in 76 systems with an accumulated output of 319 kWp. A large portion of these systems were installed on the islands of Hvaler in the south east of Norway where they are an integral part of the Smart-Grid Hvaler demonstration site.

Another support program at Enova is the program for "Buildings with High-Energy Performance". This program can offer financial support to buildings where the energy performance goes beyond the normal technical norms. "Near Zero Energy Buildings" (nZEB), "Zero Energy Buildings" (ZEB) and "Plus Energy Buildings" are examples of building categories that are eligible for support through this program. Throughout 2015, a total of 4 buildings supported by this program included PV as part of the energy concept. However, neither the amount of support towards PV, nor the installed capacity was registered by Enova.

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 was limited to 4 MNOK.

77 homes were granted support through the scheme in 2015, with the budget capacity reached in November. Only a quarter of the fund has been paid out however, since it is payable as a reimbursement after the investment on the PV system is made. The scheme has been extended for 2016 to 6 MNOK. Successful applicants have two years to realize the implementation of the system to secure reimbursement.

PV continues to be an important topic for government funded research and development, and it is one out of six research areas that are emphasized by the Norwegian National Research Strategy, Energi21. The main focus of this strategy is on the PV industry and export. There is very little focus on domestic use of PV, although the interest among researches seem to be increasing.

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 was approximately 67 MNOK (7 MEURO) for 2015. 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 sixth 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 seven work packages, six of which involve research, development and 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, new characterization methods and silicon production. The seventh is a value-chain project that applies the findings of the other six work packages to produce working solar cell prototypes. The total Centre budget is ~350 MNOK over the duration of the Centre (2009–2017).

The governmental support for the Norwegian Research Centre for Solar Cell Technology comes to an end in 2017. An application for a new centre in solar cell technology including the partners from the current centre, as well as several new entrants, has been submitted. If successful, the new centre will be awarded funding from 2017. The new centre will continue to build on its strong knowledge in the up-stream activities, but it will also include research related to innovation and industrial development, as well as PV systems.

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

- IFE (Institute for Energy Technology): Focuses on polysilicon production, silicon solar cell design, production, 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 has 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. There are some activities on PV systems at the FME-centre ZEB (Zero Emmission Buildings)
- SINTEF Trondheim and Oslo: Focus on silicon feedstock, refining, crystallisation, sawing and material characterisation.
- NMBU (Norwegian Univiersity of Life Sciences): Focus 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.

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).

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. The ramp up has continued through 2015 and several of the actors in the Norwegian PV industry have stated that 2015 was one of the best years they've had for a long time.

REC-Silicon is still noted on the Oslo stock exchange but the headquarters are no longer in Norway. There is no production left in Norway. The company was split into two companies in 2013 REC; 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. REC Solar is no longer noted on the Oslo stock exchange.

Elkem Solar's technology 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. Following a standstill during 2012 and 2013, Elkem Solar started up its production of solar grade silicon in 2014. Through the year the production was ramped up and it now runs on 100 % of the capacity. Furthermore, Elkem Solar is pursuing plans to expand the capacity to 7 500 t/y, and they are currently evaluating a capacity expansion in two of the four the former REC-facilities at Herøya in Porsgrunn.

NorSun AS manufactures high performance monocrystalline silicon ingots and wafers at its plant in Årdal in western Norway. Annual production capacity at the company's facility in Norway exceeds 350 MW. In 2015, market conditions improved and the factory was running at full capacity while a number of cost reduction improvements were implemented. They currently employ almost 200 employees.

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. 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 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 383 MW in the Czech Republic, South Africa, Rwanda, Honduras and the United States, with 43 MW under construction in Jordan. The Company has its head office in Oslo, but operates in the international market. In 2014, Scatec Solar went public and is now noted on the Norwegian Stock Exchange.

Steuler Solar Technology AS is part of the German Steuler Group who has developed and patented a new generation of crucibles for producing wafers for the PV industry. In 2012, its subsidiary in Norway established a pilot production of crucibles in the Herøya Industrial Park. The crucibles can be reused which can yield cost savings in the industry, and provide better purity of wafers and control over the crystallization process. Throughout 2015, a pilot production has been operating in parts of the former REC factory at Herøya, and Steuler Solar is considering to ramp up.

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. Uncertainty relating to regulatory framework meant that the increase in grid connected systems in 2015 was a modest increase of 1, 5 MWp compared with 1,4 MWp in 2014. 2015 saw a decrease in commercial business installations, but this was offset with the growth coming from household systems. Overall, the market remains small with a total installed capacity of approximately 15 MWp, an increase of 20 % on 2014. The off-grid market showed stable growth at 0,8 MWp installed in 2015. The market for grid-connected systems is mainly driven by players 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 2015 received attention from the media. Among them were the "Solar Emerald" in Drammen with over 1 200 square meters totaling over 127 kWp of green PV panels integrated into the façade as well as over 67 kWp on the roof. The investment support from the municipality of Oslo for private households was well received in the media, after initial issues regarding the application process and building codes.

PORTUGAL

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

PEDRO VALVERDE AND PEDRO SASSETTI PAES, EDP

Fig. 1 – New EDP Headquarters in Lisbon - 84 kW PV self-consumption.

GENERAL FRAMEWORK AND IMPLEMENTATION

The Portuguese National Renewable Energy Action Plan (Plano Nacional de Ação para as Energias Renováveis), in accordance with the Directive 2009/28/EC on the promotion of the use of energy from renewable sources, was prepared in accordance with the template published by the Commission, and provides detailed roadmaps of how each Member State expects to reach its legally binding 2020 target for the share of renewable energy in their final energy consumption.
The PNAER objectives for 2015 in terms of installed capacity for solar power were:

- 383 MW for Solar Photovoltaic; and
- 34 MW for Concentrated solar power

By the end of 2015, according to the monthly analysis of the Directorate General for Energy and Geology (DGEG), the installed capacity for solar power was:

- 101 MW for Microgeneration (Solar PV Residential);
- 73 MW for Mini-generation (Commercial rooftop PV); and
- 282 MW for Utility-scale ground mounted PV power plants;

which means that in 2015, about 63 MW of PV were added, taking total PV capacity to about 455 MW.

NATIONAL PROGRAMME

With the publishing of decree-law 215-B/2012, FiT for large scale renewable power plants was terminated. New RES-E projects have no incentive mechanisms; they were integrated into the regular energy market. The RES plants with FiT will gradually be transferred to the market regime from 2018 and there is still no clear strategy how this will occur.

By October of 2014, the new self-consumption and FiT regime regulation for small units was published (decree-law 153/2014), which repeals the old FiT scheme (micro and minigeneration). It defines rules for self-consumption systems with grid-connection, which had no regulation before, and new rules for the FiT scheme (systems under 250 kW). The regulation is fully operational.

On January 1, 2015, the Green Tax Reform was implemented. It was established that a new value for the maximum tax depreciation of solar was set at 8 %, which represents twelve and a half years. The proposal of reducing 50 % of the Municipal Real Estate tax (IMI) for RES power producing buildings was accepted and will be carried out within five years.

The Ordinance n.º 133/2015 introduced on May 15, 2015, allows the change of the technology for the installed power plants or the licensed power plants.

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 2005 PV cumulative capacity has registered a compound annual growth rate of 58 %.

This year's installed capacity (63 MW) was lower than the capacity installed in the previous year in Portugal. Most of this capacity concerns large scale projects.

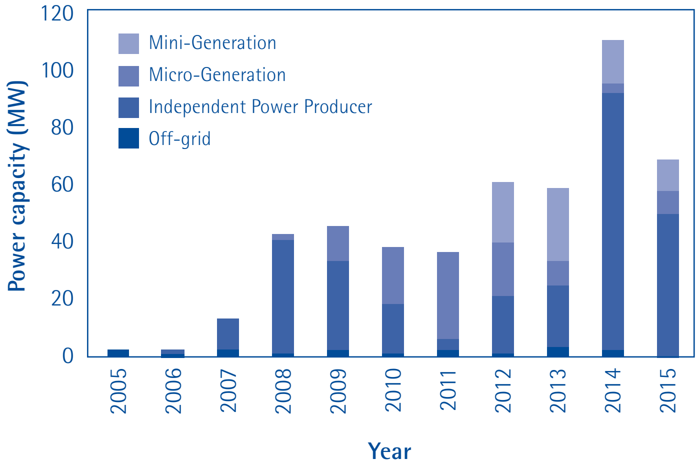


Fig. 2 – New PV power capacity installed yearly in Portugal (2005-2015).

TABLE 1 – CUMULATIVE PV POWER CAPACITY INSTALLED IN PORTUGAL (2005-2015)*

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
2015	n.a.	282	101	72	455

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

SOLARPOWER EUROPE

SOLARPOWER EUROPE'S ACTIVITIES

IOANNIS-THOMAS THEOLOGITIS, SENIOR ADVISER, SOLARPOWER EUROPE
THOMAS DOERING, POLICY ANALYST ON TECHNOLOGY AND MARKET TRENDS, SOLARPOWER EUROPE

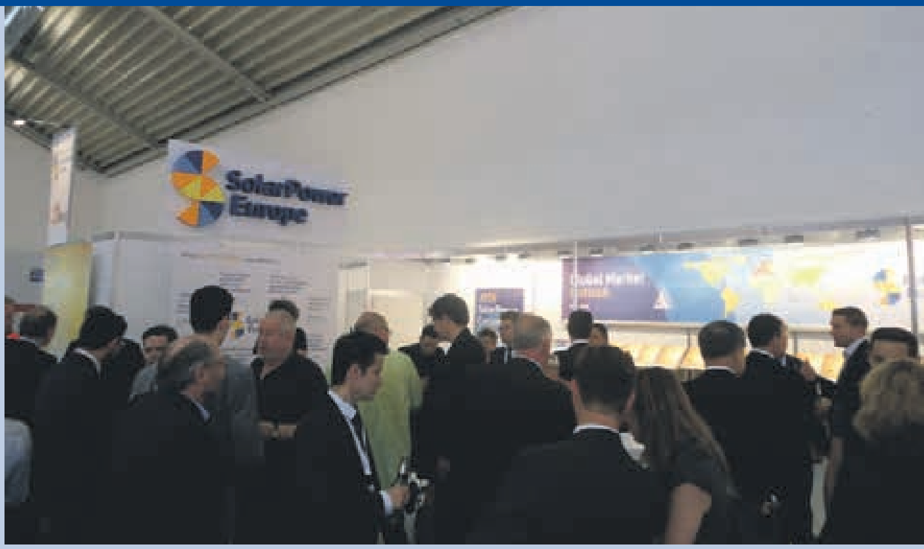


Fig. 1 – SolarPower Europe at Intersolar Europe 2015.

The new SolarPower Europe, formerly known as EPIA (European Photovoltaic Industry Association), is a member-led association representing organisations active along the whole value chain. Over the last year, there has been much change in the association, its focus and strategy placing it in a stronger and more powerful position than in the past.

A transition to a more service oriented and customer focused association with a clear vision, a re-purposed corporate identity and a business plan for the future shields the association and ensures that SolarPower Europe is relevant for today's European solar sector. This transition was underpinned by the re-branding of the association after 30 successful years of EPIA which was overwhelmingly supported by the Board and its members. SolarPower Europe is a name which is accessible and transparent, that everyone can understand and explains what the association represents.

SolarPower Europe's aim is to shape the regulatory environment and enhance business opportunities for solar power in Europe. It visions a future where solar energy is the leading contributor to the Europe's energy system and to ensure that, in 2015, the association pursued its objective of successfully positioning solar-based energy solutions with policymakers at the European and national level.

The association has been engaged in various debates during the last year, to achieve this objective. The SolarPower Europe 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 enhance its voice, SolarPower Europe has built coalitions with utilities, system operators, sectoral industry associations, NGOs and other relevant stakeholders. Some of the highlights of its participation in key discussions were:

- The 2030 framework for the development of Renewable Energy Sources in Europe;
- The debate on market design – which are the right questions to address and how solar can provide solutions and services;
- The European Commission guidance on self-consumption which will be further helpful for on-going debates at national level.

In addition to the above-mentioned highlights, SolarPower Europe worked intensively on sensitive and important topics such as the trade case and the investment protection, supporting the emergence of a new instrument to better protect investors in Europe.

SolarPower Europe's members have actively participated in the definition of its position on these key subjects mainly through involvement in our working groups and ad-hoc tasks forces. During 2015 there have been seven Task Forces (TF) active: the Operations and Maintenance (O&M) TF, the Eco-design TF, the Environmental Footprint TF, the Tendering TF, the BIPV TF, the Trade TF and the National Association TF.

SolarPower Europe has also been active outside of Brussels and has created opportunities for its members through supporting or representing them at the best business development platforms in Europe and beyond. In 2015, SolarPower Europe successfully contributed to:

- Intersolar Europe and Intersolar Worldwide, by presenting updated information about Global solar PV market developments and organizing an event on Solar Bankability.
- EU PVSEC 2015, by presenting results in the field of research and hosting an event on PV System Performance and Reliability.
- The Solar Energy UK, by hosting a tendering session and presenting the relevant impactful policies.
- The Solar Power Generation (SPG) Europe, by organising the O&M work stream and presenting first outcomes of the best practices guidelines that are being drafted by the respective O&M Task Force members of SolarPower Europe.

Fig. 2 - SolarPower Europe hosting an event at EU PVSEC 2015.

SolarPower Europe's policy and business objectives were again supported in 2015 by thought-leading research in fields such as solar PV market forecasts, industrial development, solar PV grid integration and electricity market design. Notably, the SolarPower Europe team published and/or contributed to:

- The Global Market Outlook 2015-2019, describing European and global solar PV market trends until 2019.
- The European PV Financing and Solar Bankability projects, which aim at analysing the risks associated with solar PV investments, establishing a common practice for professional risk assessment based on technical and commercial due diligence and identifying, in selected countries, the most promising business models and financing schemes for solar PV Systems.
- The European Market4RES projects, which investigate the potential evolution of the Target Model (TM) for the integration of EU electricity markets that will enable a sustainable, functioning and secure power system with large amounts of renewables.
- The European Cheetah project, 100 which aims at developing new concepts and technologies for wafer-based crystalline silicon solar PV (modules with ultrathin cells), thin-film solar PV (advanced light management) and organic solar PV (very low-cost barriers), resulting in (strongly) reduced cost of environmentally benign/abundant/non-toxic materials and increased module performance. In addition an enhanced network of experts has been created for proper knowledge exchange and transfer.

