

PVPS

# annual report 2016

PHOTOVOLTAIC POWER SYSTEMS  
TECHNOLOGY COLLABORATION PROGRAMME

P H O T O V O L T A I C   P O W E R   S Y S T E M S   P R O G R A M M E

# ANNUAL REPORT 2016



*COVER PHOTO:*

*The School with the Largest Solar Façade in the World:  
featuring LESO's development of the colored photovoltaic  
modules with KROMATIX solar glass (SwissINSO).*

*CIS Nordhavn is the Copenhagen International School's new  
campus. The campus building was designed by C.F. Møller  
Architects and sits in Nordhavn, a new district in Copenhagen.*

*The Copenhagen International School's new building is covered  
by 12 000 colored solar panels based on a technology developed  
at EPFL, Switzerland. It is one of the largest building-integrated  
solar power plants in Denmark. The 12 000 colored solar panels  
really make the Copenhagen International School's new building  
stand out. They completely cover the building and will provide  
it with 300 MWh of electricity per year, meeting over half of  
the school's energy needs. The panels are a distinctive sea green,  
yet no pigments were used to make them. The color comes  
from a process of light interference developed over a number  
of years in EPFL labs.*

*Cover photo and above by: © 2017 EPFL Philippe Vollichard &  
© 2017 EPFL Alain Herzog*

# CHAIRMAN'S MESSAGE



IEA PVPS, the Photovoltaic Power Systems Programme of the International Energy Agency, is pleased to present its 2016 annual report to you. 2016 has been another year of unprecedented development of the global photovoltaic market: A spectacular market growth and a further increase in competitiveness of solar photovoltaic (PV) power systems mark this young energy technology which is rapidly entering into a changing energy world. Achieving levelized costs of electricity from PV as low as under 3 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.

2016 has seen close to 75 GW of additional installed PV capacity worldwide, a staggering 50 % above 2015 and raising the cumulative installed capacity to about 300 GW. As in 2015, China, the USA and Japan represented the largest markets in 2016, accounting for three quarters of the additional installed capacity in these three countries alone. Meanwhile, two-thirds of the global PV capacity is being installed in the Asia-Pacific region with China ahead of all others at more than 34 GW of installed capacity in 2016. 24 countries have now reached cumulative installed capacities above 1 GW, 16 countries installed at least 500 MW during 2016 and in at least 27 countries, PV contributes with 1 % or more to the annual electricity supply. In 2017, PV will be contributing to roughly 2 % of the world's electricity generation.

These dynamic market developments as well as progress in PV technology and industry 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. More recently, building integrated PV is gaining relevance. Anticipating future needs, IEA PVPS addresses 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. Indeed, as PV is increasingly becoming a part of the energy system, integration at all levels becomes a key strategic matter.

As PV matures with a growing number of stakeholders and organizations, 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. 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 as well the utility sector. During 2016, IEA PVPS was particularly pleased to launch the first joint publication together with IRENA on end-of-life management of solar PV panels.

Interest and outreach for new membership within IEA PVPS continued in 2016. With South Africa becoming the most recent PVPS member, PVPS now has its first participant on the African continent, soon expected to be followed by Chile and thereby South America. At the end of 2016, IEA PVPS has 30 members and is one of the largest IEA technology collaboration programmes (TCPs). Exploration for membership continued with Chile, India, Morocco, New Zealand, Singapore 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.

During 2016, IEA PVPS decided to set up a new collaborative project, Task 16, on solar resource assessment for high penetration and large scale applications. This activity follows on earlier work within the IEA Solar Heating and Cooling (SHC) TCP and will be jointly carried out with the Solar Power and Chemical Energy Systems (SolarPACES) TCP. This new PVPS Task is exemplary of the increased collaboration among different IEA TCPs.

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 ([www.iea-pvps.org](http://www.iea-pvps.org)). 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 in making IEA PVPS a great success!

A handwritten signature in dark ink, reading 'S. Nowak'. The signature is fluid and cursive, with a large 'S' and a stylized 'Nowak'.

Stefan Nowak  
Chairman



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# PHOTOVOLTAIC POWER SYSTEMS PROGRAMME

## IEA

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

The IEA RD&D activities are headed by the Committee on Research and Technology (CERT), supported by the IEA secretariat staff, with headquarters in Paris. In addition, four Working Parties on End Use, Renewable Energy, Fossil Fuels and Fusion Power, are charged with monitoring the various collaborative energy agreements, identifying new areas of cooperation and advising the CERT on policy matters. The Renewable Energy Working Party (REWP) oversees the work of ten renewable energy agreements and is supported by a Renewable Energy Division at the IEA Secretariat in Paris.

## IEA PVPS

The IEA Photovoltaic Power Systems Programme (PVPS) is one of the 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 2016, sixteen Tasks were established within the PVPS programme, of which seven are currently operational.

The thirty 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, South Africa, Spain, Sweden, Switzerland, Thailand, Turkey and the United States of America. South Africa, joined PVPS in 2016.

## 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 CO<sub>2</sub> 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.



48<sup>th</sup> IEA PVPS Executive Committee Meeting, Vienna, Austria, November 2016.

### 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.
- Task 16. Solar Resource for High Penetration and Large Scale Applications. Begun late 2016.

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 – Mr. Paolo Frankl, IEA, Head of the Renewable Energy Division, presents “PV Costs and Competitiveness,” at the IEA PVPS Task 1 Workshop, “Enhancing PV Competitiveness with Energy Storage.” IEA PVPS Parallel Events, 32<sup>nd</sup> EU PVSEC, Munich, Germany, June 2016.



Fig. 2 – Joint Workshop from the IEA PVPS, Australian PV Institute (APVI) and the University of New South Wales, Sydney, Australia, October 2016.

Task 1 shares a double role of expertise (on PV markets, industry, and policies) and outreach, which is reflected in its name “Strategic PV Analysis & Outreach”.

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, as well as to foster the removal of both technical and non-technical barriers and to enhance technology co-operation.

It aims at promoting and facilitating the exchange and dissemination of information on the technical, economic, environmental, and social aspects of PV power systems.

### Expertise

- Task 1 researches market and industry development, analyses support and R&D policies.
- 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.

### 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 aspects, new and legacy of the activities.

### SUBTASK 1.1: Market, Policies and Industrial Data and Analysis

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

### 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](http://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.

### 21<sup>st</sup> 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, and additional information provided by a network of market and industry experts. 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 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 2016, twenty-one issues of *Trends* have been published. They are all available on the IEA PVPS website.

### A Snapshot of Global PV Report

Since 2013, another 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





Fig. 3 – Review and Analysis of PV Self-consumption Policies; Report: IEA PVPS T1-28:2016.

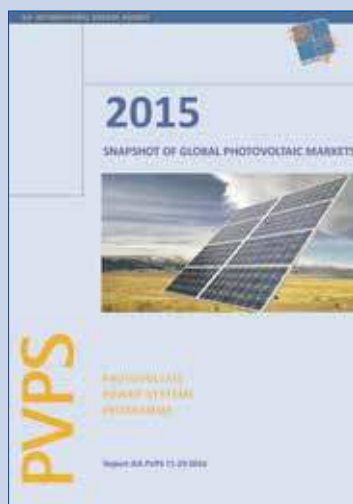


Fig. 4 – PVPS Report: A Snapshot of Global PV 1992-2015; Report: IEA PVPS T1-29:2016.



Fig. 5 – PVPS Report: Trends in Photovoltaic Applications – Survey Report of Selected IEA Countries between 1992 and 2015; Report: IEA PVPS T1-30:2016.

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.

#### Review of PV Self-Consumption Policies

This new report published in 2016 analyzes and compares policies supporting the local self-consumption of PV electricity. It accompanies the most recent developments in regulatory updates in twenty key countries allowing PV system owners to become real prosumers. It provides an independent, fair and accurate analysis on the policy evolutions currently ongoing in several countries, highlighting the technical, economic and regulatory challenges associated to the development of PV for prosumers.

#### 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 2016 several subjects that led to 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 emerging business models receives an increasing interest. In 2016, Task 1's work was focused on the finalization and the promotion of the self-consumption report through 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 2016, depending on local specifics: IEA hosted the European workshop in Paris, France, while the Asian workshop took place during the SNEC conference in Shanghai, China. The third one was held in Sydney, Australia during the second Task 1 Experts' Meeting of the year. IEA PVPS will continue to provide a platform where these actors can meet and exchange information.
- **Recommendations and Analysis:** the fast development of PV in all continents required from regulators and authorities to perfectly understand the key features of the PV technology

development. IEA-PVPS will provide a set of recommendations in various fields, to disseminate the vast experience acquired by its experts in the last years.

#### SUBTASK 1.3: Communication Activities

Task 1 aims at communicating about the main findings of the PVPS programme through the most adequate communication channels. In that respect, five main type 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 2016, the following workshops were organized in several locations around the world:

- Paris, France – January 2016: the second PV & Utilities Workshop was held in the IEA premises. It allowed participants from key European utilities and PV experts to exchange on business models for PV development.
- Madrid & Las Palmas, Spain – April 2016: In the framework of the 45<sup>th</sup> Task 1 Experts' Meeting in Spain, two workshops have been organized in parallel with the Task 1 meeting. The first meeting focused on synergies between PV and Heating & Cooling technologies. The second was dedicated to drivers for PV market development and renewable energy developments on islands.
- Shanghai, China – April 2016: in the framework of the SNEC Conference, in collaboration with the Chinese Academy of Sciences, a workshop has been organized on the role of utilities, and especially grid management aspects, in supporting PV development.
- Munich, Germany – June 2016: EU-PVSEC Conference and Exhibition: An IEA-PVPS workshop on competitiveness and the role of battery storage for PV development took place.
- Dubai, UAE – September 2016: An IEA PVPS workshop has been jointly organized with the Solar United Global PV Technology and Industry Association. This workshop focused on PV market and industry development trends with a focus on long term energy mixes and local industry development.
- Sydney, Australia – October 2016: A joint IEA PVPS, Australian PV Institute (APVI) and University of New South Wales workshop took place. This workshop examined issues of market development, including support policies and industry development.

- Singapore – October 2016: A joint IEA PVPS and SERIS workshop was organized during the Asian PVSEC-26 conference, on the subject of PV in the built environment and BIPV.
- In addition, IEA PVPS was partner of several events in 2016. Task 1 speakers represented the program in several conferences in various places.

**Webinars:** To increase its visibility, Task 1 speakers participated to three webinars organized by Leonardo Energy and ISES on PV markets, policies and industry development.

**Publications:** The publications of Task 1 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.

The new version of the *PV Power Newsletter*, the 38<sup>th</sup> edition, has been issued in 2016, with the ambition to provide accurate and complete information about the IEA PVPS program at least twice a year.

**IEA PVPS in the Media:** New publications are disseminated by press releases to around 500 contacts from media and national PV associations. This list of contact is expanded with more media from Asian, African and Latin American countries on a progressive way. Translation of press releases is done by some countries to expand the visibility.

Six press releases have been issued in 2016, covering the three Task 1 reports (Snapshot and Trends, plus the Self-consumption Report), one for the latest Task 9 report (PV Diesel Hybrids), one for the joint Task 12 & IRENA report (*End of Life Management Solar Photovoltaic Panels*) and one for the Task 14 report (*How an energy supply system with a high PV share handled a solar eclipse*).

All reports and activities are also promoted through Twitter, which counted more than 500 followers at the beginning of 2017.

#### 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 Technology Collaboration Programmes of the IEA
- Stakeholders outside the IEA network: IRENA, ISES, REN21, etc.

#### SUMMARY OF TASK 1 ACTIVITIES AND DELIVERABLES PLANNED FOR 2017

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 policy makers and others 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 and Industrial Data and Analysis

National Survey Reports will start to be published from the end of Q2 2017 on the IEA PVPS website.

The target date for publication of the 5th issue of the *Snapshot of Global PV* report is the end of Q1 2017.

The target date for publication of the 22nd issue of the *Trends in Photovoltaic Applications* report is the end of Q3 2017.

Other Task 1 reports shall also be published in 2017.

#### SUBTASK 1.2: Think Tank Activities

The main subjects to be developed in 2017 about the Think Tank activities of PVPS can be described as follow:

- 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 defining the future of the PVPS programme.

#### SUBTASK 1.3: Communication Activities

Task 1 will continue its communication activities in 2017. 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.

#### SUBTASK 1.4: Cooperation Activities

Task 1 will continue to cooperate with adequate stakeholders in 2017. It will reinforce the link with the IEA in particular and enhance its cooperation with IRENA, ISES and other organizations. Regarding the cooperation among IEA Technology Collaboration Programmes, a special focus could be put on subjects such as heating & cooling in buildings and electric vehicles.

#### 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 (2016 AND PLANNED 2017)

**The 46<sup>th</sup> Task 1 Experts' Meeting** was held in Spain, in April 2016.

**The 47<sup>th</sup> Task 1 Experts' Meeting** was held in Australia, in October 2016.

**The 48<sup>th</sup> Task 1 Experts' Meeting** will be held in Italy, in April 2017.

**The 49<sup>th</sup> Task 1 Experts' Meeting** will be possibly held in Latin America, in Autumn 2017.



Fig 6 – IEA PVPS Task 1 Experts Meeting in Spain (Photos: Lv Fang).



## TASK 1 PARTICIPANTS IN 2016 AND THEIR ORGANIZATIONS

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

COUNTRY	PARTICIPANT	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
	Christian Breyer	
France	Yvonnick Durand	ADEME
Germany	Georg Altenhöfer-Pflaum	Forschungszentrum Jülich
	Klaus Prume	
Israel	Gideon Friedmann	Ministry of National Infrastructure, Energy & Water Resources
Italy	Salvatore Guastella	RSE SpA
	Francesca Tilli	
Japan	Izumi Kaizuka	RTS Corporation
	Masanori Ishimura	NEDO
Korea	Chinho Park	Yeungnam University
Malaysia	Wei -Nee Chen	SEDA
Mexico	Jaime Agredano Diaz	Instituto de Investigaciones Electricas, Energías no Convencionales
Norway	Øystein Holm	Multiconsult
Portugal	Pedro Paes	EDP
SolarPowerEurope	N/A	SolarPowerEurope
Spain	Vicente Salas	Universidad Carlos III de Madrid
	José Donoso	UNEF
Sweden	Johan Lindahl	Uppsala University
Switzerland	Pius Hüsler	Nova Energie
Thailand	Kulwaree Buranasajjawaraporn	Department of Alternative Energy Development and Efficiency
	Pathamaporn Poonkasem	
	Thanyalak Meesap	
	Thidarat Sawai	
The Netherlands	Otto Bernsen	Netherlands Enterprise Agency RVO
Turkey	Kemal Gani Bayraktar	Gunder
USA	Robert Margolis	NREL
	David Feldman	NREL
	Daniel Boff	DoE

## TASK 9 – DEPLOYING PV SERVICES FOR REGIONAL DEVELOPMENT



Fig. 1 – Solar water pumping system in Ethiopia, Nov 2015 (Photo: SOLECO).



Fig. 2 – 29 kWp PV – 20 kW wind system for village supply, Jangkang, Province Qinghai, China 2004 (Photo: Fraunhofer ISE).

### INTRODUCTION

Close to 1 billion people are still without electricity in 2030 and 700 million people continue to live in sparsely populated rural areas where solar PV systems are the most promising solution for electrification. The IEA PVPS member countries have mature power systems and broad experience on technical and policy aspects on how to apply available technologies successfully. Following this logic, Task 9 is dealing with deploying PV services for regional development.

During its last four year program 2012–2015, Task 9 already started moving away from the more classical Solar Home Systems for individual (household and "pico" uses) to a broader range of PV applications including village mini-grid power systems, in particular hybrid systems. For its new program phase Apr 2016 – Apr 2018, a clear decision was taken to focus on PV in mini grids and distributed PV in bigger grids (grid-connected PV) including high penetration of renewable energies on Islands.

With declining PV costs, PV applications are competitive in an increasing number of situations, thus providing numerous opportunities for energy services which lead to accelerated development.

Following the opening address of Mr. Fatih Birol, the new Executive Director of IEA, in the joint TCP meeting held on 18 September 2015, 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, decision has been made to continue **focusing on emerging countries by adapting and transferring relevant knowledge and information for such countries.**

### OBJECTIVES

Task 9's vision is to act as a facilitator for large scale deployment of PV in emerging and developing regions to foster a sustainable economic and social transition process and regional development. Through its impartial, best of class research work and active dissemination of research results, Task 9 significantly contributes to this vision. By cooperating with other PVPS Tasks and national and international development partners, the outreach of Task 9 outputs is leveraged and research activities and field work of co-operating institutions are complemented and strengthened.

The current Task 9 members consider developing and emerging countries as important focus for the deployment of PV technology. Consequently, it was agreed to continue focusing on emerging and developing countries:

1. By selecting topics of high relevance for these countries;
2. By strengthening and extending its existing network with emerging countries and relevant bi- and multilateral organisations to ensure significant outreach and impact.

Task 9's overall objective during its last phase was to address the "Deployment of PV Services for Regional Development including but looking beyond rural electrification applications". This included classical Solar Home Systems (SHS), pico uses, village power systems, PV services for drinking water and health and also other social, productive and professional applications, PV in the built and urban environment and potential large scale PV. However, the latter two have not yet been covered by specific Subtasks.



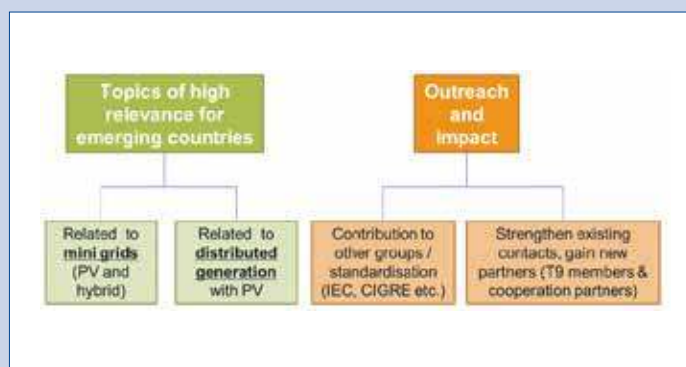


Fig. 3 - Main fields of Task 9's activities.

Past experience has shown that SHS and pico appliances have become a highly commercial business. Simultaneously, centralised electricity supply systems (mini grids for communities) and extension of the national grid (including grid-connection of RE systems) are playing more and more an important role also in developing and emerging countries. Consequently, Task 9 decided in connection with the above described vision to clearly target its future contents on:

1. PV in mini grids (including hybrid systems);
2. Distributed PV in bigger grids (grid connected PV).

Focusing on these two main fields implicates a number of complex technical and non-technical aspects.

In parallel, Task 9 intends to strengthen its outreach and dissemination activities. Close cooperation and exchange with international and development organisations ensures a demand-driven work of Task 9 in line with practitioners' problems in the field and with the needs of policy makers and other relevant stakeholders. Furthermore, it is considered 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. E.g. in countries, where the national grid is still characterized by frequent breakdowns, fluctuating voltage and frequency etc., feeding into such a grid with distributed PV systems encounters a lot of problems - quite different from industrialised countries.

Although the technology gap between OECD and non-OECD countries is narrowing, it is still necessary to translate newest outputs from PVPS to emerging countries realities.

Figure 3 shows the main fields of Task 9's activities which are closely interlinked.

## APPROACH

Task 9 is subdivided into four topical Subtasks well reflecting the above stated topics of high relevance. The fifth Subtask "outreach and impact" is contained as an activity within each of the four Subtasks as described below. In addition, the contribution to standardization bodies and other groups is part of this fifth Subtask.

## ACCOMPLISHMENTS OF IEA PVPS TASK 9

The two most recent accomplishments from the last phase which also resulted in respective publications are briefly described in the following.



Fig. 4 - "User Guide to simple monitoring and sustainable operation of PV-diesel hybrid systems".

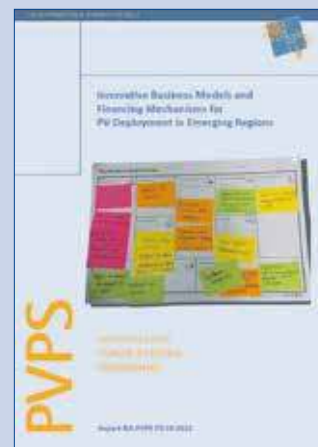


Fig. 5 - "Innovative Business Models and Financing Mechanisms for PV Deployment in Emerging Regions".

## 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 **"to simple monitoring and sustainable operation of PV-diesel hybrid systems"**. This activity was led by Sweden and the guideline was published in December 2015. 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 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 blackout, etc. For the most part, the monitoring can be managed by pen and paper, by people with no earlier experience with 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.

## 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.

## SUBTASKS AND ACTIVITIES

### SUBTASK 1: Minigrids Integrating Diesel Generation and PV

This Subtask is subdivided into two main work packages:

- a) Evaluation of existing PV hybrid systems
- b) "PV as Fuel Saver"



Fig. 6 – 20kWp PV village supply system, Gajah Bertalut, Riau, Sumatra, 2016 (Photo: Fraunhofer ISE).

### SUBTASK 1a): Evaluation of Existing PV Hybrid Systems

This first work package evaluates existing PV hybrid systems with regard to their operation experience, technical, institutional, organisational and financial challenges. Such systems are typically **in the range of less than 100 kW, consisting of a PV- and a battery-component and a small diesel generator** only used as a back-up in case the battery capacity is not sufficient. The activity can build on results from a former activity related to "PV Hybrid Systems within Mini-grids" which elaborated an overview on best practise systems. Besides, newly installed systems are analysed by means of a literature review. For the identified systems, their topology, operation, maintenance and financial data as well as non-technical information are collected and analysed to evaluate: performance, grid stability, fuel consumption and cost, load profile, maintenance effort and cost, levelized cost of energy, logistical problems and organisational issues. In addition, options to connect the respective system to the national grid - if this is approaching - are identified. Based on the results, a detailed catalogue of recommendations for policy makers and utilities will be developed as part of a final evaluation report.

#### PV-Hybrid System Brunnenbach, Germany

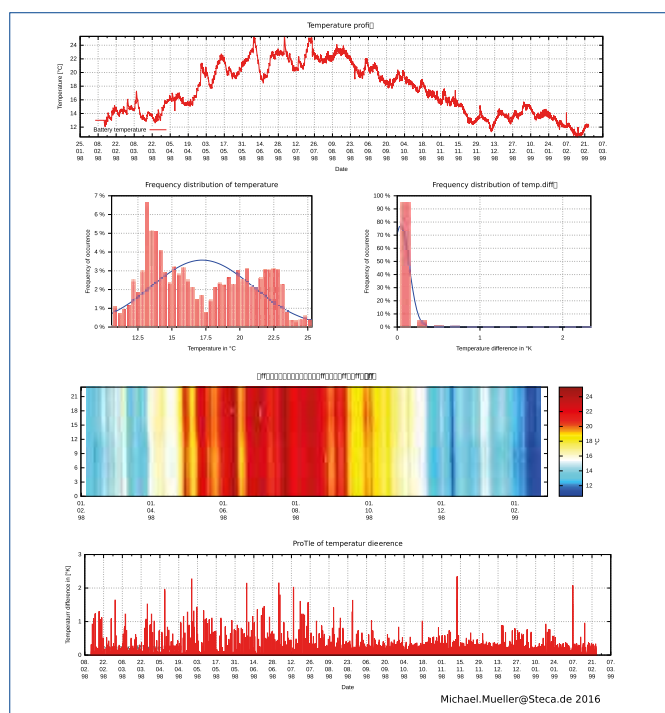


Fig. 7 – Data analysis on battery temperature [Source: Fraunhofer ISE].