As a member of the IEA PVPS, SolarPower Europe also supported the work of the PVPS Tasks 1, 13 and 14. SolarPower Europe will continue to support, contribute and also learn from the IEA PVPS activities in 2016.

SPAIN

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

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

GENERAL FRAMEWORK

During the year 2015 there was not any new net PV power added to the Spanish electrical grid. Some self-consumption installations have been made, but without grid connection, so it is quite difficult to give a reasonable number of new additions of power.

With the actual price of PV components and the irradiation conditions in Spain, grid parity is easily achieved in all Spanish geography, however, self-consumption grid connected out of PV is not a good business in Spain, as taxes applied to the producer of electricity by PV means and not feed-in-tariff at all make the final price of electricity much less attractive than standard supply. Under these circumstances, the tax regulation about self-consumption is now in court and further development of the PV business will be heavily influenced by results of trials or political decision.

Nevertheless, in this turbulent situation concerning PV and self-consumption, there have been positive announcements. Specifically, Iberdrola, the Spanish electricity company, offers to the customers the study, construction and financing of turnkey self-consumption installations as a standard product. There is no news about the success of such an initiative, but it might be the origin of future similar new proposals.

Concerning the general framework of renewable energies and photovoltaic solar energy in particular, 2015 has experienced a net decrease in demand coverage of electricity produced by RREE for the first time in the last 10 years. Electricity demand coverage has been 37,3 % for 2015 (42 % in 2014). Figure 1 shows the evolution of that parameter since 2008 and, apart from a "stabilization" in 2010-2011, 2015 is a real step back with respect to the previous tendency.

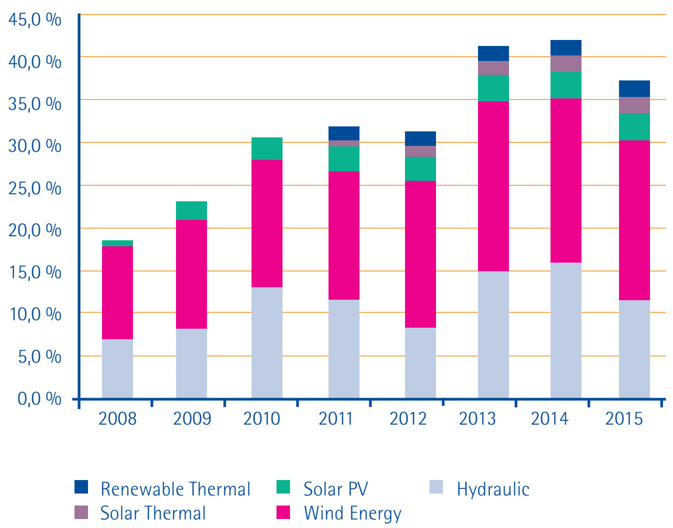


Fig. 1 – Spain's evolution of percentage of demand coverage from renewable energies (2008, 2009 data out of CNE, 2010 -2015 REE)

The analysis of contribution from different renewable technologies (Hydraulic, Wind, Solar Photovoltaic, Solar Thermoelectric, Renewable Thermal and other low carbon sources) shows a clear decline of Hydroelectric energy (from 16 % to 11,9 %) and a noticeable lower coverage from wind (from 19,3 % to 18,4 %). As no new capacity has been added on wind power in Spain, it seems that the lower contribution on those energies might have been due to the climatic causes. However, while wind electricity coverage had been increasing together with an increase in power installed, hydro, with a stable capacity seems to move historically in a cyclic way. Solar technologies have slightly increased demand coverage (solar thermal approaching 2,0 % from 1,9 % and PV close to 3,14 %); the same as other renewable thermal.

In summary, PV has contributed to electricity demand coverage with 8 264 GWh, a 3,14 %, slightly higher value than previous years allowing to position it third in the ranking of RREE producers, while wind energy still leads the contribution of RREE to the electricity generation with 48 380 GWh, a 18,4 % of total. Figure 2 shows the evolution of electricity generation for the various sources in Spain since 2007.

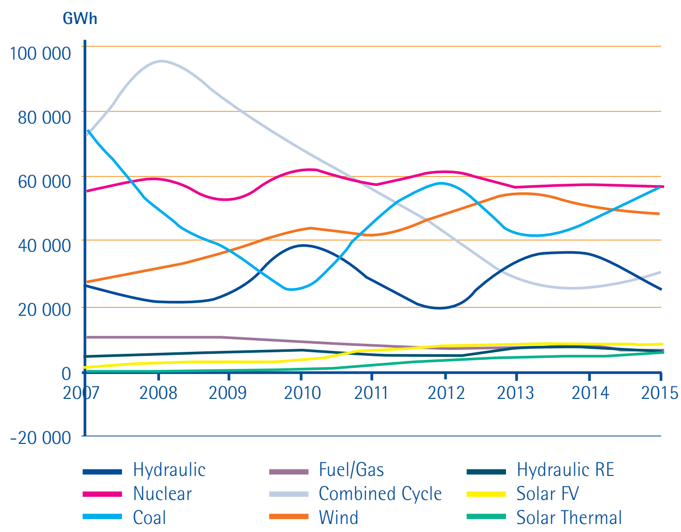


Fig. 2 - Evolution of electricity production in Spain (all energies).

In the case of the absolute values, the renewable side in 2015 has clearly gone down on the part of the majority technologies. Wind and hydro usually leading the contribution have been surpassed this year by Coal and Combined cycle. Contribution from PV (far away) remains almost constant as not having much new capacity added and, on the upper side, nuclear remains quite stable. Nevertheless, in this scenario, it should also be mentioned that, the total electricity demand during 2015 in Spain was reduced to 263 094 GWh; 1,41 % less with respect to the number in 2014.

Figure 3 shows the evolution of installed PV capacity, and corresponding absolute electricity generation due to PV. The plot shows the almost non evolution for the last 3 years due mostly to the non-new PV power added (at least to the grid connected activity). However, UNEF (photovoltaic association in Spain) has estimated capacity added, due to self-consumption close to 40 MW.

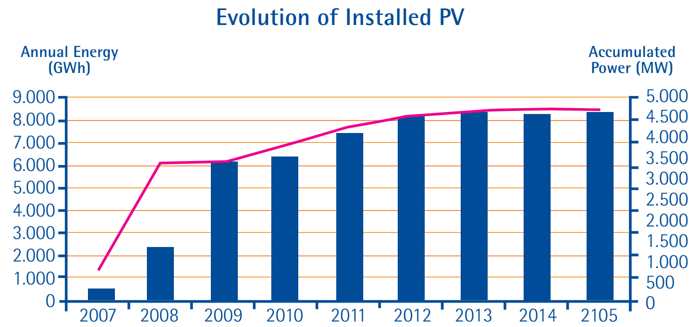


Fig. 3 - Evolution of yearly electricity generation and accumulated installed power for PV technology (Source: UNEF-CNMC; production 2012 - 2015 REE-preliminary data).

Another point of interest concerning electricity produced by PV means is the monthly demand coverage. In Figure 4, the parameter is presented since 2010. The usual maximum in demand coverage by PV during the summer timeframe and corresponding to the higher irradiation months is not the case for 2015. The very hot summer of 2015 had a premium demand and the contribution from PV to cover that demand for the months of July and August went down to values in the range of 3,7 % which usually, since 2011, were within the 4 - 4,5 % range.

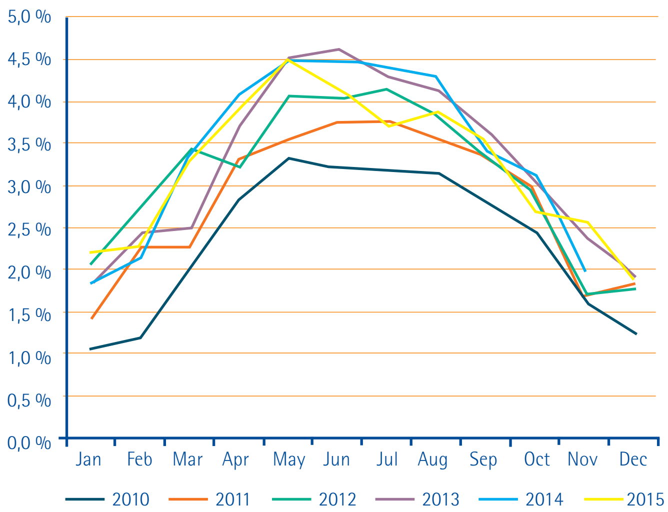


Fig. 4 - Monthly electricity demand coverage in Spain by PV.

Values for 2015 are obtained from preliminary data reported by grid operator REE (Red Eléctrica de España) as of December 2015 for both peninsular and extra-peninsular territories. Final information for the year will appear in the July 2016 timeframe.

NATIONAL PROGRAMME

The 37,3 % electricity demand coverage by Renewable Energies obtained in 2015 put Spain again in the trail for achieving the goal of 38,1 % established in the PER (Plan de Energías Renovables) for electricity demand coverage in 2020. In previous years that value was clearly surpassed, which was not the case in 2015. Specific climatic conditions and not any new incorporation of capacity in RREE have been the cause for this.

The study of the situation concerning PV is more complicated though, since 2011, when estimated accumulated power (values to achieve the 2020 goal at a reasonable ramp) was mostly coincident with the real accumulated power, the rate of installation has been much lower than what was required, so, to be in track with the plan again, the installed PV as of 2015 should be 5,41 GW while it is still at 4,67 GW. The gap is approaching 1 GW and will achieve an increase if actions are not taken concerning PV installation in Spain.

Figure 5 shows the evolution of real values of yearly PV installation and accumulated power installed until 2015, compared with the originally estimated ones based on PER in order to achieve the 2020 goals. Clear actions must be taken for PV to be again on track.

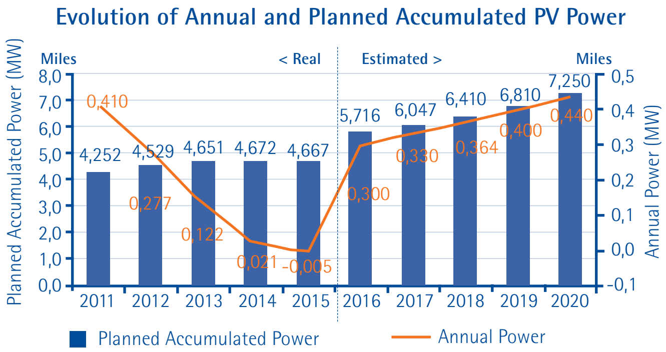


Fig. 5 – Planned Accumulated and Annual installed PV. Real values up 2015, PER 2011-2020 from 2016 on.

R&D, D

The R&D activity in Spain concerning PV technology has two main areas: on one side the very basic research devoted mostly to the last generation and novel materials (organic PV, perovskites, Graphene based materials) or III-V compounds for full spectrum absorption schemes, and on the other side more technological aspects concerning materials applicable on final products or the final products themselves (modules, inverters, trackers, etc.) and applications (BIPV, mega-plants, self-consumption, etc.).

The fact that research should be driven by industry makes it difficult for research institutions in Spain to have partners, as most of the PV specific industrial companies have closed activities, and the ones still alive share the PV world with other activities for subsistence. In this situation, companies do not have the capacity to invest themselves for the new products and R&D activity is mostly driven by institutional calls, National and European.

In Spain, there are different calls that could be used for R&D on PV. Some of them are with higher TRL (Technology Readiness Level) orientation and the need of industrial companies in the consortium (RETOS) and some others are with focus on the side of low TRL results and basic research, usually with Universities and Public research organizations leading the projects (Plan Nacional I+D).

Concerning European H2020 calls for the case of PV, the large amount of proposals and low rate of success are the situation as of today, as well as the subjects going from pure basic research to more technological concepts and components in order to support the development of big electricity generation plants. The real objective of the whole process remains to pave the way for lower cost of kWh produced by PV means. In that sense, a specific call has appeared, having as its goal the interest of recovering manufacturing capacity for Europe on PV products.

Among the recently awarded H2020 projects lead by Spanish institutions, the project MASLOWATEN (MArket uptake of an innovative irrigation Solution based on LOW WATer-ENergy consumption) under the coordination of IES-UPM (Solar Energy Institute of Politechnical University of Madrid) should be mentioned, which is dedicated to the development of PV pumping systems for productive agricultural irrigation and consuming zero conventional electricity and 30 % less water, and PVSITES coordinated by TECNALIA (Technological center in Basque country), for the development of BIPV products.

Spanish groups working on R&D on PV technology are also active on the European institutions such as EERA (European Energy Research Alliance) for PV or in the EUPVTP (European PV Technology Platform). Also having "mirror" organizations at local levels are assets, such as the FOTOPLAT (Spanish Technology Platform) that work to motivate activity in all aspects of PV and allow the interaction among companies, R&D institutions and the PV customer in the real world. Those groups are not isolated anymore and due to specificities of PV technology, a relationship with similar actors on the subject of smart grids or smart cities is a must when thinking on the final application of the PV products. Therefore, BIPV activity continues to be important in Spain and the contribution of those products to the energy efficiency in buildings' goals, are part of the challenge.

IMPLEMENTATION

The year 2015, does not appear to have a net added PV capacity. In fact, on the preliminary results out of grid operator REE (Red Eléctrica de España), the number seems to have decreased by 5 MW, so consider that the value is constant for 2015. No consideration of real isolated capacity added can be easily done. Figure 6 presents the evolution of PV power installed in Spain since 2000.

Evolution of Installed PV

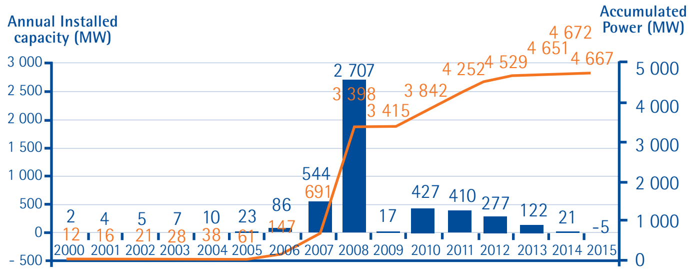


Fig. 6 – Evolution of PV power installed in Spain (Source: REE, preliminary data as of December 2015).

As it is happening in most of the countries that had a feed-in-tariff scheme for promoting PV originally, at the beginning, the installation was clearly driven for the economic reasons (2004 – 2008). Later Spain has been with reduction of feed-in-tariffs since 2008 and no feed-in-tariff at all since 2012. In this circumstance, and even when grid parity is clearly achieved in the country and big PV plants could be a clear business scheme, the long-time announced big installations of that type seem not to have materialized. Maybe, promoters wait for a clearer legal framework for it.

Figure 7 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 2015. There has been no "feed-in" tariff since 2012.

Evolution of PV Tariff

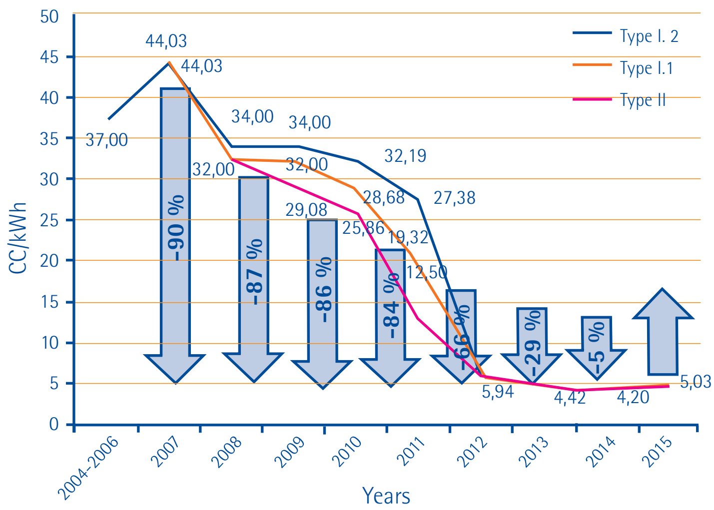


Fig. 7 – PV tariff evolution in Spain (Source: UNEF).

Values of electricity used to calculate the evolution in Figure 7's graph are yearly average. The monthly average spot price is not a constant and depends on many facts (mix of generation technologies, fuel price, renewable resource, demand, etc.). 2015 values are represented in Figure 8. Average value (5,03 EURcents) is bigger than 2014 (4,20 EURcents).

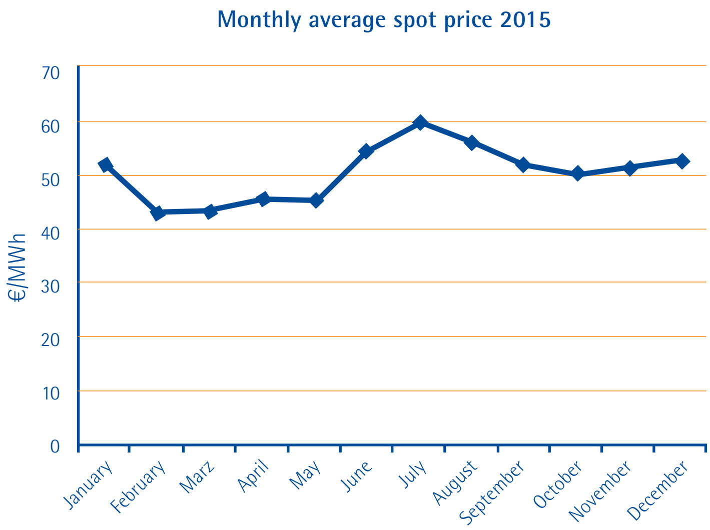


Fig. 8 – Monthly average spot price (Source: UNEF).

With these values of spot price (same all around Spain) and depending upon the irradiation conditions of different areas, it is clear that some regions are going to have advantages when applying for PV and that is the main reason for the non-uniform growth. Figure 9 shows the electricity generated by PV in the different autonomous regions in Spain (not segregated data for 2015 yet).

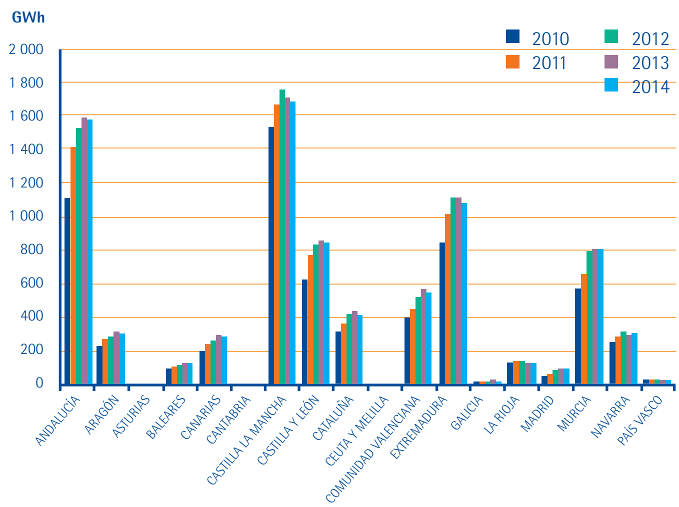


Fig. 9 - Evolution of electricity generated by PV per autonomous community.

Also depending on the activity in every region, the percentage of local demand coverage by PV has wide variation so it is interesting to see Figure 10 with percentage demand coverage. Good irradiation is not the only reason for PV installation in Spain as seen on capacity installed throughout the country.

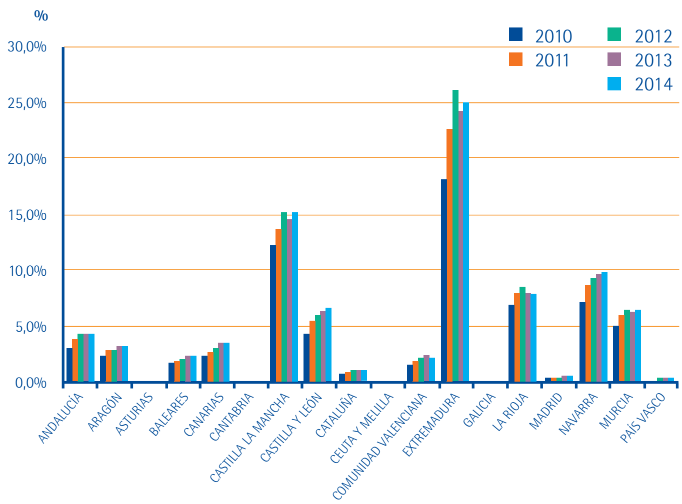


Fig. 10 - Evolution of percentage demand coverage by PV per autonomous community.

INDUSTRY STATUS

During 2015, the photovoltaic industry in Spain has been still on the slow side. The internal market is also in the same situation and the summary is that almost no PV power was added during the year. However, there are significant exceptions that continue with good activity. Examples of this on the components side are the BIPV company ONYX SOLAR (www.onyxsolar.com) that continues a wide activity on new BIPV designs fabrication and installation worldwide, the module manufacturer ATERSA (www.atersa.com) or the inverter manufacturer INGETEAM (www.ingeteam.com). For materials, it is worth mentioning the activity of Silicio Ferrosolar (www.ferroatlantica.es/index.php/en/ferrosolar-home) concerning UMG-Silicon or EVASA for encapsulant material manufacturing (www.evasa.net). Finally, and driven by the installations on heavily irradiated regions, a new generation and variety of products for solar tracking with flat modules (not necessarily CPV) are contributing to develop activity in Spain. However, the most successful activity of the Spanish companies on the PV market during 2015 seems to be on the side of the big PV plants construction. TSK, FRW (prior FOTOWATIO), ACCIONA, ISOLUX, GESTAMP (future part of X-HELIO) are among those that have been responsible for the most recent and biggest plant constructions worldwide.

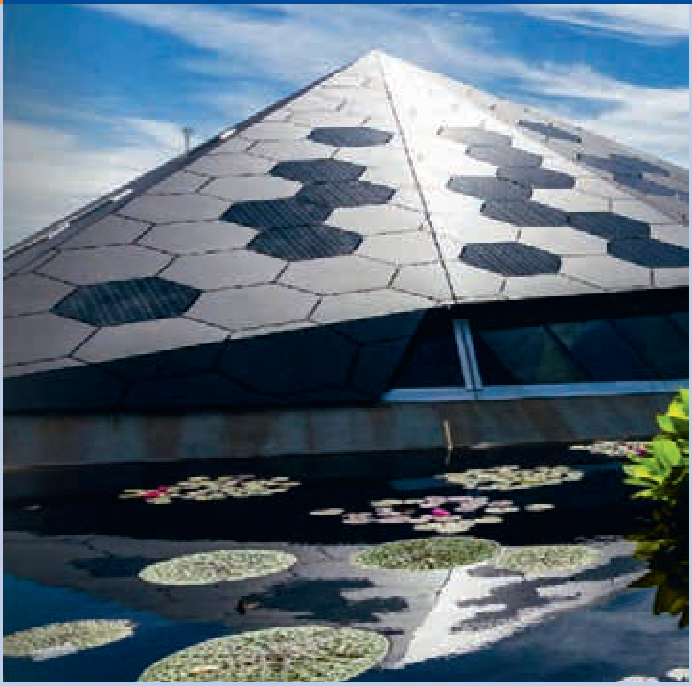


Fig. 11 - BIPV installations made from ONYX solar.

MARKET DEVELOPMENT

Market development in Spain has been very low in 2015. In fact power connected to the grid has decreased as far as grid operator Red Eléctrica de España (www.ree.es) preliminary report information. However, good irradiation conditions in the country and price of components make "grid parity" a reality in the country and all types of PV deployment a good option, therefore, sooner or later, big PV plants that are grid-connected with no feed-in-tariff or generation for self-consumption will start to be a reality in Spain again.

In that direction, all aspects related to BIPV or self-consumption PV-kits have a clear path in the market. As sign of this, during the last edition of Spanish fair for Renewable Energies, GENERA (February 2015), the biggest success among the side-conferences was on the self-consumption initiatives and products, and the interest has been continuing for the time being.

FUTURE OUTLOOK

The future outlook for PV in Spain must be clearly driven by the need to get on track again to the path for achieving the goal of installed PV power by 2020. As seen in Figure 5, the actual capacity installed and generation values are clearly lower than what should be installed as of 2015 by PER 2011-2020 (Plan de Energías Renovables).

In that sense, big PV plants that are grid-connected and with self-consumption are the clearest alternative. Not technical nor economic reasons can be an obstacle to this. On the political side, after the last elections in the country most of parties have among their goals to promote Renewable Energies and specifically, self-consumption. That might be the sense of change in the direction of PV deployment in the country.

After that, and keeping in mind that the knowledge and innovation capacity on the R&D+I groups and know-how to re-initiate industrial activities in the country do exist, the trend towards 2016 seems optimistic for PV deployment.

SWEDEN

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

TOBIAS WALLA, SWEDISH ENERGY AGENCY
PIERRE-JEAN RIGOLE, SWEDISH ENERGY AGENCY

Fig. 1 - 62 kW photovoltaics on barn roof in Bromma Gård, outside of Stockholm (Photo: Solkompaniet).

Fig. 2 - Sunflowers and part of the 1 MW PV installation outside of Västerås. A recently published monitoring project has compared the output from fixed, 1-axis and 2-axis tracking systems, with and without power optimizers (Photo: Bengt Stridh).

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. Three different calls have been performed. The first one focused on outstanding research, and the last two calls on more applied research and product development. In Autumn 2016, a new program is planned to be launched.

In 2015, a third call was opened in the SolEl-programmet; an applied research program in cooperation with the industry. Eight projects, all of them relevant to the current PV deployment in Sweden, have been 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 SolarERA NET, where a second call was held in 2013.

Fig. 3 - First stage on a planned 700 kW PV installation on roofs over a car parking, at Skaraborg Hospital (Photo: Johan Paradis).

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 (a company of Hanergy), 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.

Today, the last active module producer in Sweden, namely SweModule AB has gone into bankruptcy.

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

STEFAN NOWAK, NET NOWAK ENERGY & TECHNOLOGY LTD.
AND STEFAN OBERHOLZER, SWISS FEDERAL OFFICE OF ENERGY (SFOE)

Fig. 1 - Solar Impulse on a test flight over Abu Dhabi, a few days before take-off for the world tour (Photo: ©Solar Impulse).

GENERAL FRAMEWORK AND IMPLEMENTATION

Photovoltaic power systems continue to form a key pillar of the long term strategy for the future Swiss electricity supply. In all scenarios, the role of photovoltaics is acknowledged and expected to contribute in the order of at least 10 – 12 TWh to the national electricity supply by 2050 (60 TWh for 2015). The recent deployment trends (1,15 TWh end of 2015) are presently above the long term scenarios and underline that such contributions appear as feasible and possibly well before 2050.

In 2015, on the levels of Swiss policy and administration, work continued 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. 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.

Among these, an action plan for an increased energy research activity throughout all relevant energy technologies has been launched and implemented. Building on existing research activities, eight new national competence centres for energy research (SCCERs) have taken up their activities during 2014 and are now fully operational. The goal of these centres is to build up new permanent research and innovation capacities and institutional networks in the different technology areas. In addition to the SCCERs, CSEM (Centre Suisse d'électronique et microtechnique) recently established a PV Technology Centre in Neuchâtel with the mission to support technology transfer and industrial development in the area of photovoltaics. Two complementary national research programmes – NRP 70 "energy turnaround" (www.nfp70.ch) and NRP 71 "Managing Energy Consumption" (www.nfp71.ch) – started their projects in 2015. Alongside these structural measures, important additional financial means have been foreseen 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.

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

Fig. 2 - Self-consumption 658 kW PV system on a MIGROS supermarket with bifacial glass-glass modules, Schönbühl (Photo: Genossenschaft Migros Aare).

Fig. 3 - Inauguration of the Flisom 15 MW flexible CIGS module pilot line in Niederhasli (Photo: Flisom AG).

(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).