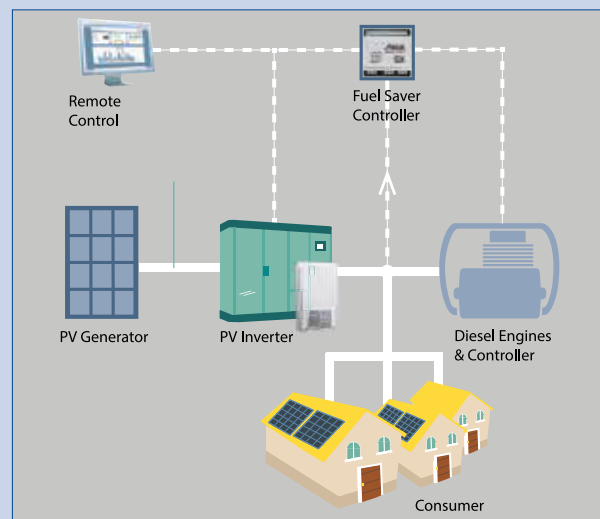


Fig. 8 – Topology of a Diesel-PV Hybrid System (Source: Fraunhofer ISE).

### SUBTASK 1b): "PV as Fuel Saver"

In the second work package, the research focus is on **bigger systems in the range of more than 100 kW which typically consist of a diesel generator supplemented by a small PV-component** (often not exceeding 20-25 % of the overall installed capacity) but without any battery component. The latter is not necessary since with a diesel generator being the "dominant part" no storage is required. For such types of systems, the potential of PV to support electricity generation is analysed. The work starts with a literature research to analyse state of the art and countries relevant for the study. The objective here is to do a case study based simulation of a specific system as it is and as it could be if the PV generation part is increased. The analysis again includes parameters such as performance, grid stability, fuel consumption, load profile, maintenance effort and levelized cost of energy. A detailed catalogue of recommendations will be developed and be part of a final evaluation report for policy makers and utilities including critical preconditions for system improvement, an overview on existing tools, e.g. HOMER and others and a flowchart for decision making.

### SUBTASK 2: Deployment of 100 % Renewables in (Small) Island States

Being a hotly debated topic, this Subtask is attracting increasing interest in the research community. A number of small-island countries, e.g. Cook Islands have ambitious 100 % RE targets, while many others have high targets such as 60 to 80 %. In most of the countries the



Fig. 9 – Fixing of a PV system in a Pacific Island (Photo: GSES).



Fig. 10 - PV training in Ghana (Photo: GSES).

objective is to reduce their dependency on imported fossil fuels, in particular diesel, for electricity generation. Targets often being set by politicians, the relevant Government departments and utilities are then "left alone" with the task to identify and address all the technical and non-technical requirements to meet the target. This Subtask will collect documentary evidence of the technical and non-technical (social, economic and regulatory) issues that have been identified and addressed in small island countries that are working towards 100 % RE targets. A series of case studies will be compiled. The areas to be addressed in a final guideline will include: penetration level of different renewable energy technologies, size of systems and the required land areas, energy storage, grid stability and control requirements, ownership of systems, power purchase agreements, tariff structure, regulatory requirements, capacity building, community and social issues. Gathering case study data and collating the information in a suitable format will provide guidance for other small island countries.

#### SUBTASK 3: Guideline to Introducing Quality Renewable Energy Training Programs

Under this Subtask which is almost accomplished, a guide has been developed for the RE industry, multi-lateral and bi-lateral donors and government ministries/departments that want to introduce competency based quality RE training programs for technicians into a country or region. The guide provides an overview of:

- 1) Quality training frameworks;
- 2) The processes involved in developing competency based quality-training programs; and
- 3) The capacity building requirements for the technical and vocational education sector.

It supports stakeholders in identifying the best way to introduce RE courses into an existing quality training framework or, if one does not exist, to establish a process whereby the training being provided is following quality procedures. The guide concludes with a recommendation that the global RE industry should consider the introduction of an international framework that would provide a mechanism for renewable energy training programs to be accredited by a third party.



Fig. 11 - Solar rooftop system (Photo: Greenpeace).

#### SUBTASK 4: PV Development as Prosumers

Under PVPS Task 1, a study on this topic was concluded in 18 industrialised countries. The objective of Task 9's fourth Subtask is to broaden the study scope by including emerging and developing countries. A few countries (or cases) already having in place or intending to establish a net metering policy are selected; e.g. Philippines, Malaysia, Tunisia, Morocco, Ghana, Cape Verde, Sri-Lanka. They reflect problems as well as success stories but also schemes of different scale. The conceptual phase is important to well identify partners (e.g. ECREEE, GIZ, IRENA, ARE, CLUB ER, ASEF, etc.), understand the needs of developing countries interested in prosumers development in terms of knowledge transfer and capacity building e.g. Ivory Coast, Senegal, Tanzania, and to define the target group/s and appropriate dissemination strategy for the deliverables. The parameters to classify prosumers' regulatory and financial compensation schemes in the first set of countries (with net-metering in place) will be selected among the following: specific load profile, peak demand, existing regulatory framework, retail electricity price, institutional environment, revenue structure of energy utilities, estimated cost associated with T&D adjustment on the grid and level of access to finance. In the second set of countries (being at an early stage of developing net-metering policies), knowledge transfer and capacity building needs to encourage prosumers development have to be identified. This will be done through interviews with local stakeholders (ministries, regulatory agencies, utilities, banks, potential prosumers, PV producers / retailers). In these countries, the following parameters will be analysed: solar potential, urban growth, demographic projection, quality of electricity supply, generation mix, forecast load growth in urban area, energy efficiency, level of PV penetration.

Based on the analysis and comparison of different countries, a comprehensive evaluation will be made to identify main hindrances, best practices etc. The results being compared with those from the former study will be an excellent tool to facilitate N-S-S exchange. The study will reveal the importance of self-consumption compared to net-metering. The analysis mostly focuses on urban residential and commercial prosumers development. Finally, the idea is to develop a prospective view on the main opportunities and challenges arising from rapid urbanization in developing countries in terms of energy production and consumption schemes.





Fig. 12 – Task 9 members at their Meeting in Bad Hersfeld, Germany, September 2016.

### SUBTASK 5: Outreach and Dissemination

In the current situation of strengthening Task 9 activities, of consolidating networks for outreach and for gaining new members to support Task 9, this Subtask of "outreach and dissemination" is of outstanding importance. Switzerland having the role of Operating Agent, leads this Subtask but also involves further Task 9 members wherever possible. The activities 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.

Under this Subtask 5, Task 9 experts also contribute to various standardization bodies and other working groups:

- **IEC 62109 (Safety of Charge Controllers)** within IEC-TC-82 (Solar PV energy systems): the overall goal is to separate requirements of inverters from those of charge controllers; DE, ES → work has started, T9 participation in 2 meetings in September 2016 Frankfurt.
- **Contribution to CIGRE, C6.28 WG;** DE, probably FI, NO, ES; review existing draft and write PV chapters (Hybrid Systems for off-grid power supply) → work has started, meeting August 2016, Paris.
- **Contribution to IEA working group 28** (IEA Wind Energy TCP), IEA PVPS Task 1, IEA PVPS, Task 13 and IEA PVPS Task 14; DE, DK, ES; content to be determined.

### PUBLICATIONS

#### PUBLISHED IN 2015/2016

- December 2015: "A User Guide to Simple Monitoring and Sustainable Operation of PV-diesel Hybrid Systems; Handbook for System Users and Operators".
- September 2016: "Deploying PV Services for Regional Development, Products and Future Activities of the IEA Working Group" in OTTI Conference Proceedings "International Conference on Solar Technologies & Hybrid Mini Grids".

#### PLANNED FOR 2017

- March 2017: "Guideline to Introducing Quality Renewable Energy Training Programs".
- December 2017: "Study on PV Development as Prosumers: the Role and Challenges Associated to Producing and Self-consuming PV Electricity".

### TASK 9 MEETING SCHEDULE (2015/2016 AND PLANNED 2017)

#### Concluded Activities 2015 / 2016

**45<sup>th</sup> IEA PVPS ExCo Meeting Paris**, France, 28-29 April 2015  
 IEA PVPS & Günder Workshop Istanbul, Turkey, 27 October 2015;  
 Task 9 OA participation  
**45<sup>th</sup> Task 1 Meeting Istanbul Turkey**, 27-30 October 2015;  
 Task 9 OA participation  
**46<sup>th</sup> IEA PVPS ExCo Meeting Daegu**, Korea, 10-11 November 2015;  
 Task 9 OA participation  
**47<sup>th</sup> IEA PVPS ExCo Meeting Leuven**, Belgium, 26-27 April 2016;  
 Task 9 OA participation  
**48<sup>th</sup> IEA PVPS ExCo Meeting Vienna**, Austria, 15-16 November 2016;  
 Task 9 participation

#### Organized by Task 9 and/or Task 9 contribution:

**IEA PVPS Task 9 Workshop**, Zurich, Switzerland, 29 February 2016  
 Virtual Meeting on Subtask "100 % Renewables in Island Countries", 16 June 2016

**Task 9 Side Event at the OTTI Conference**, "International Conference on Solar Technologies & Hybrid Mini Grids to Improve Energy Access", 20 September 2016

**PVPS Workshop at PVSEC 26**, Singapore, Task 9 represented by Katarina Uherova Hasbani / ARE, 26 October 2016

#### Task 9 Working Meetings

**Task 9 Experts Meeting**, Istanbul, Turkey, 30 October 2015  
**Task 9 Experts Meeting**, Zurich, Switzerland, 1 March 2016  
**Task 9 Virtual Experts Meeting**, 4 May 2016  
**Task 9 Experts Meeting**, Bad Hersfeld, Germany, 20 September 2016

#### Planned 2017

**Task 9 Experts Meeting**, Dusseldorf, Germany, 13 March 2017

TABLE 1 – TASK 9 PARTICIPANTS

COUNTRY	NAME	AFFILIATION
Australia	Geoff Stapleton	GSES
China	Zhao Dongli	Beijing Corona
Denmark	Peter Ahm	PA Energy Ltd.
Finland	Christer Nyman	Soleco Oy
France	Anjali Shanker	IED
France	Elodie René	IED
France	Jean-Christian Marcel	MJC PV Consulting on behalf of IED
Germany	Georg Bopp	Fraunhofer ISE
Germany	Michael Müller	STECA
Germany	Caspar Priesemann	GIZ
Germany	Roland Rösch	IRENA, Bonn
Japan	Takayuki Nakajima	Japan Photovoltaic Energy Association (JPEA)
Japan	Masanori Ishimura	NEDO
Norway	Kirsten Ulsrud	University of Oslo
Spain	Xavier Vallvé	TTA, Trama TecnoAmbiental, Spain
Spain	Alberto Rodriguez Gomez	TTA, Trama TecnoAmbiental, Spain
Spain	Vicente Salas	Universidad Carlos III de Madrid (UC3M)
Sweden	Frank Fiedler	Dalarna University
Sweden	Caroline Bastholm (Nielsen)	Dalarna University (SERC)
Switzerland	Stefan Kessler (OA)	INFRAS, Research and Consulting
Switzerland	Hedi Feibel (OA)	SKAT Consulting Ltd.
Turkey	Muhyettin Sirer	UNDP
Turkey	Yesilata, Bulent	Gunder
Turkey	Kemal Gani Bayaktar	Gunder, Izocam
Austria, SE4ALL	Martin Niemetz	Country Action Officer, SE4ALL, GFT

- 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

### 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. Sustainable management of the material flows are a precondition for further advancement of the technology, leading to additional efficiency increases, cost reductions and creating new value chain segments, e.g. at end-of-life through secondary resource recovery and recycling. The photovoltaics industry – as well as a growing number of regulatory, societal and scientific stakeholders –, 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, yielding greater need for and importance of health and the environmental issues for PV.