On the implementation level, three elements characterize the national regulatory framework for photovoltaic power systems: a onetime investment subsidy for systems up to 30 kW, a feed-in-tariff scheme for systems above 10 kW and, since 2014, measures for self-consumption. As the financial means for the different support schemes have their origin in a fixed levy on the electricity bill, there continues to be a cap on the total amounts available, resulting in a particularly long waiting list for the feed-in-tariff for photovoltaic power systems. Therefore, self-consumption and new business models implemented by utilities and other commercial operators contribute increasingly to the market deployment (Figure 2).

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 (www.photovoltaic.ch). The SFOE research programme Photovoltaics 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. 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 standards and design tools.

The strategy to promote international co-operation on all levels continued, related to activities in the Horizon 2020 Programme of the European Union, the European PV Technology and Innovation Platform, the European SOLAR-ERA.NET Network, the IEA PVPS programme and in technology co-operation projects. SOLAR-ERA.NET (www.solar-era.net) is coordinated by Switzerland and continued in 2015 with a third joint call covering both PV and concentrated solar power (CSP) which again had a high resonance in the research community.

RESEARCH, DEVELOPMENT AND DEMONSTRATION

In 2015, 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 research efforts. On the technical level, the topics of priority are silicon heterojunction cells, passivating contacts for high-efficiency crystalline silicon solar cells as well as different thin-film solar cell technologies for building integration. New concepts such as perovskite solar cells and tandem cells with these are increasingly being investigated. Further downstream, new approaches for building and grid integration are being developed and tested in pilot and demonstration projects.

Work at the Swiss Federal Institute of Technology (EPFL) and the CSEM PV Technology Centre in Neuchâtel have focussed on heterojunction and passivating contacts for high-efficiency crystalline silicon solar cells. On the more fundamental R&D side, in a recent project on perovskite tandem structures, a perovskite silicon tandem solar cell of 21 % efficiency was presented. Another highlight of the photovoltaic research at CSEM in Neuchâtel was achieved in collaboration with NREL in the United States: A dual junction gallium indium phosphide / crystalline silicon solar cell achieved a record efficiency of 29,8 %. The Neuchâtel PV group extended its cooperation with PV and other industries.

With regard to CIGS solar cells, the Swiss Federal Laboratories for Materials Testing and Research EMPA have continued their work focussed on high efficiency flexible CIGS cells on plastic and metal foils. As for silicon solar cell research, the efforts are directed both to increased efficiency as well as industrial implementation. A new, more fundamental project explores the route towards 25 % efficiency CIGS solar cells. On the way towards industrial implementation, cooperation continued with the Flisom company which has inaugurated a new 15 MW pilot production plant in 2015 (Figure 3).

Fig. 4 - New 70 kW PV façade at the CSEM building in Neuchâtel (Photo: CSEM SA).

Fig. 5 - PV rooftop and façade systems on an office building in Flums (Photo: © NET Ltd. / DanielForster.com).

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 21 % (world record).

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 2015, the EU project TREASORES led by EMPA was concluded. The project concerned the cheaper production of large area organic electronics and focussed on developing materials and processes compatible with roll-to-roll processing technology – in particular transparent electrodes, barrier foils and encapsulation layers.

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. Using new approaches and designs for surface appearance and coloured PV modules, a number of new pilot projects have started to test these new technologies.

As a recent topic rapidly gaining relevance in some countries and regions, grid integration has continued to generate interest and innovative 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 Southern Switzerland (SUPSI) and Bern (www.pvtest.ch) carefully evaluate products such as PV modules, inverters and new systems. A number of further Universities of Applied Sciences (e.g. ZHAW Winterthur, Rapperswil, Wädenswil) have strengthened their PV system infrastructure and analysis. Long term experience with the operation of photovoltaic power systems is carefully tracked for a number of grid-connected systems, ranging between 10 and more than 30 years of operation.

The solar powered airplane SolarImpulse (www.solarimpulse.com) by Bertrand Piccard, André Borschberg and their team has undertaken the attempt for their first round the world flight between March and June 2015. Taking off from Abu Dhabi (Figure 1), the plane has successfully flown to India, China, Japan and Hawaii. The record flight from Japan to Hawaii was the longest and most challenging one, bringing the technologies to their ultimate limits and covering a distance of more than 7 000 km in 118 hours of uninterrupted flight.

INDUSTRY AND MARKET DEVELOPMENT

Swiss industrial PV products cover the full PV value chain starting from materials, production equipment and small scale manufacturing of solar cells and modules, over diverse components and products all the way to system planning and implementation. After the consolidation period related to the global PV industry development of the past years, the signs increase that the Swiss PV industry is overcoming this difficult period, based on new competitive technologies and products which very much relate to recent technology innovations.

The largest equipment supplier for complete PV module manufacturing lines and advanced PV module technologies continues to be Meyer Burger. The company increased its efforts in advanced solar cell technology (silicon heterojunction, smart wire, glass-glass modules) and further developed a silicon heterojunction solar cell pilot production line together with CSEM. 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 (Figure 4). The target upon further process optimisation is to reach a PV module efficiency of 21 % with a production cost below 0,6 CHF/Wp. After commissioning of the pilot line, first promising results have been achieved. Measuring equipment for PV module manufacturers is produced by Pasan (a part of Meyer Burger Group).

Another company in the PV industry supply area is Evatec which is active in thin film technology, namely PVD systems for antireflection coatings and back side metallization of crystalline silicon solar cells. Moreover, solar plugging systems are offered by Multicontact as well as Huber & Suhner.

Flisom, a young company active in CIGS thin film technology, has inaugurated its facilities for a 15 MW pilot production of flexible CIGS modules in Switzerland. The targets of the pilot line are certified 1 m wide flexible CIGS modules with 12 % efficiency. 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 2 energy, Solaronix).

Based on the US company Power One, ABB has strengthened its business in the inverter market and is a leading worldwide inverter supplier. ABB is further active in the technologies for PV grid integration. 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 (Figure 5). System sizes have increased over the past years with up to 5 MW systems being installed on building complexes.

There has been a strong development in the framework of the different support schemes in recent years which were formerly mostly driven by utilities own green power marketing schemes. Depending on size and type of the PV system, different support conditions apply. Moreover, in order to compensate for the long waiting list for the feed-in-tariff, intermediate support schemes by regional governments and utilities have diversified 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 2014. The total installed capacity by the end of 2015 has risen to above 1,3 GW (Figure 6) corresponding to about 160 W/capita. With this installed capacity, more than 2 % of the annual national electricity consumption can now be covered by photovoltaics in Switzerland which ranks PV number two in renewable electricity sources in Switzerland after hydro power.

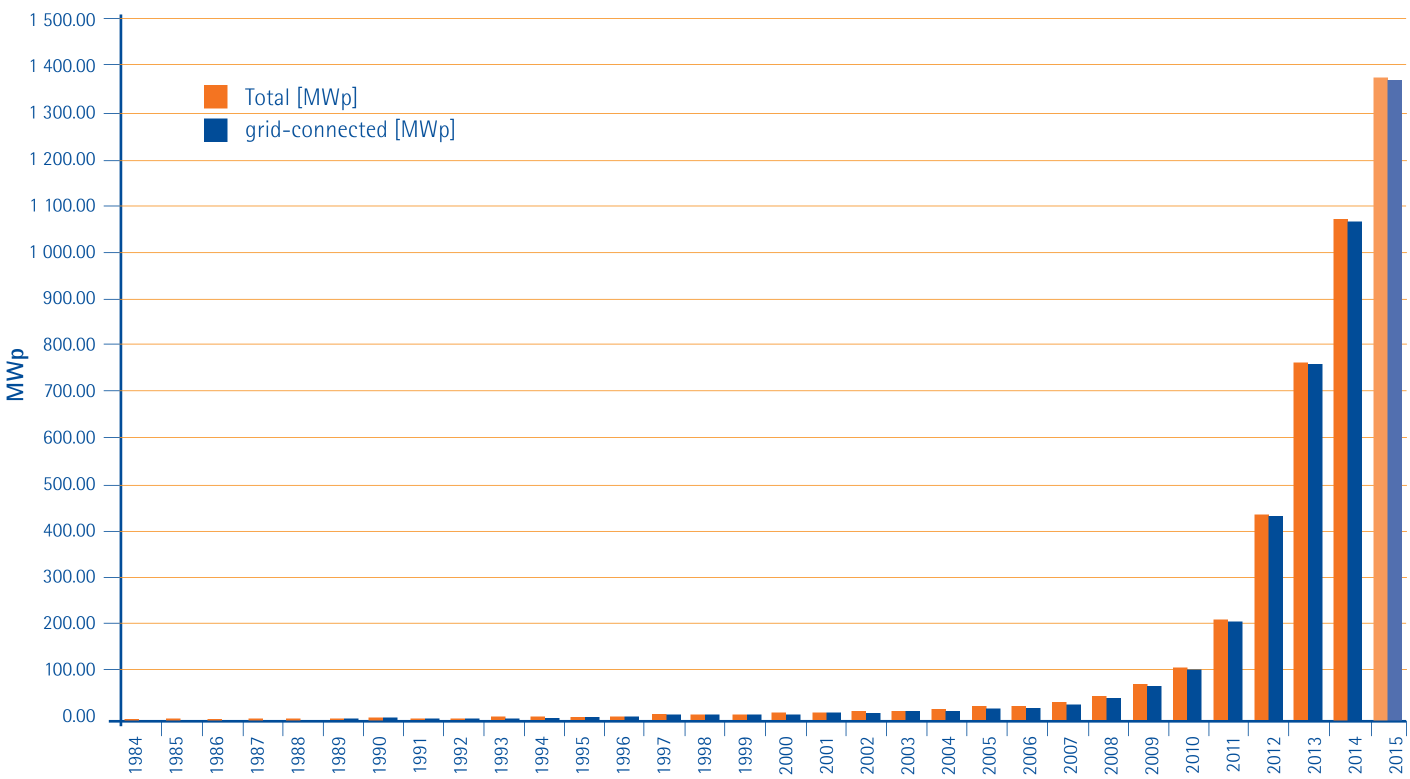


Fig. 6 – 30 years of PV in Switzerland: Evolution of the installed photovoltaic capacity in Switzerland between 1984 and 2015 (total and grid-connected, estimated values for 2015).

THAILAND

PV TECHNOLOGY STATUS AND PROSPECTS

MR. THAMMAYOT SRICHUAI, DIRECTOR GENERAL, DEPARTMENT OF ALTERNATIVE ENERGY DEVELOPMENT AND EFFICIENCY
MR. KUSON CHIVAGON,DEPUTY DIRECTOR GENERAL, DEPARTMENT OF ALTERNATIVE ENERGY DEVELOPMENT AND EFFICIENCY
MS. KULWAREE BURANASAJJAWARAPORN, DIRECTOR OF SOLAR ENERGY DEVELOPMENT BUREAU, BUREAU OF SOLAR ENERGY DEVELOPMENT, DEPARTMENT OF ALTERNATIVE ENERGY DEVELOPMENT AND EFFICIENCY

GENERAL FRAMEWORK AND IMPLEMENTATION

In 2015, Thailand approved the new long-term Energy Master Plan of the country which integrated all energy plans: the Alternative Energy Development Plan (AEDP), Energy Efficiency Development Plan (EEDP), Power Development Plan (PDP) and Oil and Gas Development Plan. The Master Plan is planned for 20 years (2015-2036), which will raise the share of renewable energy in the form of electricity, heat and biofuels to 30 % in 2036 to reduce gas consumption. These integrated plans will enable Thailand to have a good management to secure the country's energy supply, fair energy pricing and energy conservation in long run.

In this AEDP, the country is escalating the target of solar power to 6,000 MWp by the end of 2036.

NATIONAL PROGRAM

The country has continued the fixed 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 systems installations.

In 2015, the solar power projects have been advanced into operation by the National Energy Policy Committee (NEPC).

- 1) Ground-mounted PV power plants with installed capacity up to 90 MWp which have been submitted the application of selling electricity before the June 2010, and have not received acceptance from utilities, will be back in process of acceptance. The project should accept the new FiT rate of 5,66 THB/kWh for supporting a period of 25 years. The status of this program has already approved PPA 170 projects with 983,05 MWp. and planned to COD by December 2015.
- 2) The Solar Rooftop for residential scale with installed capacity up to 10 kWp for phase 2 will get the new rate which has been adjusted to 6,85 THB/kWh. The target is set to complete 100 MWp and COD by December 2015.
- 3) The Solar Program for governmental agencies and agricultural cooperatives for ground-mounted systems with the target of 800 MWp and the FiT rate have been set at 5,66 THB/kWh for a supporting period of 25 years and have been postponed COD for phase 1 with the target of 600 MWp by September 2016; and phase 2 with the target of 200 MWp COD by June 2018. In addition, phase 1 has already openly applied the application since November 2015.

Table 1 summarizes the fixed FiT for the three solar PV supporting programs.

TABLE 1 – THE FEED-IN TARIFF FOR SOLAR POWER FOR 2014 -2015

INSTALLED CAPACITY (MWp)	FIT RATE FOR 2014-2015		
	FIT RATE (THB/kWh)	FIT RATE (USD/kWh)	SUPPORT PERIOD
PV Ground Mount			
≤ 90 MWp	5,66	0,16	25 Years
PV Rooftop (Household)			
≤ 10 kWp	6,85	0,21	25 Years
PV Rooftop (Commercial/Factory)			
> 10 – 250 kWp	6,40	0,19	25 Years
> 250 – 1,000 kWp	6,01	0,17	25 Years
PV Ground Mount (Government Site and Agriculture Cooperative)			
≤ 5 MW	5,66	0,16	25 Years

**Exchange Rate 1 USD=36,28 THB*

Thailand's new solar power installed capacity at the end of October 2015 was 31,15 MWp with the cumulative capacity for both PV on grid and off grid of 1 329,65 MWp. Cumulative and annual Installation PV capacities from 2005-2015 are show in Table 2 and Fig. 1.