### OVERALL OBJECTIVES

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

The overall objectives of Task 12 are to:

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

The first objective is served with Life Cycle Assessment (LCA) that describes energy, material and emission flows in all stages of the life cycle of PV. The 2nd objective is accomplished by proactive research and support of industry-wide activities (e.g., input to industry associations, such as SolarPower Europe or industry standardization activities to develop and help implementing voluntary or binding policies – such as WEEE and the Product Environmental Footprint Guidelines for photovoltaics in Europe and the development of a Sustainability Leadership Standard for Photovoltaic Modules in the United States). The 3<sup>rd</sup> 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 4<sup>th</sup> 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 34<sup>th</sup> IEEE Photovoltaic Specialists Conference (PVSC) in Philadelphia in June 2009, and supporting the 1<sup>st</sup> and 2<sup>nd</sup> International Conference on PV Module Recycling, in 2012 and 2013, hosted by EPIA and PV CYCLE.

Carrying on this long history, Task 12 embarked on a collaboration project with the International Renewable Energy Agency (IRENA) to develop an analysis of the global regulatory frameworks which affect the end-of-life management of photovoltaic panels. The study was complemented by the first ever global waste projection for PV panel waste streams until 2030 and 2050 based on a statistical model and analysis of existing failure modes in the field. The project concluded in the publication of a joint Task 12 – IRENA Report "End-of-Life Management: Photovoltaic Panels". The report was presented during a joint side event to the 2016 European PV Solar Energy Conference (EU PVSEC) in Munich, as well as during the 10<sup>th</sup> edition of the World Future Energy Summit in Abu Dhabi. This work will be followed by an additional report on the technical state-of-the-art in PV recycling technologies and a comprehensive patent analysis focusing on the unit operations of PV recycling in 2017.

Publications by Task 12 members include articles on the life cycle impact of recycling of PV panels and components as well as analysis of regulatory framework conditions in the context of waste classification and characterization of PV panels.



Fig. 1 – The latest generation, continuous processing reactor for the recycling of thin film solar panels at First Solar, Perrysburg Ohio, USA. PVPS Task 12 Experts visited this facility in September 2016.



Fig. 2 – The PVPS Task 12 Experts Meeting was hosted by First Solar at their Perrysburg, Ohio, USA manufacturing, research and recycling facility, September, 2016.

## 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 3<sup>rd</sup> 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 (Ferroni and Hopkirk, 2016) 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. Task 12 experts led the development of a comprehensive response to the Ferroni and Hopkirk journal article, which was published in the same journal as the original article so that readers can have a balanced – and corrected – understanding of the role of PV in providing energy to society (Raugei et al. 2016). This rebuttal of the Ferroni and Hopkirk paper is an important example of the usefulness of Task 12's methodology guidelines for net energy analysis in the context of providing unbiased and objective tools to policy makers and interested stakeholders to do a thorough and diligent technology assessment and comparison.

Increasing the accessibility of life cycle assessment and inventory data to satisfy the increasing attention broader stakeholder groups from governmental and non-state actors are giving to the PV technologies and their deployment, has also been a key objective of Task 12 from its beginning. The successful launch of a web-based GIS-LCA visualization tool, called ENVI-PV, marked an important milestone in this effort in 2016. The web-based tool will be further disseminated through integration in the new IEA PVPS website eventually. It can be accessed

at [http://viewer.webservice-energy.org/project\\_iea](http://viewer.webservice-energy.org/project_iea); a prominent link to this site will be developed on the PVPS website in 2017, as well as consideration of other hosting and branding options.

The support of the multi-year pilot project for the development of Product Environmental Footprint Category Rules for photovoltaic electricity generation according to the European Commission Environmental Footprint Guidelines has also been successfully progressed and the Technical Secretariat, led by IEA PVPS Task 12 co-operating agent Andreas Wade, has passed the final stakeholder consultation on the proposed category rules, as well as the independent Scientific Review by globally leading LCA researchers.

## SUBTASK 3: Safety

A comprehensive review report on fire safety standards for PV systems in various jurisdictions has progressed throughout 2016 and will be published in 2017.

## ACTIVITIES IN 2016

### SUBTASK 1: Recycling of Manufacturing Waste and Spent Modules

Andreas Wade, co-Operating Agent of Task 12 and Chairman of the SolarPower Europe Environmental Footprint Taskforce sustainability working group, and SolarPower Europe's representative to Task 12, is leading this Subtask. The publication of the first joint report with IRENA on the topic of end-of-life management of PV modules (Weckend, Stephanie, Wade, Andreas, Heath, Garvin, und Wambach, Karsten. "End-of-Life Management: Photovoltaic Panels", IEA PVPS Task 12 & IRENA, June 2016, Munich / Abu Dhabi) and the successful launch of the report during two high level events at the EU PVSEC in Munich (September 2016) and the World Future Energy Summit in Abu Dhabi (January 2017) completed a Subtask which developed the first ever global waste projection as well as a comprehensive review of the regulatory framework conditions for the management of end-of-life photovoltaic panels in major global PV markets. Developing an outlook on potential value creation out of high value recycling in the coming decades complemented the report and caught a lot of external attention during and after the launch event, with over 50 quotes in trade press and international media.

Task 12 is developing and has further progressed on additional projects about 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.



## 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, EPIA (now SolarPower Europe), the International Thin-Film Solar Industry Association (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. The Technical Secretariat successfully met the milestones outlined for 2016 by completing the final public consultation, an external scientific review, as well as the application of the draft category rules to current PV products.

Another project (Activity 2.1.d) within this Subtask area was 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 has been successfully completed and the web service has been launched in 2016. Eventually this service will be integrated into the new IEA PVPS website and make the information more widely accessible.

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 5-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.

By end of the third quarter of 2017, a comprehensive update to the Task 12 LCI report is planned. It will entail an update to the inverter life cycle inventory data – which has already been drafted, is currently under review and being commented on by the Task 12 expert group – will add sections covering:

- the inventory data for the recycling of PV modules, based on an investigation by Dr. Wambach, which will be completed in Q1 2017;
- the inventory data on water usage throughout the lifecycle of PV systems based on the analysis of NREL-collected data by treeze;
- an update of the inventory data of the global supply chain section, including an update of the Chinese grid mix and the multi-crystalline Silicon supply chain data out of China.

A response to a recent paper (Ferroni and Hopkirk, 2016) regarding the net energy of PV in Switzerland that has received some degree of attention for its negative findings was developed by a group of international experts in PV net energy and led by Task 12's expert, Marco Raugei. The rebuttal was published in *Energy Policy* (Raugei, Marco, Sgouris Sgouridis, David Murphy, Vasilis Fthenakis, Rolf Frischknecht, Christian Breyer, Ugo Bardi, u. a. "Energy Return on Energy Invested (ERoEI) for Photovoltaic Solar Systems in Regions of Moderate Insolation: A Comprehensive Response". *Energy Policy* 102 (March 2017): 377–84. doi:10.1016/j.enpol.2016.12.042.).

The Task 12 expert group has approved a new activity under this Subtask being an outcome of a long discourse among the participants on the social and economic aspects of photovoltaic technology deployment. In order to achieve a terawatt scale deployment of PV in the coming decade and tap the associated environmental benefits, it is important to consider PV's social and economic implications as they are relevant for decision makers and, under the right framework conditions, can be used as additional arguments to advocate in favor of PV deployment, or, conversely, help to inform through objective analysis debates about negative social or economic impacts that could thwart PV deployment. While interest on the socio-economic and social dimensions exists among various stakeholders, there is a need to better understand and critically evaluate the existing indicators and underlying assessment methodologies aimed at quantifying the socio-economic and social impacts of energy systems and, in particular, PV systems. Thus, a first initial work product has been approved by PVPS and included in the current Workplan – a report reviewing available methods for quantifying socio-economic and social aspects of photovoltaic technologies. The deliverable of this activity will be a publication offering a critical review of currently available methods, the alignment with selected criteria (such as capability of quantification; conformity with a life-cycle approach; peer review) and their applicability to PV.





Fig. 3 – PVPS Task 12 Experts reviewing environmental health and safety aspects of PV manufacturing in China.



Fig. 4 – PVPS Task 12 Experts Dinner on Jeju Island, South Korea, April, 2016.

### SUBTASK 3: Safety in PV Industry

This Subtask 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. Japan (Namakawa and Komoto) has been leading on this activity and the final report is expected by Summer 2017.

### GOVERNANCE, DISSEMINATION AND NEXT MEETINGS

#### Membership

Total membership stands now at ten countries and one industry association, with ~thirteen active experts. Inactivity by some members, delays in receipt of funding and other circumstances has limited progress on certain topics, but Task 12 has managed to maintain momentum.

#### 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. A new work item proposal from Korea was submitted to the IEC WG82 on the PV Sustainability and EHS risk assessment report/technical specification, which has led to the development of a first draft report on both topics, endorsing the work done previously by Task 12 (PV LCA Method Guidelines) and providing a comprehensive glossary of definitions and methods on these topics. The future development of this report – either into a technical specification or technical report -- will be discussed and evaluated by the project team (which includes two Task 12 experts – Sinha (USA) and Frischknecht (Switzerland)) and the Technical Committee within the IEC Working Group in the coming year.

2. ANSI – a new PV sustainability standard being developed in the USA following the American National Standard Institute (ANSI) process is nearing its completion. The last Joint (steering) Committee Meeting was held in October 2016 and the draft standard was sent for electronic balloting to all representatives of the Joint Committee by end of November 2016. Three Task 12 members are members of the Joint (steering) Committee (Heath, Wade, Sinha). The Sustainability Leadership Standard has developed a comprehensive framework for the establishment of product sustainability performance criteria and corporate performance metrics that exemplify sustainability leadership in the market. The standard covers the management of substances throughout the life cycle, preferable materials use with incentives for high value recycling of PV components, LCA (largely based on the Task 12 methodology guidelines), a framework for the assessment of energy efficiency and water use, as well as end of life management and recycling, and the evaluation of corporate responsibility of value chain partners.

### PLANS FOR 2017

2017 will see the completion of several important projects for Task 12 – including the report reviewing PV fire safety issues, PV recycling technology trends, LCI report expansion and update, LCA of PV recycling technologies, and the review of PV-relevant social and economic indicators and methods, amongst others.

In 2017, the new Task 12 Workplan will be developed for the next work period as agreed by the ExCo in October 2016 and shall accompany the change of the Task 12 title to "PV Sustainability". One focus area of the new Workplan will be the broadened approach with regard to sustainability analytics on socio-economic and social impact categories.

### PUBLICATIONS

IRENA and IEA-PVPS (2016), End-of-Life Management: Solar Photovoltaic Panels. International Renewable Energy Agency and International Energy Agency Photovoltaic Power Systems. ISBN 978-3-906042-36-7. IEA-PVPS Report Number: T12-06:2016. <http://iea-pvps.org/index.php?id=357>.

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 T12-06:2016, ISBN 978-3-906042-38-1.

Methodological guidelines on Net Energy Analysis of Photovoltaic Electricity, IEA-PVPS Task 12, Report T12-07:2016, ISBN 978-3-906042-39-8.

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.

Methodology Guidelines on Life Cycle Assessment of Photovoltaic Electricity, 2<sup>nd</sup> edition, IEA PVPS Task 12, International Energy Agency Photovoltaic Power Systems Programme. Report T12-03:2011. ISBN: 978-3-90642-01-5.

Life Cycle Inventories and Life Cycle Assessment of Photovoltaic Systems, International Energy Agency Photovoltaic Power Systems Programme. Task 12, Report T12-02:2011. ISBN: 978-3-906042-00-8.