TABLE 2 – DEVELOPMENT OF PV APPLICATIONS BETWEEN 2005 AND 2015 (MWP/YEAR)

YEAR	CUMULATIVE INSTALLATION			ANNUAL INSTALLATION		
	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	793,73	29,73	823,46	435,89	-0,45*	435,44
2014	1 268,77	29,73	1 298,51	474,71	0	474,71
2015**	1 299,622	30,028	1 329,65	30,852	0,298	31,15

**Some of the off-grid systems were dismantled.*
***Preliminary data at the end of October 2015*

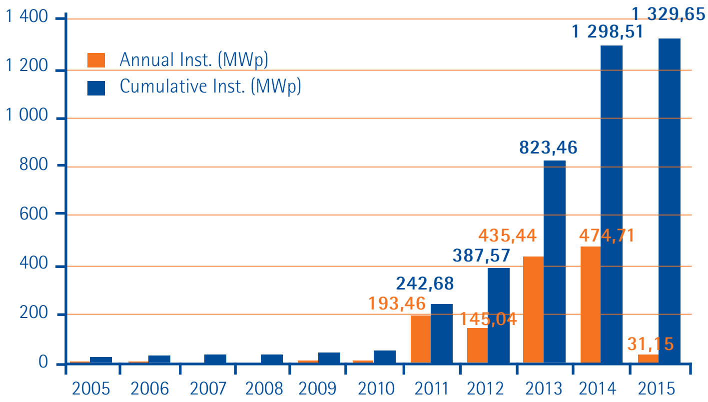


Fig. 1 - Cumulative Installation of PV Power Generation in Thailand as of October 2015.

Fig. 2 – 500 kWp PV Rooftop of the Smart Grid System at the University of Phayao (Photos: University of Phayao).

Additionally, in the near future after the cessation of the feed-in tariff program for rooftop solar, a possible support scheme for rooftop solar power in Thailand is the "Quick Win" program, which is a net-metering program designed to support residential and commercial-scale rooftop solar systems.

RESEARCH DEVELOPMENT AND DEMONSTRATION ACTIVITIES

Presently, the priority research topics are still the long term monitoring and system evaluation. Several collaborations from universities, research institutes and the private sector in Thailand are working towards long-term monitoring of PV power plant systems such as KMUTT, SERT, NASTDA. In 2015, DEDE also has established a study of monitoring and system evaluation for PV rooftop systems specifically and the result of this study will be completed soon.

After the PV roadmap research by DEDE and ERI of CU last year, ERI has been continuing to conduct the policy research "Business Model and Financing Structures for a Rapid Scale-up of Rooftop Solar Power Systems in Thailand" in 2015. This study captures the dynamics of the rooftop solar market through its in-depth review of the emerging models and financial analysis of business models. The result of this study will be an advantage for the "Quick Win" Program in the future.

Furthermore, many research development and demonstration activities of solar power have been undertaken by the universities, research institutes and utilities. For example, EGAT joined with MUT have been initiating a project to study the safety standard and best practice for the installation of floating PV power plants. DEDE with PTECH have started a project on the solar PV rooftop standard for quality and safety for installations and systems. SERT of NU conducted the solar PV water pumping for agriculture application, which is supported by DEDE. NSTDA is focusing on the development of solar cells with low temperature coefficient which are suitable for using in high temperature regions. NSTDA is also trying to develop wide band gap thin film silicon solar cells, high efficiency silicon hetero-junction solar cells, perovskite solar cells, etc.

Finally, at the end of 2015, DEDE approved and started to study the management of PV modules' waste from Solar Power projects in order to manage and treat PV modules waste properly, with no environmental impact in the future. This study aims to support sustainability of Solar Power Generation in Thailand. The project has obtained cooperation from many organizations through the efforts of a working group.

INDUSTRY AND MARKET DEVELOPMENT

In 2015, Thailand has still been attractive for investment in solar power thanks to direct policy support with the feed-in tariff scheme, indirect policy support, especially the support from BOI where renewable energy is still almost the top priority to support. The supports from BOI are available in different categories: Solar power plant, Solar PV cell manufacturing and raw material for solar PV cell manufacturing, solar module and BOS manufacturing and support for the use of solar PV as tool to improve production efficiency.

In addition, 6 projects of solar PV cell manufacturing and raw material for solar PV cell manufacturing, solar module and BOS manufacturing have been approved by BOI with the total amount of investment of 45 913 MTHB and 161 solar power plant projects for both solar power plants and solar rooftops have been approved with the total amount of investment of 66 617 MTHB.

Fig. 3 - The Biggest SPP Project in 2015. This project has achieved COD since February 2015 in Lampang province. Total installed capacity 126,396 MWp with Poly Crystalline Solar Cell, Solar Tracking System (Photos: Energy Absolute Public Company Limited).

The average prices of PV systems in Thailand were approximately 60-100 THB/Wp (1,65-2,75 USD/Wp*) for residential scale (<10 kWp), 50-55 THB/Wp (1,38-1,52 USD/Wp) for commercial and industrial scale (>10-1 MWp) and 30-50 THB/Wp (0,83-1,38 USD/Wp) for power plant scale (>1 MWp). The variable of price depends on system warranties and maintenance services.

ABBREVIATIONS

AEDP	*Alternative Energy Development Plan*
COD	*Commercial Operation Date*
FiT	*Feed-in Tariff*
PDP	*Thailand Power Development Plan*
PPA	*Power Purchasing Agreement*
RE	*Renewable Energy*
SPP	*Small Power Producer (>10 - ≤ 90 MWp)*
VSPP	*Very Small Power Producer (≤ 10 MWp)*

ACRONYMS

BOI	*Board of Investment*
CU	*Chulalongkorn University*
DEDE	*Department of Alternative Energy Development and Efficiency*
EGAT	*Electricity Generating Authority of Thailand*
ERI	*Energy Research Institute*
KMUTT	*King Mongkut's University of Technology Thonburi*
MUT	*Mahanakorn University of Technology*
NED	*Natural Energy Development Co., Ltd*
NEPC	*National Energy Policy Committee*
NSTDA	*National Science and Technology Development Agency*
NU	*Naresuan University*
PTEC	*Electrical and Electronic Product Testing Center*
SERT	*School of Renewable Energy Technology*

REFERENCES

http://www.dede.go.th/download/state_58/sit_57_58/re-2oct_calendar.pdf
http://www3.egat.co.th/research/
http://www.nstda.or.th/index.php
http://www.ces.kmutt.ac.th/
http://www.eri.chula.ac.th/eri-main/?page_id=9&lang=TH
http://www.sert.nu.ac.th/research_eng.htm
http://www.boi.go.th/upload/Stat_20160121_83597.pdf

TURKEY

PV TECHNOLOGY STATUS AND PROSPECTS

AHMET YILANCI, EGE UNIVERSITY SOLAR ENERGY INSTITUTE, IZMIR, TURKEY

GENERAL FRAMEWORK AND IMPLEMENTATION

Turkey, with a population of around 79 million [1], is one of the fastest growing energy markets in the world. Additionally, one of the big advantages of Turkey is her operating as an energy hub between Europe and the Middle East. Economic expansion, rising per capita income, positive demographic trends and the rapid pace of urbanization have been the main drivers of energy demand, which is estimated to increase by around 6 percent per annum until 2023. 73,15 GW installed capacity of electricity by the end of 2015 is expected to reach 125 GW by 2023 to satisfy the increasing demand in the country. Now, the total installed capacity of electricity broken down by resources is 57,3 % thermic (natural gas, coals, liquid fuels etc.), 35,4 % hydro, 6,1 % wind and other renewables. The total electricity consumption of Turkey resulted in 264,137 GWh where the total electricity production resulted as 259,691 GWh by 2015 [2].

Turkey's power distribution network is completely in private sector hands, while the privatization of power generation assets is set to be completed within the next few years – has given the country's energy sector a highly competitive structure and new horizons for growth. The privatization of energy generation assets, coupled with a strategy to clear the way for more private investments, has resulted in an increased share of private entities in the electricity generation sector, from 32 % in 2002 to 75 % in 2015 [3].

Turkey pays millions of dollars to its energy imports every year. The solar energy has the potential to reduce this cost in outstanding size in medium and long term. Opportunities for renewable forms of energy production – hydro, wind, solar, geothermal and others – are abundant in Turkey, and encouraging policies backed by favourable feed-in tariffs are expected to increase their share in the national grid in the coming years. Turkey is now aiming to get at least 30 % of its electricity requirements via renewable energy sources by the year 2023. The specific goals for the country are: 34 GW of hydroelectric, 20 GW of wind energy, 1 GW of geothermal, 1 GW of biomass (this is not yet included in the official documents), and 5 GW of solar electricity (photovoltaic and concentrated solar power) [4]. Energy and Natural Resources Ministry (ETKB) has updated its Strategy Plan (2015-2019) and 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 [5].

The total amount of investments to be made to meet the energy demand in Turkey until 2023 is estimated around 110 BUSD [3]. In the face of increase in energy consumption and the need for national energy security and reducing carbon emissions, it is widely recognized that it is imperative for Turkey to increase the contribution of renewable energy resources rapidly.

NATIONAL PROGRAMME

Solar Energy is the most important alternative clean energy resource which is still untapped in Turkey with a potential of min. 500 GW. Cumulative installed PV power in Turkey has reached about 248,8 MW and increased rapidly compared to the previous year's data, 55 MW [6]. The yearly average solar radiation is 1 527 kWh/m^2 per year and 4,2 kWh/m^2 per day. The total yearly solar radiation period is approximately 2 738 hours per year and 7,5 hours per day. The energy yield potential for a PV plant is 1 300-1 600 kWh/kWp [7].

Turkey's current national energy regulation is articulated in the following laws with secondary regulations for renewable energy [4]:

- New Electricity Market Law (Law No. 6446)
- The Law on the Utilization of Renewable Energy Resources for the Purpose of Generating Electrical Energy (Law No: 5346)
- Law Amending the Law on the Utilization of Renewable Energy Resources in Electricity Generation (Law No: 6094)
- Energy Efficiency Law (Law No: 5627)
- Environmental Law (Law No: 2872)

The Laws 6446 and 6094 are the two main laws directly related to utilization of solar energy. The Law 6446 introduces some important changes in the current electricity market system, including amendments to license types, framing its provisions around each type of market activity, specific provisions for certain license types (generation, transmission, distribution, wholesale, retail, auto-producer and auto-producer group), the introduction of a preliminary licensing mechanism and investment incentives, such as extended deadlines and grace periods for environmental compliance. In reference to the renewable energy sector, it establishes:

- The maximum installed capacity for a renewable energy plant to operate without a license has been raised from 500 kW to 1 MW, with the ease of increasing up to 5 times (5 MW) by a decree of the Council of Ministers without a change in the Law. Furthermore, with the new Law, there is no limit for renewable energy facilities that serve for self-consumption without feeding into the grid.
- Renewable generation facilities that extend over more than one premise can be considered one single generation entity provided that they are connected to the system from the same point.
- The Law reasserts the exemptions and discounts in land use rights as described in the Renewable Energy Law.
- The pre-licensing step is defined in the licensing process and all M&A activities at this stage are restricted.
- For wind and solar power plants that would compete for the grid access rights, the tendering process has been modified to reduce the 20 year payment period of contribution fees to the Transmission System Operator to 3 years. The contribution fee that was paid according to generated kWh was modified to be paid for unit installed capacity (per MW).

The Law 6094 law introduces significant amendments to improve the incentive mechanism under the Renewable Energy Law and encourage renewable energy investment opportunities. According to the Law 6094,

- Each supplier who sells electrical energy to consumers has an obligation to pay a renewable energy fee proportional to the amount of electricity that the supplier has sold to its consumers divided by the total electric energy that all suppliers have sold to all consumers in the country. In other words, they are indirectly obliged to purchase electricity that is generated from renewable resources.

- A new feed-in tariff plan, categorizing the different levels of feed-in tariff for different technologies is introduced. In addition, the local equipment bonus is to be added to the feed-in tariff plan.
- The scope of time for the support mechanism of 5-years is extended for facilities that are commissioned before December 31, 2020, by a Board Decision in 2013.
- Feed-in tariffs are based on the USD (United States Dollar) and not subject to any escalation.
- Land Usage Fee Incentives: Until 2020, a discount of 85 % for permission, lease, easement rights and servitude right fees for generation facilities based on renewable energy resources will be applicable for the first 10 years, including the period of investment and operation.

According to the Law 6094, a purchase guarantee of 13,3 USDcents/kWh is given for solar electric energy production for ten years. The incentives are available for the PV power plants for 5-years which are or will be in operation before December 31, 2020. Some supplementary subsidies for local equipment products for the first five years of operation are as follows:

- PV module installation and mechanical construction (+0,8 USDcents/kWh)
- PV modules (+1,3 USDcents/kWh)
- PV cells (+3,5 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 declared to the public on December 3rd, 2014 [5]. According to this plan, it is aimed to reach 5000 MW by the end of 2023 (Table 1).

TABLE 1 – THE PROJECTED SOLAR ENERGY CAPACITY BY ETKB [5].

	2015	2017	2019	2023
PV Power Plant (MW)	300	1 800	3 000	5 000

INDUSTRY AND MARKET DEVELOPMENT

The legislation defines the unlicensed electricity power limit as max. 1 MW. Up to now, only the unlicensed PV power plants were installed in Turkey. Some investors preferred to setup MW scaled PV power plants in total by covering a few unlicensed plants. 362 of 2 750 small-scale PV power projects (up to 1 MW) are already installed with 248,8 MW in total in 2015 while the rest of projects with a capacity of 2 096,2 MW applied to the Turkish Electricity Distribution Company (TEDAŞ) are already received the approval. By the end of 2015, there are 362 PV power plants in operation, which are all in the unlicensed segment. Although the installed capacity is only 248,8 MW up to now, it proves an acceleration since the cumulative grid-connected installed PV power was about 2,5 MW, 6 MW and 55 MW at the end of 2012, 2013 and 2014, respectively.

Additionally, in 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 and 587 MW received their preliminary licenses in 2014 and 2015 respectively, following the competition process driven by Turkish Electricity Transmission Company (TEİAŞ) which was given by Energy Market Regulatory Authority (EPDK). It is expected that the new capacity for licensed projects will be declared by 2017.

Another important circumstance in Turkish PV sector is that the new notification, which is valid by December 19, 2015, was published by Turkey's Ministry of Economics. By this notification, PV module imports will be charged an import tax, based on weight – specifically, $35/kg – as of December 19. Manufacturers will also need to apply for a supervisory document for each module type from thĕir production sites [8]. An exemption from the tax exists by presenting "Investment Incentive Certificate".