Methodology Guidelines on Life Cycle Assessment of Photovoltaic Electricity, 1<sup>st</sup> edition, IEA PVPS Task 12, International Energy Agency Photovoltaic Power Systems Programme. Report 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. A few important papers in 2016 from Task 12 members include:

P Pérez-López, B Gschwind, P Blanc, R Frischknecht, P Stolz, Y Durand, G Heath, L Ménard, I Blanc. 2016. ENVI-PV: an interactive Web Client for multi-criteria life cycle assessment of photovoltaic systems worldwide. Progress in Photovoltaics: Research and Applications (Special Issue), DOI: 10.1002/pip.2841. <http://onlinelibrary.wiley.com/doi/10.1002/pip.2841/full>

Raguei M, Sgouris Sgouridis, David Murphy, Vasilis Fthenakis, Rolf Frischknecht, Christian Breyer, Ugo Bardi, Charles Barnhart, Alastair Buckley, Michael Carbajales-Dale, Denes Csala, Mariska de Wild-Scholten, Garvin Heath, Arnulf Jæger-Waldau, Christopher Jones, Arthur Keller, Enrica Leccisi, Pierluigi Mancarell, Nicola Pearsall, Adam Siegel, Wim Sinke, Philippe Stolz. 2016. Energy Return on Energy Invested (ERoEI) for photovoltaic solar systems in regions of moderate insolation: A comprehensive response. Energy Policy 102: 377-384. <http://dx.doi.org/10.1016/j.enpol.2016.12.042>

For more information, contact the Task 12 Operating Agent: Garvin Heath, National Renewable Energy Laboratory (NREL), USA and Task 12 co-Operating Agent: Andreas Wade, c/o SolarPower Europe, Strategy Committee, Belgium

## MEETING SCHEDULE (2016 AND PLANNED 2017)

In 2016, the **Task 12 Experts met** April 7-8 in Jeju Island, Korea, and September 7-8 at First Solar Manufacturing and Recycling Facility, in Perrysburg, Ohio, USA.

In 2017, **Task 12 will meet** March 15-17 in Madrid, Spain and the Task 12 Experts are scheduled to meet in Japan, in Autumn 2017.

TABLE 1 - TASK 12 PARTICIPANTS

COUNTRY	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 Comerç 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 Experts' Meeting at EURAC research, Bolzano, Italy, 6–8<sup>th</sup> April 2016 (Photo: Thomas Nordmann).

### INTRODUCTION

The PV community has a continued high interest in obtaining 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 current 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 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 Europe, Asia-Pacific, 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 analyzes the economic aspects of PV system performance and reliability. This has been achieved by reviewing current practices used in financial modelling of PV investments with focus on the input parameters reflecting 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 have been 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 and operation and maintenance costs. The questionnaire's results were presented at the European PVSEC 2016 conference in Munich and submitted for a peer-reviewed journal.

Based on the internal analysis, screening of the scientific literature and discussions with key stakeholders during a couple of public meetings, the current practices have been compared with available scientific data and state-of-the-art methods to identify important gaps. The main outcomes of this analysis are presented in a public report as general guidelines and recommendations on how to mitigate and hedge financial risks in a PV investment by selecting and utilizing appropriate and relevant technical assumptions in the financial models.

### SUBTASK 2: System Performance and Analysis

Entire PV systems and their performance are the focus of Subtask 2. 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. In addition, various stakeholders are involved as well. In fact, with PV becoming main stream, this base of stakeholders 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 2016:

- Subtask 2.1 – Performance Databases
- Subtask 2.2 – Improving Efficiency of PV Systems Using Statistical Performance Monitoring
- 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 large challenge to contribute substantial amounts of data for all countries of high PV market penetration.

Within Subtask 2.1, also 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 since 2015. Final yields are displayed by colour-encoding on a geographical map, using GIS (geographical information system). The lack of on-site irradiation data, however, means that performance ratio (PR) cannot be determined.

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 favor of performance accuracies: when looking at the mean of the performance distributions and their particular shape, dubbed "power of statistics". With targeting all countries in Western Europe to be included for this innovative approach, 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 "Improving Efficiency of PV Systems Using Statistical Performance Monitoring". This topic examines the use of advanced statistical methodologies to ascertain the existence of a fault, failure or loss of efficiency in a PV system. Current state of the art depends on simple comparative algorithms and the use of sensors to calculate efficiency based on irradiation and temperature conditions, such as the PR or temperature corrected PR. Four statistical methodologies developed by three research teams in different countries, Australia, Israel and the USA, are examined.

The Australian system uses freely available weather parameters including irradiation maps, system configuration and the AC parameters monitored at the grid interface in the resident electrical distribution panel to analyse system efficiency by simulating the yield based on the acquired parameters and comparing to actually produced yield. Statistical tools have been developed to analyse differences in production versus the simulation.

The first Israeli system uses machine learning algorithms on the day's hourly weather parameters acquired from a local publically available



weather server and hourly energy production reported by the inverter to ascertain daily state of health. This system works with no solar irradiation data. The second Israeli system uses clustering statistics to predict a future fault in the system based on system parameters and local weather predictions, using no solar irradiation data.

The system being developed in the USA is using neural networks to quickly ascertain when a fault is present. The use of statistical analysis on readily available parameters, with or without the use of any meteorological sensors, promises to offer quicker fault detection, even prediction in large plants and enable performance monitoring in small systems that cannot afford sensors.

In Subtask 2.3 the focus is on underlying technical considerations that affect uncertainty of predicted PV energy yield. The idea is to summarize uncertainties in life-time energy yield predictions of PV, address methodological considerations, provide numerical quantification of uncertainties and discuss combined uncertainties by means of Monte Carlo simulations. Additionally, the major sources of uncertainties as irradiation data or degradation and long-term stability will be reviewed and quantified using real data. The economic impact and how uncertainties are considered in modelling of financial risks are part of Subtask 1.

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 tests. 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 4<sup>th</sup> PV Performance Modelling and Monitoring Workshop in Cologne in October 2015 were compiled in a technical report and will be published in March 2017.

### 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 ratings; 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 today's 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 in order to 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 of PV modules aged multiple years for trends to identify the most common failures using visual inspection 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. Participants have collected and analysed field data of 1 200 PV modules from various sources with minimum two years field exposure. A database tool has been developed to aggregate and analyze the available field data. Figure 2 shows the occurrence of specific failure types of wafer-based silicon PV modules in different climate zones. Here, we find that moisture ingress and snail tracks are the prominent failure types for moderate climate, while defect frame is dominant for Si modules in cold & snow climate. The results of the visual inspection field data analysis are included in the technical report on *Assessment of PV Module Failures in the Field*.

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 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 and by drones, or single dismounted modules are scanned using a mobile test center on-site. The team has prepared a review of existing guidelines and best practices for recording and processing IR and EL images in the field, which will be published as a technical report in May 2017.

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 specific failures on the module's

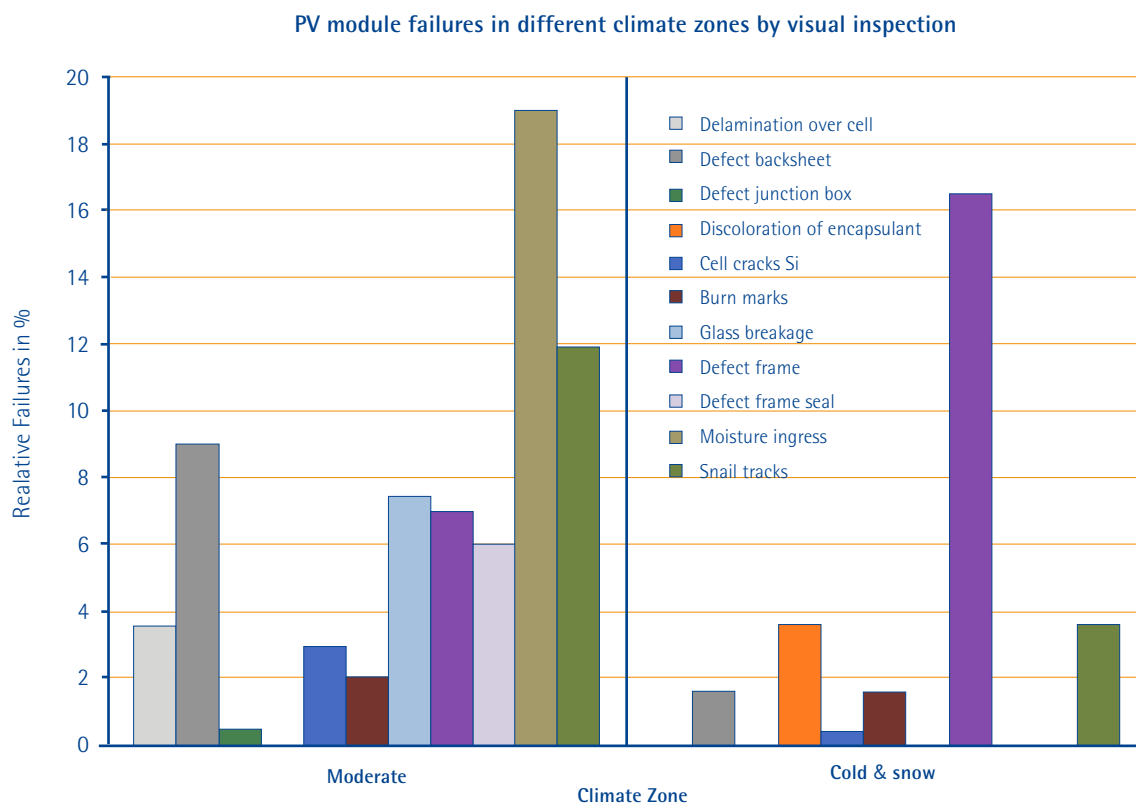


Fig. 2 - The occurrence of specific failure types of PV modules is documented as a function of the climate zone. The wafer-based silicon PV modules are operating in the field between 2 and 20 years prior to visual inspection.

performance, a survey on the impact of PV system failures in different climatic zones was conducted. The data was collected from various sources and 147 PV system failure reports have been included and analysed. The preliminary results of the survey were presented in a plenary paper at the European PVSEC 2016 conference in Munich. These results are evaluated to assess the relevance of standard test methods for the application of PV modules in different climate zones. Furthermore, the technical report on *Assessment of PV Module Failures in the Field* includes new test methods, which 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:

- Task 13 Workshop on *PV Module and System Performance & Reliability*, EURAC Research, Bolzano, Italy, 08 April 2016.
- SOPHIA Workshop on *Module Reliability*, AIT in Vienna, 28-29, April 2016: Task 13 talk on performance and reliability.
- Solar EXPO, Milan, Italy, 03-05 May 2016.
- 42<sup>nd</sup> IEEE PV Conference, Portland, Oregon, USA, 5-10 June 2016.
- EU PVSEC 2016, Munich, 20-24 June 2016: Task 13 scientific publications and presentations.
- EU PVSEC Parallel Event: PV Production, Quality, and Innovation Forum 2016 (*SOLARUNITED*).

- Intersolar exhibition 2016, Munich, 22-24 June 2016: New Task 13 flyer & Task 13 poster @ PVPS booth.
- SPI conference, Las Vegas, 12-15 September 2016: New Task 13 flyer distribution.
- 6<sup>th</sup> PV Performance Modelling and Monitoring Workshop, Fraunhofer Institute for Solar Energy Systems ISE, Freiburg, Germany, 24-25 October 2016.

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 (Figure 3). The updated Task 13 flyer is available electronically and in paper copy.

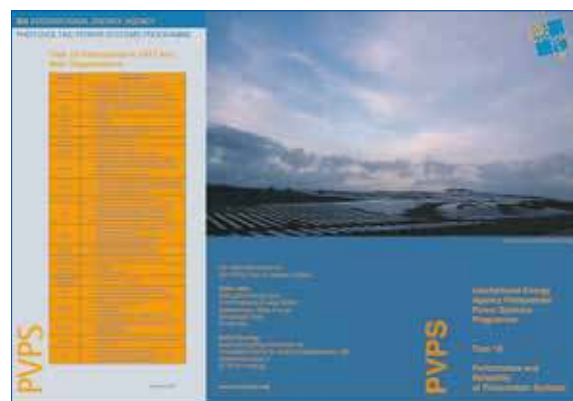


Fig. 3 - IEA PVPS Task 13 Flyer, version: January 2017.



Fig. 4 -150 participants from Europe, the US, Asia and Australia at the 6<sup>th</sup> PV Performance Modelling and Monitoring Workshop in Freiburg, Germany, 24-25 October 2016.

Fraunhofer Institute for Solar Energy Systems ISE, Sandia National Laboratories, and the IEA PVPS Task 13 have co-organized the "6<sup>th</sup> PV Performance Modelling and Monitoring Workshop" held in Freiburg, Germany, 24-25 October 2016. This workshop was very successful and each drew about 150 participants from industry, universities, and national research institutes from around the world. Topics that were presented and discussed included: solar resource uncertainty, PV forecasting, bifacial PV modules and systems, soiling and mismatch losses and modelling approaches, reviews of new features in PV performance models and updates on monitoring and model validation studies (Figure 4).

All publications and Task 13 presentations from both workshops held in 2016 are publicly available for download at the workshops section on the IEA PVPS website: <http://www.iea-pvps.org/index.php?id=165>.

Furthermore, Task 13 experts were invited to give presentations during the following international events and workshops in 2016:

- Task 13 Workshop on PV Module and System Performance & Reliability, EURAC Research, Bolzano, Italy, 08 April 2016.
- SOPHIA Workshop on Module Reliability, AIT, Vienna, Austria, 28-29 April 2016: Task 13 talks on:
  - PV Reliability addressed in Task 13
  - Assessment of PV reliability in EU Solar Bankability.
- EU PVSEC 2016, Munich, Germany, 20-24 June 2016 (1 plenary ST 3.4, 1 oral ST 1, 2 orals ST 2.1).
- EU PVSEC Parallel Event: PV Production, Quality, and Innovation Forum 2016 (SOLARUNITED): Task 13 talk and panel discussion.
- SAYURI-PV 2016, International Workshop on the Sustainable Actions for "Year by Year Aging" under Reliability Investigations in Photovoltaic Modules, AIST, Tsukuba, Japan, 4-5 October 2016: Task 13 talk on reliability.
- 6<sup>th</sup> PV Performance Modelling and Monitoring Workshop, Fraunhofer Institute for Solar Energy Systems ISE, Freiburg, Germany, 24-25 October 2016: 2 day-workshop with several talks on modelling, uncertainty and bifacial PV modelling & testing as well as panel discussion on monitoring & validation of modelling approaches and practices.

#### MEETING SCHEDULE (2016 AND PLANNED 2017)

**The 14<sup>th</sup> PVPS Task 13 Experts' Meeting** was hosted by EURAC Research and took place in Bolzano, Italy, 6-8 April 2016.

**The 15<sup>th</sup> PVPS Task 13 Experts' Meeting** was hosted by SANDIA and took place in Albuquerque, NM, USA, 27-29 September 2016.

**The 16<sup>th</sup> PVPS Task 13 Experts' Meeting** will be hosted by SUPSI and will take place in Lugano, Switzerland, 27-29 March 2017.

**The final PVPS Task 13 Experts' Meeting** will be hosted by TÜV Rheinland and will take place in Cologne, Germany, 10-11 October 2017.

## TASK 13 PARTICIPANTS IN 2016 AND THEIR ORGANIZATIONS

COUNTRY	ORGANIZATION
Australia	<ul style="list-style-type: none"> <li>CAT Projects, Desert Knowledge Precinct</li> <li>Murdoch University</li> <li>The University of New South Wales (UNSW)</li> </ul>
Austria	<ul style="list-style-type: none"> <li>Austrian Institute of Technology (AIT)</li> <li>Polymer Competence Center Leoben (PCCL) GmbH</li> </ul>
Belgium	<ul style="list-style-type: none"> <li>3E nv/sa</li> <li>KU Leuven</li> </ul>
China	<ul style="list-style-type: none"> <li>Institute of Electrical Engineering, Chinese Academy of Sciences (CAS)</li> </ul>
Denmark	<ul style="list-style-type: none"> <li>Silicon &amp; PV Consulting</li> </ul>
Finland	<ul style="list-style-type: none"> <li>Fortum Power &amp; Heat Oy</li> <li>Turku University of Applied Sciences</li> </ul>
France	<ul style="list-style-type: none"> <li>Commissariat à l'Énergie Atomique et Énergies Alternatives/ Institut National de l'Énergie Solaire (CEA - INES)</li> <li>Electricité de France (EDF R&amp;D)</li> </ul>
Germany	<ul style="list-style-type: none"> <li>Fraunhofer Institute for Solar Energy Systeme (ISE)</li> <li>Institute for Solar Energy Research Hamelin (ISFH)</li> <li>TÜV Rheinland Energy GmbH</li> </ul>
Israel	<ul style="list-style-type: none"> <li>M. G. Lightning Electrical Engineering</li> </ul>
Italy	<ul style="list-style-type: none"> <li>European Academy Bozen/Bolzano (EURAC)</li> <li>Gestore dei Servizi Energetici - GSE S.p.A.</li> <li>IMT Institute for Advanced Studies Lucca</li> <li>Ricerca sul Sistema Energetico - RSE S.p.A.</li> </ul>

COUNTRY	ORGANIZATION
Japan	<ul style="list-style-type: none"> <li>National Institute of Advanced Industrial Science and Technology (AIST)</li> <li>New Energy and Industrial Technology Development Organization (NEDO)</li> </ul>
Malaysia	<ul style="list-style-type: none"> <li>Universiti Teknologi MARA (UiTM)</li> <li>Universiti Teknologi Malaysia (UTM)</li> </ul>
Netherlands	<ul style="list-style-type: none"> <li>Utrecht University, Copernicus Institute</li> </ul>
Norway	<ul style="list-style-type: none"> <li>Prediktor</li> <li>University of Agder</li> </ul>
SOLARPOWER EUROPE	<ul style="list-style-type: none"> <li>SOLARPOWER EUROPE</li> </ul>
Spain	<ul style="list-style-type: none"> <li>DNV GL - Energy - Renewables Advisory</li> <li>National Renewable Energy Centre (CENER)</li> </ul>
Sweden	<ul style="list-style-type: none"> <li>ABB AB, Corporate Research</li> <li>Paradisenergi AB</li> <li>Solkompagniet</li> <li>SP Technical Research Institute of Sweden</li> </ul>
Switzerland	<ul style="list-style-type: none"> <li>Scuola Universitaria Professionale della Svizzera Italiana (SUPSI)</li> <li>TNC Consulting AG</li> </ul>
Thailand	<ul style="list-style-type: none"> <li>King Mongkut University of Technology Thonburi (KMUTT)</li> </ul>
USA	<ul style="list-style-type: none"> <li>Case Western Reserve University</li> <li>National Renewable Energy Laboratory (NREL)</li> <li>Sandia National Laboratories (SNL)</li> </ul>

Updated contact details for Task 13 participants can be found on the IEA PVPS website [www.iea-pvps.org](http://www.iea-pvps.org).



## 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 de-ployment of PV and avoid potential need for retroactive measures. Key issues in-clude 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 aug-mentation planning process and will allow PV to be fully integrated into power sys-tems, 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 and 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 level, but also on a countrywide level in more and more countries.

Following the wide scale deployment of grid connected PV in recent years, High Penetration PV has become a truly global issue today in regions around the world. This development is supported by significant technical advancements at the research as well as the industrial level. With PV becoming a game changer on the bulk power system level in several markets, new fundamental challenges arise, which are being addressed through global cooperation.

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.

Tackling these urgent issues, Task 14 addresses high penetration PV throughout 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 addresses primarily the technical issues of high penetra-tion of PV in electricity networks. Issues related to implications of high-penetration PV on the level of electricity markets are considered in close cooperation with PVPS Task 1.

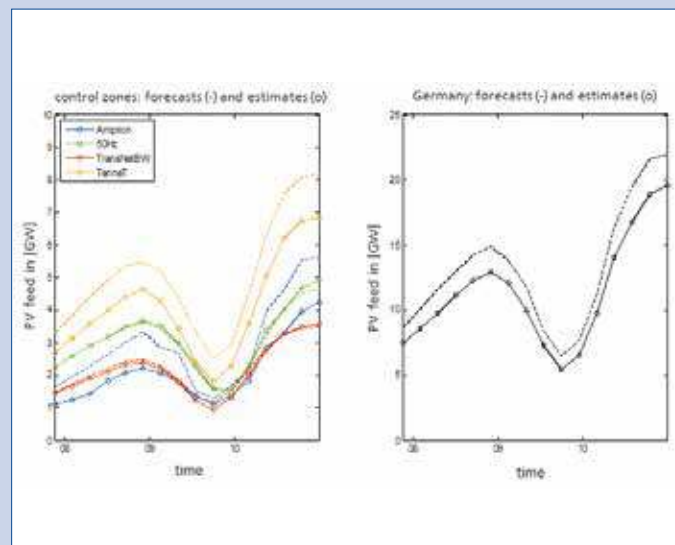


Fig. 1 – How an energy supply system with a high PV share handled a solar eclipse – Comparison of the PV feed in and day-ahead forecast for the individual control zones of the four German TSOs (left) and for all of Germany (right) (Source: Fraunhofer IWES).

Technical issues which are covered by the Task 14 work programme include energy management aspects, grid interaction and penetration related aspects related to local distribution grids and central PV generation scenarios. Besides these grid-focused aspects, requirements for components such as PV power converters acting as the smart interface between the PV generator and the electricity grid will be covered.

As the smart grid integration of decentralised solar PV is highly dynamic and strongly interlinked with the development of (future) smart grids, this aspect has been inte-grated in Task 14's work programme.

### PROGRESS AND ACHIEVEMENTS

The massive deployment of grid-connected PV in recent years has brought PV pene-tration 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 de-mand-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.

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

- In May, 2016, IEA PVPS Task 14 together with IEA Wind Task 25 organized a joint workshop at the premises of energinet.dk (Danish Transmission System Op-erator) in Fredericia, Denmark. The one day event audience consisted of experts, representing utilities, consulting companies, funding agencies, regulators, re-search agencies and mostly international members of the IEA PVPS and IEA WIND TCPs.