In 2015, the largest PV system in Turkey with the installed capacity of 18,5 MW was mounted on Kızören, Konya (expected 30,7 GWh annual electricity generation, but still pending approval for grid connection; see Figure 1). Also, Turkey's largest single axis tracking PV power plant is installed in Korkuteli, Antalya. The plant, which is a combination of 5 unlicensed projects, is located on an area of 66,000 m² with the capacity of 4,6 MW. In comparison to fixed-angle mounting systems, an additional power increase - from 22 % to 28 %- is targeted in the plant. According to data from December, it is mentioned that the current tracking system is 22 % more efficient than fixed-angle systems. In addition, Antalya Arena Stadium will be the first stadium in Turkey powered by PV panels with the capacity of 1,4 MW [9].

Fig.1 - The largest PV system in Turkey with the installed capacity of 18,5 MW (expected 30,7 GWh annual electricity generation) in Konya (still pending approval for grid connection) [10].

Regarding PV manufacturing activities, currently there is not any manufacturer on feedstock, ingots and wafers in Turkey. Currently, there are 20 PV module manufacturers in Turkey with a production capacity of more than 1 500 MW annually. There are also a few PV module constituents (glass, frame etc.) manufacturers in Turkey.

REFERENCES

[1] "The Results of Address Based Population Registration System, 2013", Turkish Statistical Institute, 2015.

[2] "Statistics on Turkey's Electricity", TEİAŞ (Turkish Electricity Transmission Company), http://www.teias.gov.tr/TurkiyeElektrikIstatistikleri.aspx.

[3] "Invest in Turkey", The Republic of Turkey Prime Ministry, Investment Support and Promotion Agency, http://www.invest.gov.tr/en-US/sectors/Pages/Energy.aspx.

[4] "National Renewable Energy Action Plan for Turkey", Republic of Turkey Energy and Natural Resources Ministry, December 2014.

[5] "Republic of Turkey Energy and Natural Resources Ministry – Strategic Plan (2015 – 2019)", www.enerji.gov.tr

[6] "Data on Unlicensed Electricity Production", TEDAS (Turkish Electricity Distribution Company), http://www.tedas.gov.tr/#!tedas_lisanssizelektrikuretimi

[7] "Solar Energy in Turkey", The Republic of Turkey Energy and Natural Resources Ministry - General Directorate of Renewable Energy, http://www.eie.gov.tr/eie-web/english/solar/solarTurkey_e.html

[8] "Notification on the implementation of surveillance in importing solar cells and modules", No: 2015/9, Official Gazette, November 2015.

[9] "World's largest solar PV stadium project", GUNDERGI, January-March 2015 www.gunder.org.tr

[10] "Konya'da Türkiye'nin en büyük GES'i kuruldu", http://www.dunya.com/sirketler/konyada-turkiyenin-en-buyuk-gesi-kuruldu-285351h.htm

[11] www.gunder.org.tr

For More Information:

Tel: +90 312 4181887
E-mail: info@gunder.org.tr

THE UNITED STATES OF AMERICA

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

DANIEL BOFF, ENERGY ANALYST, MANTECH CORPORATION, UNITED STATES DEPARTMENT OF ENERGY
DAVID FELDMAN, SENIOR FINANCIAL ANALYST, NATIONAL RENEWABLE ENERGY LABORATORY

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 2015, the U.S. Environmental Protection Agency (EPA), which regulates power plant carbon emissions, issued final rules for carbon emissions reductions of 30 % (from 2005 levels) by a state-by-state approach to be implemented between 2020 and 2030. Additionally, in 2015, EPA expanded their draft rules to include a Clean Energy Incentive Program (CEIP) to encourage states to meet carbon reduction goals through wind, solar and energy efficiency. Under this arrangement, states can utilize solar projects installed before the carbon rules take effect to meet Federal emissions requirements for 2020-2029. This program provides substantial incentive for states to accelerate the deployment of solar and wind technologies in the short term. 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 7,3 GW of PV capacity in 2015, bringing the cumulative installed capacity in the US up to 25,6 GW. [1].

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, as well, as time of use rate structures. Third-party ownership continues to be a popular option for financing the installation of PV systems, particularly in the residential sector. Loans have also emerged as an effective financial mechanism for residential systems, due to the declining cost of solar, and new loan products entering the market. Loans are even beginning to rival third-party ownership in some residential markets. Companies have also issued innovative financing mechanisms to raise cheaper sources of capital through public markets.

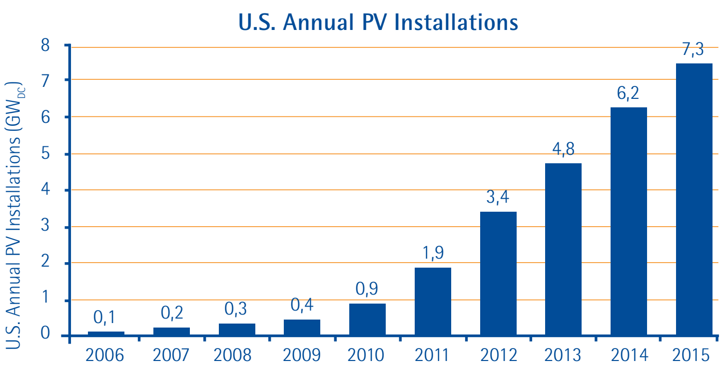


Fig. 1 - U.S. Annual PV Installations. Source: GTM/SEIA, U.S. Solar Market Insight Report Q4 2015. March 2016.

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). Though the ITC was set to expire in 2016, the 30 % credit was recently extended to 2020. Beginning in 2020, the credits will step down gradually until they reach 10 % in 2022 for commercial entities and expire for individuals.

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 October 2015, twenty-nine 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 electricity produced by a solar energy system fed back to the grid. In 2015, 42 states had laws crediting customers for exported electricity, typically through a net metering arrangement. Additionally, several states expanded their net metering caps or modified the process by which customers can sell energy back to the grid. Furthermore, analysts have estimated that in 2015, 4,1 GW of PV was procured outside of RPS obligations, based on solar's competitiveness with other sources of generation. [3]

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

1] *GTM Research/ SEIA, Q4 2015: U.S. Solar Market Insight. March 2016*

[2] *North Carolina Clean Energy Technology Center. Renewable Portfolio Standard Policies. Accessed January 20, 2016. http://www.dsireusa.org/resources/detailed-summary-maps/*

[3] *GTM Research/ SEIA, Q4 2015: U.S. Solar Market Insight. March 2016.*

Fig. 2 - A photovoltaic system in New York City.

America's electricity generation by 2030 (assuming other systemic issues are addressed as well). [4] 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 2015 include:

- Working with small businesses to eliminate market barriers, reduce non-hardware costs, and to encourage technology innovation to support SunShot goals.
- Working with industry, national laboratories, and university researchers to enable the development and demonstration of integrated, scalable, and cost-effective technologies for solar that incorporates energy storage and works seamlessly to meet both consumer needs and the needs of the electricity grid, enable widespread sustainable deployment of low-cost, flexible, and reliable PV generation, and provide for successful integration of PV power plants with the electric grid.
- Working with researchers in physics, chemistry, and advanced data analysis to gain a better understanding of how and why solar PV modules degrade to enable evaluation of module reliability and improved prediction of performance over time.

TABLE 1- BREAKDOWN OF SOLAR ENERGY TECHNOLOGIES OFFICE FY 15 R&D ACTIVITIES

RESEARCH	MUSD	50
DEVELOPMENT	MUSD	63
DEMONSTRATION	MUSD	42
DEPLOYMENT	MUSD	78
TOTAL	**MUSD**	**233**

[4] *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*

Fig. 3 - A ground mounted PV system in Southwestern Colorado, USA.

It has been estimated that the RD&D funding provided by SETO, as shown in Table 1, accounts for approximately 50 % of all public RD&D for PV technology development in the U.S. In addition, U.S. RD&D funding has also come 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 2015, the U.S market is expected to have increased its annual installations by approximately 1 GW, from roughly 6,2 GW in 2014 to 7,3 GW in 2015. [5] U.S. annual installations have been growing rapidly during the past five years, from 0,9 MW in 2010 to 7,3 MW in 2015. 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, Nevada, North Carolina, and New Jersey, which comprise roughly two-thirds of the market. However, this trend is changing slowly as 28 states currently have 50 MW or more of PV capacity and 17 states each installed more than 50 MW in 2015 alone. [6] With more than 18 GW of contracted utility scale PV projects in the pipeline as of October, total installations in 2016 are expected to increase yet again. [7] 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 2016 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, continued to recover in 2015. Module production has increased 28 % from Q3 14 to Q3 15, and growth is expected to continue in 2016. [8]

Additionally, U.S. manufacturing has a significant presence in other parts of the PV value chain, including polysilicon, encapsulants, wiring, and fasteners. In 2015, the U.S. solar manufacturing sector employed 30 282 people, a 6,8 % decrease since 2014. However, the sector is expected to recoup those losses and expand in 2016, with an expected job growth of 12,7 %. [9] Additionally, manufactured hardware is only a portion of the total solar value chain. Industry-wide, approximately 115 000 jobs relating to solar were added from 2010 to 2015, growing to a total of nearly 209 000 employees (35 000 of which were added in 2015 alone). The growth rate from 2014 to 2015 of 20 % was twelve times faster than what the overall U. S. economy experienced during that same time period. [10]

[5] GTM Research/ SEIA, Q4 2015: U.S. Solar Market Insight. March 2016

[6] GTM Research/ SEIA, Q3 2015: U.S. Solar Market Insight. December 2015.

[7] Ibid.

[8] Ibid.

[9] Solar Foundation. (2016). National Solar Jobs Census 2015. Washington, DC: The Solar Foundation.

[10] Ibid.

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

For information, contact the former Task 2 Operating Agent or visit the PVPS website:

Ms Ulrike JAHN
Senior Scientist
Renewable Energies
TÜV Rheinland Energie und Umwelt GmbH
Test Centre for Energy Technologies
Am Grauen Stein, D-51105 Köln, Germany
Tel: +49 221 806 2232, fax: +49 221 806 1350
Email: ulrike.jahn@de.tuv.com

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.

CONTACT INFORMATION

For information, contact the former Task 3 Operating Agent or visit the IEA PVPS website.

Former Task 3 Operating Agent:
Mr. Philippe JACQUIN
PHK Consultants
17 bis, Rue Jean Marie Vianney
FR-69130 Ecully
Tel.: 33-(0) 4 78 33 3614
Fax: 33-(0) 4 78 33 3808
Email: philippe. jacquin@phkconsultants.com

COMPLETED TASKS
TASK 5 - GRID INTERCONNECTION OF BUILDING INTEGRATED AND OTHER DISPERSED PHOTOVOLTAIC SYSTEMS

OVERALL OBJECTIVE
The objective of Task 5 was to develop and verify technical requirements, which served as the technical guidelines for grid interconnection with building-integrated and other dispersed PV systems. The development of these technical requirements included safety and reliable linkage to the electric grid at the lowest possible cost. The systems to be considered were those connected with a low-voltage grid, which was typically of a size between one and fifty 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
For information, contact the former Task 5 Chairman or visit the PVPS website:
For the Task 5 Chairman:
Mr Tadao ISHIKAWA
CRIEPI
2-11-1 Iwato-kita Komea-shi
JPN - 2018511, Tokyo
Email: ishikawa@criepi.denken.or.jp

COMPLETED TASKS
TASK 6 - DESIGN AND OPERATION OF MODULAR PHOTOVOLTAIC PLANTS FOR LARGE SCALE POWER GENERATION

OVERALL OBJECTIVE

Task 6 officially completed its activities in May 1998. The main objective of this Task was to further develop large-scale modular photovoltaic plants for peaking and long-term baseload power generation in connection with the medium-voltage grid.

MEANS

The Task 6 work was performed by structural engineers and PV industry experts. The work was structured into four 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

CONTACT INFORMATION

For information contact the former Operating Agent of Task 6 of visit the IEA PVPS website:

Mr Alberto Iliceto
CESI S.p.A.- SFR/ERI
Via Rubattino, 54
20134 Milano
Italy
Fax: +39 (0)2 2125.5626
Email: iliceto@cesi.it
Web: http://www.cesi.it

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

OVERALL OBJECTIVES

The work on very large scale photovoltaic power generation (VLS-PV) systems first began under the umbrella of the IEA PVPS Task 6 in 1998. After that, the new Task 8 – Study on Very Large Scale Photovoltaic Power Generation (VLS-PV) Systems was established in 1999 and concluded in 2014.

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

Issues covered reflected the many facets of VLS-PV for target groups from political and governmental organisations as well as for institutes worldwide to provide a better understanding of these issues.

Task 8 has recognised that states/governments all over the world consider solar power plants as a viable option for their electrical energy supply. Decision-makers should be informed in an appropriate manner on the feasibility of such projects for accelerating and implementing real VLS-PV projects and results of Task 8 can contribute to achieving this vision.

MEANS

During the activity period from 1999-2014, Task 8 consisted of seven Subtasks.

SUBTASK 1: Conceptual Study of the VLS-PV System

Subtask 1 conducted development of the conceptual configuration of VLS-PV systems by extracting the dominant parameters of the conditions in which the systems were technically and economically feasible from a life-cycle viewpoint. The criteria for selecting regions suitable for case studies of the installation of VLS-PV were identified and then the regions for the case studies were nominated.

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

Employing the concepts of VLS-PV, as well as the criteria and other results produced under the Subtask 1, Subtask 2 undertook case studies on VLS-PV systems for the selected regions and evaluating the resulting effects, benefits and environmental impact. Feasibility and potential of VLS-PV on deserts were evaluated from local, regional and global viewpoints. As for the environmental aspects of VLS-PV systems, Task 8 carried out information exchange and collaborative work with Task 12.

SUBTASK 3: Comprehensive Evaluation of the Feasibility of VLS-PV

Subtask 3 undertook joint assessment of the results of the case studies performed under Subtask 2, summarizing similarities and differences in the impact of VLS-PV system installation in different areas, and proposed mid- and long-term scenario options, which enabled the feasibility of VLS-PV.