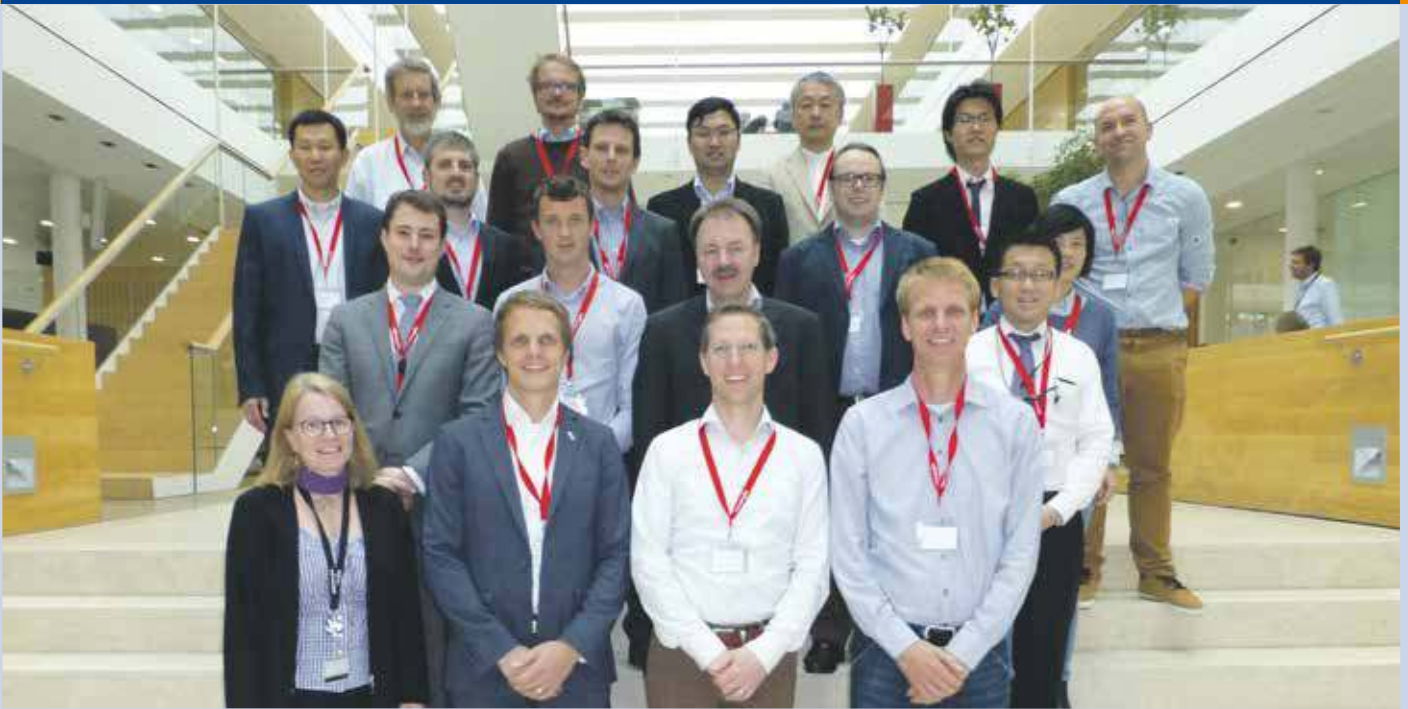


Fig. 2 - Task 14 Experts at Meeting in Fredericia, Denmark (Photo: IEA PVPS Task 14).

As an outcome of the workshop, the work on a joint publication between IEA PVPS and IEA WIND on "Recommended Practices for Integration Study Method-ologies" (IEA WIND RP16 update together with PVPS) has been initiated. A joint document is expected to be released in 2017, bringing together experiences from the wind and PV sector.

- In November 2016, Task 14 supported the 6th Solar Integration Workshop, held in Vienna, Austria by organizing a conference session on "PV Grid Integration". The topics addressed by Task 14 presentations included
  - Innovative Transmission System Operation of Transmission Level with Generation Forecast and Innovative Flexibility Resources.
  - Actual Potential of Grid Support Functions to Enhance the Hosting Capacity of Distribution Networks with a High PV Penetration
  - Latest Grid Code Developments in Europe and Selected International Markets with Respect to High Penetration PV
  - Automated Grid Planning for Distribution Grids with Increasing PV Penetration
  - Country Case Studies from Japan and the U.S.A.

Task 14 Workshop presentations 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 2017

Task 14 activities in 2017 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 2017.
- 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 Workplan for Task 14. In addition, a number of PV industry and utility representatives also directly participate in the Task 14 group.

Besides the country participation, 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 2016, Task 14 published 1 official report:

- How an Energy Supply System with a High PV Share Handled a Solar Eclipse, Report IEA-PVPS T14-06:2016
- 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.
- March 2016: Photovoltaische Solarenergie Bad Staffelstein: Wie groß sind die Schwankungen des Solarstroms im Netz?, (J. Remund, Meteotest)
- October 2016: Singapore International Energy Week (SIEW), Asia PVSEC: Building Integration of PV and High Penetration of PV in Electricity Grids, Task 14 @ PVPS Workshop (C. Mayr, OA)



Fig. 3 - Task 14 Session at Solar Integration Workshop Vienna  
(Photo: IEA PVPS Task 14).

- October 2016: Singapore International Energy Week (SIEW), Asia PVSEC: The Role of Grid Codes in the Sustainable Grid Integration of PV - Latest De-velopments in Europe and Worldwide (R. Bründlinger, Subtask 4)
- November 14, 2016: Solar Integration Workshop, Vienna, Austria: IEA PVPS Task 14 Session
  - Survey and Case Study of Innovative Transmission System Operation of Transmission Level with Generation Forecast and Innovative Flexi-bility Resources, K. Ogimoto et.al. (Subtask 3)
  - A Comprehensive Study on the Actual Potential of Grid Support Func-tions to Enhance the Hosting Capacity of Distribution Networks with a High PV Penetration, B. Bletterie, et.al. (Subtask 2)
  - Review and Assessment of Latest Grid Code Developments in Europe and Selected International Markets with Respect to High Penetration PV, R. Bründlinger (Subtask 4)
  - Automated Grid Planning for Distribution Grids with Increasing PV Penetration, A. Scheidler et.al. (Subtask 2)
  - Progress and Future of Japan's PV Deployment, K. Ogimoto, (CC Subtask)
  - Managing Integration of Distributed PV in North America, T. Key (Sub-task 2)
- November 16, 2016. Wind Integration Workshop, Vienna: Contribution to IEA Wind Task 25 session: Survey and Case Studies of Transmission Level PV Integration Assessments Utilizing Generation Forecasts and Innovative Flexi-bility Resources, K. Ogimoto et.al. (Subtask 3)

Presentations of all Task 14 events organised so far are publicly available for down-load 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. These events will be announced on the IEA PVPS website.

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 (2016 AND PLANNED 2017)

### 2016 Meetings

**The 13<sup>th</sup> Experts' Meeting** was held in Fredericia, Denmark, May 2016, host-ed by energinet.dk.

**The 14<sup>th</sup> Experts' Meeting** was held in Singapore, October 2016, hosted by Solar Energy Institute of Singapore (SERIS).

### 2017 Meetings (tentative)

**The 15<sup>th</sup> Experts' Meeting** is planned to be held in Washington DC, U.S.A, June 2016, hosted by EPRI and NREL.

**The 16<sup>th</sup> Experts' Meeting** is planned to be held in Amsterdam Sept 2017, joint meeting with PVPS Task 16.



Fig. 4 - IEA PVPS Task 14 Organization.

TABLE 1 – LIST OF TASK 14 PARTICIPANTS 2016 (INCLUDING OBSERVER)

COUNTRY	PARTICIPANT	ORGANISATION
Australia	Iain McGill	University of NSW
	Anna Bruce	University of NSW
	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	Kenenergy
EC	Arnulf Jäger-Waldau	European Commission
Finland	Jesse Kokkonen	ABB
Germany	Gunter Arnold	Fraunhofer IWES
	Martin Braun	Fraunhofer IWES
	Markus Kraiczy	Fraunhofer IWES
	Thomas Stetz	Fraunhofer IWES
	Daniel Premm	SMA Solar Technology AG
	Gerd Heilscher	Hochschule Ulm
Israel	Moshe Ohayon	Israel Electrical Company
Italy	Giorgio Graditi	ENEA-Portici Research Centre
	Adriano Iaria	RSE
	Daniele Bacchiocchi	GSE – Gestore Servizi Energia
Japan	Ken Obayaski	NEDO
	Koichi Asano	NEDO
	Kazuhiko Ogimoto	The University of Tokyo
Malaysia	Azah Ahmad	SEDA
Portugal	Catarina Calhau	EDP Energias de Portugal
Spain	Ricardo Guerrero Lemus	University of La Laguna
Sweden	Antonis Marinopoulos	ABB Corporate Research
Switzerland	Christof Bucher	Basler Hofmann
	Lionel Perret	Planair SA
	Pierre Renaud	Planair SA
	Davy Marcel	Planair SA, Switzerland
	Jan Remund	Meteotest
United States	Benjamin Kroposki	National Renewable Energy Laboratory NREL
	Barry Mather	National Renewable Energy Laboratory NREL
	Ben York	EPRI
Singapore (observer)	Thomas Reindl	SERIS
	Yanqin Zhan	SERIS



## TASK 15 – ENABLING FRAMEWORK FOR THE ACCELERATION OF BIPV



Fig.1 – Office Väla gård, Helsingborg, Sweden (Photos: Klas Andersson – Skanska).

### 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 might 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 there has to be a 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, avoiding transportation and storage losses and solving the challenges of climate change and energy shortage. To facilitate large-scale introduction of these systems, integration in the built environment is necessary. On the track towards large-scale introduction, five key developments are necessary; price decrease, efficiency increase, storage, improved durability, and building integration.

Building Integrated PV (BIPV) systems consist of PV modules doubling as construction products, which are integrated in the building envelope as part of the building structure, replacing conventional building materials and contributing to the aesthetic quality of the building as an architectural component.

Current BIPV technology has a small market share, 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 broken down.

### 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. These thresholds are reflected in the key developments 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 five Subtasks has been developed, focused on growth from prototypes to large-scale producible and applicable products. The Subtasks with their target audiences are:

- A. BIPV project database - Designers and architects;
- B. Economic transition towards sound business models - Business developers / project managers;
- C. International harmonization of regulations - BIPV product manufacturers / installers;
- D. BIPV environmental assessment issues - Policy makers, building environmental assessors;
- E. Applied research and development for the implementation of BIPV- Researchers, BIPV product developers;

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

### ACTIVITIES OF IEA PVPS TASK 15 IN 2016

#### SUBTASK A: BIPV Project Database

Subtask contact persons from all participating countries have been requested to provide ten BIPV projects each that are representative for their country and suitable for international comparison and dissemination. Twelve countries have responded at the moment of writing, and in total, over 145 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 is written and sent around for comments. Based on the comments received, the questionnaire was updated and finalized. The questionnaire is used as a guideline for in-depth project interviews. Each participating country was asked to deliver one project with in depth interviews by the 3<sup>rd</sup> Task Experts' Meeting (November 2016). By the end of 2017, all participating countries will have 3 full project inventories, of which a selection will be part of a publication.

#### 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.



Fig. 2 - New Hotel with black PV façade, Aarhus, Denmark (Photos: Karin Kappel / Arkitema).

Several conceptualizations and decisions were made during 2016:

1. Choice of representative BIPV [solutions/application] sets:
  1. Residential house rooftop
  2. Tertiary building cold façade (double skin)
  3. Industrial/Commercial "light construction" roof
2. For each represented country, Subtask B participants volunteer to select 1 existing project belonging to the chosen BIPV [solutions/application] sets and applicable to mass deployment + to document it in full to complement Subtask A as input to B.2
3. Analysis of economic/non-economic barriers to BIPV implementation (financial, regulatory, social, behavioural, etc.) as inputs to the design of innovative Business Models.
4. Use of Business Model Canvas to support the creative process (already used in PVPS T9)
5. Use of "Onedrive" as a sharing tool among Subtask B participants. Once documents are final, they are transferred to Task 15 intranet.
6. Bimonthly plenary conference call for all Subtask B participants

Subtask B is further sub-divided into four activities.

#### B.1 - Analysis of Status Quo

This activity 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 activity 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 (BM) that prevails for establishing the financial viability of the solution.

- Case gathering started according to decision made for each Subtask B participant. An Interview guide to complement Subtask A cases has been developed, and discussed in the Subtask B participant group.

#### B.2 - Analysis of Boundary Conditions

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

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

- Further develop gathered cases in activity B1. First half of 2017.

#### B.3 - Development of New Business Models

This is the core activity 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.

- BM framework under consideration.

#### B.4 - Testing the New Business Models

This activity 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

At the November Task 15 Experts' Meeting in Marrakesh, the division of work in Subtask C into activities was clarified. The activities and their modified titles are thus:

#### C.0 - International Definition of "BIPV"

In this activity, initial activities are based on the following definition (based on EN 50583 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."

As agreed at the Task 15 Experts' Meeting in February 2016, working definitions to distinguish between BIPV products and BIPV systems were formulated as follows:

A BIPV product is the smallest (electrically and mechanically) non-divisible photovoltaic unit in a BIPV system which retains building-related functionality.