SUBTASK 4: Practical Project Proposals of VLS-PV Systems

Taking into account of the mid- and long term scenario studies proposed in the Subtask 3 and the guidelines discussed in the Subtask 5, Subtask 4 developed practical proposals for initial stage of VLS-PV systems, which would enable sustainable growth of VLS-PV systems for some desert.

SUBTASK 5: General Instruction for Practical Project Proposals to Realise VLS-PV Systems in the Future

Detailed practical instructions for the development of practical project proposals to enable to implement VLS-PV systems in a sustainable manner were discussed. Employing the results developed under the Subtask 4, financial and institutional scenarios were discussed further, and instructions for practical project proposals were discussed. Based on the discussions, implementing strategies and engineering designs for accomplishing VLS-PV projects were discussed and proposed.

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

Subtask 6 proposed and analysed various technical options for implementing VLS-PV systems, including scenarios for storage and for reliable integration of VLS-PV systems into the existing electrical grid networks. From the viewpoint of future electrical grid stability, a global renewable energy system utilizing globally dispersed VLS-PV systems as the primary electrical energy source were discussed. To clarify requirements for VLS-PV system to integrate with energy network in the near-term and mid- & long-term, combination with other renewable energy technology or energy source were discussed as well.

SUBTASK 7: VLS-PV Vision, Strategy and Communication

Based on the results of other subtasks and changing market environment, Subtask7 performed active dissemination and communication with stakeholders to develop VLS-PV vision and strategy. As well, possible approach and enabler to achieve the vision and implement the strategy were developed and identified.

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

Task 8 published extensive reports as a series of "Energy from the Desert", focusing on VLS-PV systems. The books showed that the VLS-PV is not a simple dream but is becoming realistic, and have been well-known all over the world.

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 Systems, Socio-Economic, Financial, Technical and Environmental Aspects”, 2009
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: “Summary - Energy from the Desert: Very Large Scale Photovoltaic Power - State-of-the-Art and into the Future”, 2013
Report: “Energy from the Desert: Very Large Scale PV Power Plants for Shifting to Renewable Energy Future”, 2015 (ISBN 978-3-906042-29-9)
Report: “Summary - Energy from the Desert: Very Large Scale PV Power Plants for Shifting to Renewable Energy Future”, 2015
Brochure: “Energy from the Desert: Fact sheets and the Summary of the Research”, 2015

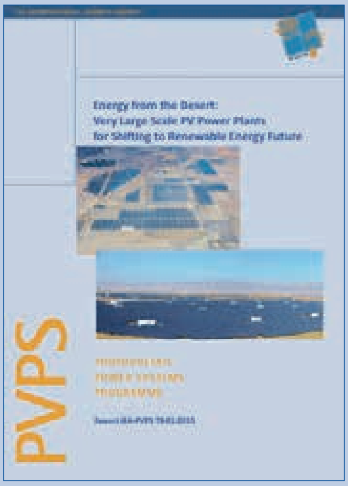


Fig. 1 - Energy from the Desert: Very Large Scale PV Power Plants for Shifting to Renewable Energy Future.

TASK 8 PARTICIPANTS

In its final year of activity, the following countries participated in Task 8: Canada, China, France, Germany, Israel, Italy, Japan, Korea, the Netherlands, Spain (observer), USA (observer), Finland (observer) and Mongolia (observer).

The management of the Task – the Operating Agent – was executed by Japan.

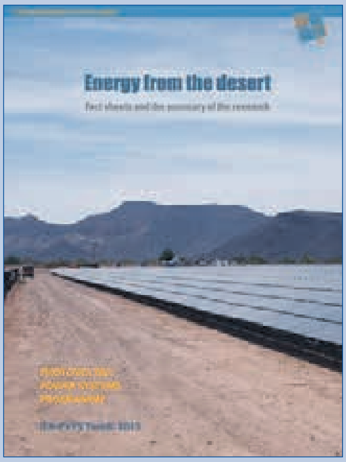


Fig. 2 - Brochure “Energy from the Desert: Fact sheets and the Summary of the Research”.

CONTACT INFORMATION

For information, contact the former Task 8 Operating Agent or Secretary, or visit the PVPS website:

Mr Keiichi KOMOTO
IEA PVPS Task 8 Operating Agent
Mizuho Information & Research Institute, Japan
keiichi.komoto@mizuho-ir.co.jp

Mr Masanori ISHIMURA
IEA PVPS Task 8 Secretary
New Energy and Industrial Technology Development Organization (NEDO), Japan
ishimuramsn@nedo.go.jp

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.

CONTACT INFORMATION

For information, contact the former Task 10 Operating Agent or visit the PVPS website:

Ms Christy HERIG
Segue Energy Consulting
17609 1st St. E
St. Petersburg, FL 33708 USA
Tel: 001 (0) 727 319 2405
cherig@tampbabay.rr.com

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.

CONTACT INFORMATION
For information, contact the former Task 11 Operating Agent or the Task 9 Operating Agent, or visit the PVPS website:

Mr Konrad MAUCH
Task 11 Operating Agent
KM Technical Services
1358 Sea Lovers Lane
CAN - Gabriola BC V0R 1X5
Tel: 1(0)25 0247 9577
konrad.mauch@ieee.org
konrad.mauch@gmail.com

Ms. Anjali SHANKER
Task 9 Operating Agent
Directeur Général Délégue
IED
2, chemin de la Chauderaie
FRA - 69340 Francheville (Lyon)
Tel: 33 (0)4 72591320
a.shanker@ied-sa.fr

ANNEX A

IEA-PVPS EXECUTIVE COMMITTEE

AUSTRALIA
Ms Renate EGAN
Chair, APVI
Australian Centre for Advanced Photovoltaics
Tyree Energy Technologies Building, Room 124
University of New South Wales
AUS - Sydney, Australia 2052
Cell: 61 408 223 653
chair@apvi.org.au
r.egan@unsw.edu.au

Ms Muriel WATT – Alternate
IT Power Australia
Unit 6, 9 McKay St
Turner
AUS – ACT 2612
(or this address)
PO Box 6127
O'Connor
AUS - ACT 2602
Tel: 61(0)2 6257 3511
Cell: 61(0)4 2772 7368
muriel.watt@itpau.com.au

AUSTRIA
Mr Hubert FECHNER – Deputy Chair
Renewable Urban Energy Programme
University of Applied Sciences
Technikum Wien
Höchstädtplatz 6
AUT -1210 Vienna
Tel: 43(0)1 3334 0775 72
Cell: 43(0)6 6461 92572
hubert.fechner@technikum-wien.at

BELGIUM
Mr Bart HEDEBOUW
Vlaams Energieagentschap
Koning Albert II-laan 20 bus 17
BEL - 1000 Brussels
Tel: 32(0)2 5534 627
Fax: 32(0)2 5534 601
bart.hedebouw@vea.be

Ms Leen VAN LISHOUT
Projectbeheerder, Directie Energie
Leefmilieu Brussel – BIM
Dpt. Duurzame gebouwen
- begeleiding van professionelen
Thurn & Taxis-site
Havenlaan 86C/3000
BEL - 1000 Brussels
Tel: 32(0)2 5634 297
Fax: 32(0)2 5634 326
lvanlishout@leefmilieu.irisnet.be

Ms Laurence POLAIN
Attachée, Research Team
Service Publique de Wallonie – DGO4
Direction de la Promotion de l'Énergie durable
Chaussée de Liège, 140-142
BEL - 5100 Jambes
Tel: 32(0)8 1486 342
Fax: 32(0)8 1486 303
laurence.polain@spw.wallonie.be

All three of Belgium's regions represented by:

Mr Gregory NEUBOURG
Renewable Energy Analyst
APERe asbl
Rue Royale 35
BEL -1000 Brussels
Tel: 32 (0)2 209 04 04
gneubourg@apere.org

CANADA
Mr John GORMAN
President & CEO
CANSIA
Canadian Solar Industries Association
150 Isabella Street, Suite 605
CAN - Ottawa, ON, Canada, K1S 1v7
Tel: 1 613 736 9077 Ext. 223
Toll free: 1 866 522 6742 Ext. 223
jgorman@cansia.ca

Ms Lisa DIGNARD-BAILEY - Alternate
Director, Integration of Renewable and
Distributed Energy Resources Program
Natural Resource Canada – CanMET Energy
Government of Canada
1615, Lionel-Boulet
CAN - Varennes, Québec, Canada, J3X I56
Tel: 1 450 652 5161
Fax: 1 450 652 5177
lisa.dignard@canada.ca

Mr Wesley JOHNSTON - Alternate
Vice President
Canadian Solar Industries Association
150 Isabella Street, Suite 605
CAN - Ottawa, Ontario, Canada, K1S 1V7
Tel: 1 613 736 9077
wjohnston@cansia.ca

CHINA
Mr Xu HONGHUA
Researcher of the Electrical Engineering Institute
Chinese Academy of Sciences
No. 6 Bei-er-tiao
Zhongguancun
Haidian Dist.
CHN - 100190 Beijing China
Cell: 13 70 102 1351
Tel: 86 10 825 47026
Fax: 86 10 825 47028
hxu@mail.iee.ac.cn

Mr Wang SICHENG - Alternate
Researcher
Energy Research Institute
National Development and Reform Commission
China
No. 6 Bei-er-tiao
Zhongguancun
Haidian Dist.
CHN - 100190 Beijing China
Cell: 13 90 138 8270
Tel: 86 10 825 47025
Fax: 86 10 825 47028
jikewsch@163.com

COPPER ALLIANCE
Mr Fernando NUNO
Project Manager
European Copper Institute
Avenue de Tervueren 168 B 10
BEL - 1150 Brussels, Belgium
Tel: 34 670 80 46 37
fernando.nuno@copperalliance.es

Mr Hans De KEULENAER - Alternate
Director – Energy & Electricity
European Copper Institute
Avenue de Tervueren 168 B 10
BEL - 1150 Brussels, Belgium
Tel: 32(0)2 777 7084
hans.dekeulenaer@copperalliance.eu

DENMARK
Mr Flemming KRISTENSEN
EnergiMidt A/S
Tietgensvej 2 - 4
DEN – 8600 Silkeborg
Tel: 45(0)7 658 1130
Cell: 45(0)2 086 9638
fvk@energimidt.dk

Mr Peter AHM - Alternate
Director, PA Energy A/S
Snovdrupvej 16
DEN - 8340 Malling
Tel: 45(0)8 693 3333
ahm@paenergy.dk

EUROPEAN UNION
Mr Fabio BELLONI
European Commission
Directorate-General for Research & Innovation
OFFICE: CDMA 0/081
Rue du Champ de Mars 21
BEL - 1049 Brussels, Belgium
Tel: 32(0)2 2952 472
Fax: 32(0)2 2994 991
Fabio.BELLONI@ec.europa.eu

Mr Pietro MENNA
European Commission
Directorate-General for Energy
Office: DM24 3/116
BEL - 1049 Brussels, Belgium
Tel: 32(0)2 2954 512
Fax: 32(0)2 2966 221
Pietro.MENNA@ec.europa.eu

FINLAND
Ms Karin WIKMAN
Programme Manager
TEKES, the Finnish Funding Agency
for Innovation
P.O. Box 69
FIN - 00101 Helsinki, Finland
karin.wikman@tekes.fi
Tel: 358 50 5577 723

Mr Jero AHOLA - Alternate
Professor
LUT, Lappeenranta University of Technology
P.O.Box 20
FIN - 53851 Lappeenranta, Finland
Tel: 358 40 5298 524
jero.ahola@lut.fi

FRANCE

Mr Yvonnick DURAND
PV R&D and Market Engineer
ADEME – Service Réseaux et
Energies Renouvelables
500 route des Lucioles
FRA - 06560 Valbonne, France
Tel: 33(0)4 9395 7911
yvonnick.durand@ademe.fr

Mr Paul KAAIJK – Alternate
Engineer International Actions and Survey
ADEME – Renewable Energies Department
500 route des Lucioles
FRA - 06560 Valbonne, France
Tel: 33(0)4 9395 7914
paul.kaaijk@ademe.fr

GERMANY

Mr Christoph HÜNNEKES - Deputy Chair
Forschungszentrum Jülich GmbH
Projektträger Jülich - EEN
DEU - 52425 Jülich
Tel: 49(0)2 4616 12227
Fax: 49(0)2 4616 12840
ch.huennekes@fz-juelich.de

Mr Klaus PRUME – Alternate
Forschungszentrum Jülich GmbH
Projektträger Jülich - EEN
DEU - 52425 Jülich
Tel: 49(0)2 4616 19174
Fax: 49(0)2 4616 12840
k.prume@fz-juelich.de

ISRAEL

Ms Rona SARFATY
Manager Research & Development Programs
Ministry of National Infrastructure,
Energy & Water Resources
Office of the Chief Scientist
14 Hartom St., P.O.B. 36148
ISR - 9136002 Jerusalem
Tel: 972-2-5316139
Cell: 972-50-6206-341
ronas@energy.gov.il

Mr Gideon FRIEDMANN - Alternate
Technologies & Renewable Energy
Section Manager
Ministry of National Infrastructure,
Energy & Water Resources
Office of the Chief Scientist
14 Hartom St., P.O.B. 36148
ISR - 9136002 Jerusalem
Tel: 972 2 5316 020
Cell: 972 5 8533 7565
Fax: 972 2 5316 017
gideonf@energy.gov.il

ITALY

Mr Salvatore CASTELLO
ENEA - Casaccia
Via Anguillarese, 301
ITA - 00123 S.Maria di Galeria - RM
Tel: 39(0)6 3048 4339
Fax: 39(0)6 3048 6405
salvatore.castello@enea.it

Mr Salvatore GUASTELLA
RSE S.p.A. (Ricerca Sistema Energetico S.p.A.)
via Rubattino, 54
ITA - 20134 Milano
Fax: 39(0)2 3992 5626
salvatore.guastella@rse-web.it

JAPAN

Mr Hiroyuki YAMADA – Deputy Chair
Director
Solar Energy Systems
New Energy Technology Dept.
New Energy and Industrial Technology
Development Organization (NEDO)
18F Muza Kawasaki Building, 1310, Omiya-cho, Saiwai-ku
JPN - Kawasaki City Kanagawa 212-8554
Cell: 81(0)8 0410 39831
Tel: 81(0)4 4520 5277
Fax: 81(0)4 4520 5276
yamadahry@nedo.go.jp

Mr Masanori ISHIMURA - Alternate
Technical Researcher
Solar energy Systems
New Energy Technology Dept.
New Energy and Industrial
Technology Development Organization (NEDO)
18F Muza Kawasaki Building, 1310, Omiya-cho, Saiwai-ku
JPN - Kawasaki City Kanagawa 212-8554
Cell: 81(0)8 0410 39756
Tel: 81(0)4 4520 5277
Fax: 81(0)4 4520 5276
ishimuramsn@nedo.go.ip

KOREA

Mr Donggun LIM
Korea National University of Transportation
50 Daehak-ro, Chungju-si
KOR – Chungbuk 380-702, Korea
Tel: 82(0)43 841 5172
Fax: 82(0)43 841 5160
dglim@ut.ac.kr

MALAYSIA

Dato' Dr Nadzri bin YAHAYA
Deputy Secretary General (Energy Sector)
Ministry of Energy, Green Technology and Water
Block E 4/5, Parcel E
Pusat Pentadbiran Kerajaan Persekutuan
MYS - 62668 Putrajaya
Malaysia
Tel: 603 8883 6111
Fax: 603 8889 1335
nadzri@kettha.gov.my

Ms Catherine RIDU– Alternate
Chief Executive Officer
Sustainable Energy Development Authority Malaysia
Galeria PjH, Aras 9, Jalan P4W, Persiaran Perdana, Presint 4
MYS - 62100 Putrajaya, Malaysia
Tel: 603 8870 5800
Fax: 603 8870 5900
C.Ridu@seda.gov.my

MEXICO

Mr Jaime AGREDANO DIAZ
Instituto de Investigaciones Electricas
Gerencia de Energias Renovables
Reforma 113 Colonia Palmira
MEX - Cuernavaca, Morelos 62490
Tel: 52(0)7 77362 3830
Fax: 52(0)7 77362 3808
agredano@iie.org.mx

Mr Jorge M. HUACUZ VILLAMAR - Alternate
Instituto de Investigaciones Electricas
Gerencia de Energias Renovables
Reforma 113 Colonia Palmira
MEX - Cuernavaca, Morelos 62490
Tel: 52(0)7 77318 3811 ext. 7741
Fax: 52(0)7 77318 3808
jhuacuz@iie.org.mx

NETHERLANDS

Mr Bouke BUSSEMAKER
Ministry of Economic Affairs
P.O. Box 20401
NLD - 2500 EK Den Haag
Tel: 31 70 379 7849
Fax: 31 70 379 6872
B.H.Bussemaker@minez.nl

Mr Otto BERNSEN - Alternate
Netherlands Enterprise Agency RVO
Department: Energy Innovation
Directorate, Energy & Climate
Prinses Beatrixlaan 2
NLD - 2595 AL Den Haag
Tel: 31(0)7 0373 5650
Fax: 31(0)8 8602 9023
otto.bernsen@rvo.nl

NORWAY

Mr Bjorn THORUD
Multiconsult
P.O. Box 265
Skoyen
NOR – 0213 Oslo
Tel: 47(0)2 1585 528
Cell: 47(0)4 8181 266
bjorn.thorud@multiconsult.no

Ms Lisa HENDEN GROTH - Alternate
Senior Consultant
Middelthunsgate 29
P.O. Box 5091 Majorstua
NOR - 0301 Oslo
Tel: 47 9771 5939
Fax: 47 2295 9000
lhg@nve.no

PORTUGAL

Mr Pedro VALVERDE
EDP INOVAÇÃO
Cleaner Energy
Av. 24 de Julho, Nº 12
Torre Poente N – 2º Piso
PRT - 1249-300 Lisboa
Tel: 351 21 001 89 55
Cell: 351 93 560 60 27
pedro.valverde@edp.pt

Mr Pedro SASSETTI PAES - Alternate
EDP Energias de Portugal S.A.
Sustainability Office
Av. 24 de Julho, Nº 12
Torre Poente N – 2º Piso
PRT - 1249-300 Lisboa
Tel: 351 210012173
Fax: 351 210012220
Cell: 351 936281837
pedro.paes@edp.pt

SEPA
Ms Julia HAMM
President & CEO
Solar Electric Power Association
1220 19th Street, Suite 800
USA - Washington, DC 20036 USA
Tel: 1(0)2 0255 92025
Fax: 1(0)2 0259 2035
jhamm@solarelectricpower.org

SEIA
Mr Tom KIMBIS
Vice President, External Affairs
and General Counsel
Solar Energy Industries Association SEIA
505 9th Street, NW, Suite 400
USA - Washington, DC 20004
Tel: 1(0)2 0246 93737
Cell: 1(0)2 0271 43737
tkimbis@seia.org

SOLARPOWER EUROPE
Mr Ioannis-Thomas THEOLOGITIS
Senior Advisor
SolarPower Europe
Rue d'Arlon 69-71
BEL - 1040 Brussels, Belgium
Tel: 32 2 709 55 40 / 32 2 709 55 20
i.theologitis@solarpowereurope.org

Mr Thomas DÖRING - Alternate
Policy Analyst – Technology and Markets
SolarPower Europe
Rue d'Arlon 69-71
BEL - 1040 Brussels, Belgium
Tel: 32 2 709 55 43 / 32 2 709 55 20
t.doering@solarpowereurope.org

SPAIN
Ms Ana Rosa LAGUNAS ALONSO
Photovoltaic Department Director
CENER (National Renewable Energy Centre)
Ciudad de la Innovación 7
ESP - 31621 Sarriguren-Navarra
Tel: 34 9 4825 2800
Fax: 34 9 4827 0774
alagunas@cener.com

SWEDEN
Mr Tobias WALLA
Swedish Energy Agency
P.O. Box 310
SWE - 631 04 Eskilstuna
Sweden
Tel: 46 (0)16 544 20 54
tobias.walla@energimyndigheten.se

Mr Pierre-Jean RIGOLE
Swedish Energy Agency
P.O. Box 310
SWE - 631 04 Eskilstuna
Sweden
Tel: 46 (0)16 544 21 91
pierre-jean.rigole@energimyndigheten.se

SWITZERLAND
Mr Stefan OBERHOLZER
Sektion Energieforschung
Bundesamt für Energie
CHE - 3003 Bern
Tel: 41(0) 58 465 89 20
Cell: 41(0)7 9231 4850
stefan.oberholzer@bfe.admin.ch

Mr Stefan NOWAK - Chairman
NET - Ltd.
Waldweg 8
CHE - 1717 St. Ursen
Tel: 41(0)2 6494 0030
Fax: 41(0)2 6494 0034
stefan.nowak@netenergy.ch

THAILAND
Mr Thammayot SRICHUAI
Director General
Department of Alternative Energy Development and Efficiency
17 Kasatsuk Bridge, Rama 1 Road
Pathumwan District
THA – Bangkok 10330
thammayot@dede.go.th

Mr Kuson CHIVAGON - Alternate
Deputy Director General
Department of Alternative Energy Development
and Efficiency
17 Kasatsuk Bridge, Rama 1 Road
Pathumwan District
THA – Bangkok 10330
kuson_c@dede.go.th

Ms Kulwaree BURANASAJJAWARAPORN – Alternate
Director of Solar Energy Development Bureau
Department of Alternative Energy Development and Efficiency
17 Kasatsuk Bridge, Rama 1 Road
Pathumwan District
THA – Bangkok 10330
kulwaree_b@dede.go.th

Ms Patthamaporn POONKASEM - Alternate
Director of Innovation Group
Bureau of Solar Energy Development
Department of Alternative Energy Development and Efficiency
17 Kasatsuk Bridge, Rama 1 Road
Pathumwan District
THA – Bangkok 10330
poonkasem_energy@hotmail.com

Ms Thanyalak MEESAP – Alternate
Professional Engineer, Innovation Group
Bureau of Solar energy Development
Department of Alternative Energy Development and Efficiency
17 Kasatsuk Bridge, Rama 1 Road
Pathumwan District
THA – Bangkok 10330
thanyalak_m@dede.go.th

Ms Thidarat SAWAI – Alternate
Professional Scientist, Innovation Group
Bureau of Solar energy Development
Department of Alternative Energy Development
and Efficiency
17 Kasatsuk Bridge, Rama 1 Road
Pathumwan District
THA – Bangkok 10330
thidarat_s@dede.go.th

TURKEY
Mr Ahmet YILANCI
GUNDER
Bestekar Sok.
Cimen Apt. No: 15/12
Kavaklidere
TUR - Ankara, Turkey
Tel: 90 312 418 18 87
Fax: 90 312 418 08 38
ahmetyilanci@gmail.com
info@gunder.org.tr

Mr Fatih GOKKAYA - Alternate
GUNDER
Bestekar Sok.
Cimen Apt. No: 15/12
Kavaklidere
TUR - Ankara, Turkey
Tel: 90 312 418 18 87
Fax: 90 312 418 08 38
fatih.gokkaya@tedas.gov.tr
info@gunder.org.tr

Mr Bulent YESILATA - Alternate
Professor & Director
GAP Renewable Energy and Energy Efficiency Center
Harran University, Sanliurfa/Turkey
Cell: 90 536 736 0900
Fax: 90 414 318 3799
byesilata@yahoo.com
byesilata@harran.edu.tr
info@gunder.org.tr

UNITED STATES OF AMERICA
Mr Lenny TINKER
Solar Energy Technologies Office
US Department of Energy
1000 Independence Avenue, SW
USA - Washington, DC 20585
Tel: 1 202 287-1534
Fax: 1 202 287 1417
Lenny.Tinker@ee.doe.gov

EXCO SECRETARY
Mrs Mary BRUNISHOLZ
IEA PVPS
NET - Ltd.
Waldweg 8
CHE - 1717 St. Ursen
Tel: 41(0)2 6494 0030
Fax: 41(0)2 6294 0034
mary.brunisholz@netenergy.ch

IEA DESK OFFICER
Mr Yasuhiro SAKUMA
Renewable Energy
Implementing Agreement Desk Officer
International Energy Agency
9, rue de la Fédération
FRA - 75739 Paris Cedex 15
Tel: 33(0)1 4057 6562
Yasuhiro.SAKUMA@iea.org

ANNEX B

IEA-PVPS OPERATING AGENTS

TASK 1 – STRATEGIC ANALYSIS AND OUTREACH

Mr Gaëtan MASSON
Becquerel Institute
69-71 Rue d'Arlon
BEL - 1040 Brussels
Belgium
Cell: 32 478 28 05 11
g.masson@iea-pvps.org

TASK 9 – DEPLOYING PV SERVICES FOR REGIONAL DEVELOPMENT

Ms Hedi FEIBEL
Skat Consulting Ltd.
Vadianstrasse 42
CHE - 9000 St. Gallen
Switzerland
Tel: 41 71 228 54 54
Fax: 41 71 228 54 55
hedi.feibel@skat.ch

Mr Stefan KESSLER
INFRAS
Binzstrasse 23
CHE - 8045 Zürich
Switzerland
Tel: 41 44 205 95 95
Fax: 41 44 205 95 99
stefan.kessler@infras.ch

TASK 12 – PV ENVIRONMENTAL, HEALTH AND SAFETY (E, H & S) ACTIVITIES

Mr Garvin HEATH
National Renewable Energy Laboratory
15013 Denver West Parkway
USA - Golden, CO 80401
Tel: 1(0)303 384 7460
garvin.heath@nrel.gov

Ms Carol OLSON (Deputy OA)
Energy Research Center of
The Netherlands (ECN)
Westerduinweg 3
NLD - 1755 LE Petten
Tel: 31 88 515 48 56
olson@ecn.nl

TASK 13 – PERFORMANCE AND RELIABILITY OF PHOTOVOLTAIC SYSTEMS

Ms Ulrike JAHN
TÜV Rheinland Energy GmbH
Am Grauen Stein
DEU - 51105 Köln, Germany
Tel: 49(0)2 2180 62232
Fax: 49(0)2 2180 61350
ulrike.jahn@de.tuv.com

Mr Nils REICH
Division Photovoltaic Modules, Systems and Reliability
Fraunhofer Institute for Solar Energy Systems ISE
Heidenhofstrasse 2
DEU - 79110 Freiburg, Germany
Tel: 49 (0)761 4588 5826
Fax: 49 (0)761 4588 9826
Cell: 49 (0) 152 0905 8308
nils.reich@ise.fraunhofer.de

TASK 14 – HIGH-PENETRATION OF PV SYSTEMS IN ELECTRICITY GRIDS

Mr Roland BRÜNDLINGER
AIT Austrian Institute of Technology GmbH
Giefinggasse 2
AUT - 1210 Vienna
Tel: 43 50550 6351
Fax: 43 50550 6390
roland.bruendlinger@ait.ac.at

Mr Christoph MAYR
AIT Austrian Institute of Technology GmbH
Giefinggasse 2
AUT - 1210 Vienna
Tel: 43 50550 6633
Fax: 43 50550 6390
christoph.mayr@ait.ac.at

TASK 15 – ENABLING FRAMEWORK FOR THE ACCELERATION OF BIPV

Mr Michiel RITZEN
Nieuw Eyckholt 300
Postbus 550
NLD - 6400 AN Heerlen
Tel: 31 (0)6 24460817
michiel.ritzen@zuyd.nl

Ms Martje VAN HORRIK
Centre of Expertise NEBER
Nieuw Eyckholt 300
6419 DJ Heerlen
P.O. Box 550
NLD - 6400 AN Heerlen
Tel: 31 (0)6 51353166
martje.vanhorrik@zuyd.nl

Mr Zeger VROON
Nieuw Eyckholt 300
Postbus 550
NLD - 6400 AN Heerlen
Tel: 31 (0)45 400 6515
zeger.vroon@zuyd.nl

COLOPHON

Cover Photograph
©R. Nicolas-Nelson / Armée de l'Air
Task Status Reports
PVPS Operating Agents
National Status Reports
PVPS Executive Committee Members and Task 1 Experts
Editor
Mary Jo Brunisholz
Layout
Autrement Dit
Paper
Normaset Puro blanc naturel
Type set in
Rotis
Printed in 1000 copies by
Imprimerie St-Paul, Fribourg, Switzerland
ISBN
978-3-906042-41-1