A BIPV system is a photovoltaic system in which the PV modules satisfy the definition above for BIPV products. It includes the electrical components needed to connect the PV modules to external AC or DC circuits and the mechanical mounting systems needed to integrate the BIPV products into the building.

### C.1 – Analysis of User Needs for BIPV & BIPV Functions

### C.2 – BIPV Technical Requirements Overview

### C.3 – Multifunctional BIPV Evaluation

Within these three activities, which are strongly interconnected, separate Excel overviews of requirements for BIPV products and BIPV systems have been prepared in several iterations by Subtask C participants. Technical requirements from the four reviewed standards (EN 50583:2016, ISO FDIS 18178, IEC 62980 and IEC 82-10-55-NP) were included in these overviews. The following technical requirements were identified:

- Mechanical resistance and stability
- Safety in case of fire
- Hygiene, health and the environment
- Safety in use
- Protection against noise
- Energy economy and heat retention
- Sustainable use of natural resources
- Electrical properties
- Durability/Reliability/Water tightness/Air tightness
- Seismic resistance
- Other (e.g. for bifacial or curved modules)

Japanese participants have proposed and applied a classification scheme for the technical requirements and their relevance to different types of standards and technical guidelines at the international, national and regional level. The categories are:

- I. (Internationally mandatory for any category of BIPV)
- II. (Internationally mandatory for each material category of BIPV products)
- III. (Internationally mandatory for each structural application of BIPV systems)
- IV. (Local requirements for BIPV products and systems)
- V. (Not mandatory for BIPV product certification, but useful to characterize BIPV)
- VI. (Not mandatory for BIPV product certification, but useful to design BIPV)
- VII. (Others)

As a basis for reporting the recommendations of Subtask C on standards and guidelines addressing BIPV, contact has been established with ISO TC 160 (Glass in building) and IEC TC82 (Solar photovoltaic energy systems).

### C.4 – Suggest Topics for Exchange between Different Standardization Activities at the International Level

The next planned steps in Subtask C are:

- Identify expectation of other Subtasks, particularly Subtask A, for output of C.1
- Prepare draft reports for C.0 and C.1
- For C.2, prepare and conduct a third iteration to revise the existing systematic overview on the regulations, standards and requirements with relevance for BIPV, requesting participants to add further existing standard that may be useful for BIPV product and application
- Use contacts to ISO TC 160 and IEC 82 to identify potential for introducing requirements to international standards
- Collate experience with implementation of EN 50583
- To proceed with C.3:
  - Identify groups of products and applications based on a list of examples and products from Subtask A
  - Define evaluation schemes for the groups of applications
  - Specify test and calculation methods for the different groups

### SUBTASK D: Environmental Benefits of BIPV

29 persons from 12 countries have indicated participation in this Subtask, and have been contacted. Many of them are implicated as informative persons, and 11 persons (five countries) will be involved in this work as supportive persons. 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 (December 2015). The state of the art, realized by University of Applied Sciences Technikum Vienna and by Cycleco, regarding different existing environmental assessment guidelines for both PV and building elements is finalized (however, participants comments may still result in changes). The second stage of the BIPV environmental monitoring is in progress. This stage concerns the development of a methodology allowing a consistent environmental assessment at international scale. In order to create a robust international guideline, participant's contribution is essential. The development of the environmental assessment methodology for BIPV led by Cycleco follows 4 steps;

1. In order to not omit crucial elements, Cycleco and University of Applied Sciences Technikum Vienna suggest a first draft of the methodological guidelines including a detailed product description and the important steps leading to the BIPV environmental assessment.
2. Participants involved in this Subtask share their inputs to complete the draft.
3. A strong collaboration with IEA PVPS Task 12 – PV Environmental, Health And Safety (E,H & S) Activities is intended to combine the knowledge base concerning environmental assessments for PV, Buildings and BIPV.
4. Cycleco and University of Applied Sciences Technikum Vienna adapt and finalize the guidelines.



Fig. 3 - Task 15 Experts at the Task 15 Meeting in France, February 2016.



Fig. 4 - Task 15 Experts at the Task 15 Meeting in Morocco, November 2016.

### SUBTASK E: Applied Research and Development for the Implementation of BIPV

35 people from 11 countries are involved in Subtask E. Subtask E aims on strengthening applied research in the field of BIPV to accelerate the development and the implementation of BIPV demonstration projects. The Subtask is split into five different activities. Activity E 1 "Inventory of Existing Test Sites" and Activity E 2.1 "Identification of BIPV-Outdoor Test Facilities" within Subtask E 2 "Comparison Field and Reliability Tests" have been of major interest. In a combined effort and questionnaire, information from 29 nations concerning their test and research institutions was collected, and in addition 17 institutions delivered information concerning their BIPV outdoor test facilities. These findings are summarized within the report "BIPV Research Teams & BIPV R&D Facilities: An International Mapping". This report is to be balloted by the Task members at the 4<sup>th</sup> Task Experts' Meeting in March 2017 and serves as final deliverable for Subtask E 1 and Subtask E 2.1

The planned additional steps for Subtask E can be extracted from the list below:

E1.: Inventory of Existing Test Sites

Work Completed

E2.: Comparison Field and Reliability Tests

E 2.1 Identification of BIPV-Outdoor Test Facilities

- Additional contributors (Singapore, Norway)
- Report: BIPV research teams & BIPV R&D facilities - An international mapping shall be done.

E 2.2 Round Robin – Strategy Discussion in Marrakech

- A methodology for a possible BIPV module round-robin will be developed
- Possibility will be evaluated and discussed during the coming Task 15 meeting

E 2.3 Investigation of Use Cases in the Different Member States

- Positive feedback on this idea during the last meeting in Marrakech
- Call for action will be sent out until the coming Task 15 meeting

E3.: Installation and Maintenance Issues

Real life installation and maintenance issues

Goal: Guide for best practice installation and maintenance of BIPV

E 3.1 Identify Contributors

- Work on the methodology and more detailed information
- Current action – call for contributors by country

E4.: Diversity of Products (Shape, colors, technologies, etc.)

Goal: Report on diversity of BIPV combined with international research and development needs in the field of BIPV

E 4.1 Investigation of International Market Needs in BIPV in Respect to the Diversity of Products (Work in progress)

- Presentation of the idea was given in the last meeting in Marrakech
- Idea of E.4. accepted and additional ideas were given by members of Subtask E
- Contributors were identified (EURAC, SUPSI, Sintef, OFI, Joanneum, FHTW, ERTX, etc.)
- Work on diversity of BIPV (color, shape, etc.) started – structure of the draft report expected next meeting

E5.: Performance Analysis (Monitoring & Evaluation)

Goal:

- Overview of lab simulation tools (software)
- Input for software distributions (planning and designing stage)
- Cross link for interdisciplinary solutions (LCA, optical, acoustics, etc.)
- A presentation about the idea of Subtask E 5 was given and first work steps have been evaluated
- A final structure for the Workplan in Subtask E 5 will be sent to the participating institutions and further steps will be discussed during the next meeting.



## TASK 15 ACTIVITIES IN 2016

FEB. 2016	2, 3, 4	France	Sophia Antipolis	Task meeting
APR. 2016	25, 26, 27	Belgium	Leuven	ExCo meeting
JUNE 2016	23	Germany	Munich	Task coordination meeting
	23	Germany	Munich	EU PVsec parallel session
OCT. 2016	28	Singapore	Singapore	PVsec Singapore task presentation
NOV. 2016	8.9	Morocco	IRESEN	Task meeting
	10	Morocco	Marrakesh	Task presentation at COP22
	14, 15, 16	Austria	Vienna	ExCo meeting
	23	the Netherlands	Veldhoven	SundayNL

## SUMMARY OF TASK 15 ACTIVITIES PLANNED FOR 2017

Task 15 general activity in 2017 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:

Interviewing the main actors of selected BIPV projects in Subtask A, resulting in 2/3 projects per country.

Analysis of the BIPV business models status quo in the participating country in Subtask B.

Finalizing the draft report on C.0 and C.1 in Subtask C.

Finalizing the report on D.1. in Subtask D.

Finalizing the report on E.1 and E.2 in Subtask E. Provide Subtask E3 main process to collect data.

## 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 (2016 AND PLANNED 2017)

**The 2<sup>nd</sup> Task 15 Experts' Meeting** was held in Sophia Antipolis, France, 2-4 February 2016.

**The 3<sup>rd</sup> Task 15 Experts' Meeting** was held in Munich, Germany, 23 June 2016

**The 4<sup>th</sup> Task 15 Experts Meeting** was held in Marrakesh, Morocco, 8-10 November 2016.

**The 5<sup>th</sup> Task 15 Experts Meeting** will be held in Madrid, Spain, 15-17 March 2017.

**The 6<sup>th</sup> Task 15 Experts Meeting** will be held in Uppsala, Sweden, 4-8 September 2017.

## Selection of Outreach Events 2016

March 25<sup>th</sup> 2016: Seminar in cooperation with Copenhagen Municipality about BIPV in urban areas, with focus on BIPV as new solutions for red tile roofs.

April 18<sup>th</sup> 2016: PowerPoint presentation about Task 15 held at IEA PVPS seminar, arranged by TEKNIQ and the Danish PV Association.  
May 3<sup>rd</sup> 2016: Conference with presentation of new BIPV products in Denmark with results from a 3-year poll in EUDP (The Danish Energy Agency), as part of Task 15.

November 11<sup>th</sup> 2016: Conference at Design Museum Denmark about new PV products and architectural integration, along with presentation of the winners in a competition for architect students in the Nordic countries about new ways to integrate solar, as part of Task 15.  
Austria's National Task 15 dissemination activities (2016):

- Poster Task 15 - OTTI Forum BIPV - 31.3.2016 - Kloster Banz Germany
- Presentation Task 15 - Victor Kaplan Lectures - Österreichs Energie, 16.06.2016
- Presentation Task 15 - Austrian TPPV Meeting 10.10.2016
- Presentation Task 15 - National IEA Network Meeting 2016, 10.2016
- Presentation Task 15 - Austrian PV conference 2016 (Lukas Maul / Dieter Moor), 11.2016
- Poster Task 15 ST E in cooperation with the national project PV@Fassade - Austrian PV conference 2016, 11.2016
- Presentation in Porsgrunn, Norway, as part of the national R&D project "Building Integrated Photovoltaics for Norway" ([www.bipvno.no](http://www.bipvno.no)), 21.11.16

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

COUNTRY	PARTICIPANT	ORGANISATION	COUNTRY	PARTICIPANT	ORGANISATION
Austria	Lukas Maul	University of Applied Sciences Technikum Wien	Korea	Jun-Tae Kim	Kongju National University
	Karl Berger	AIT - Austrian Institute of Technology - Energy Department		Jae-Yong Eom	Eagon Windows & Doors Co.
	Astrid Schneider	AIT - Austrian Institute of Technology - Energy Department	The Netherlands (OA and lead Subtask A)	Michiel Ritzen	Zuyd University of Applied Sciences, S-Built
	Gabriele Eder	OFI - Austrian Institute for Chemistry and Technology		Martje van Horrik	S-Built
	Susanne Woess- Gallasch	Joanneum Research		Tjerk Reijenga	BEAR-iD
	Gerhard Peharz	Joanneum Research	Norway	Anne Gerd Imenes	Teknova
	Philipp Rechberger	FH Upper Austria (formerly ASIc - Austrian Solar Innovation Centre)		Anna Fedorova	NTNU
	Dieter Moor	ERTEX Solar GmbH		Reidun Dahl Schlanbusch	SINTEF
Belgium	Patrick Hendrick	ULB-Aero-Thermo-Mechanics	Spain	Tore Kolas	SINTEF
Canada	Veronique Delisle	Natural Resources Canada		Nuria Martin Chivelet	CIEMAT
Denmark	Karin Kappel	Solar City Denmark		Estefania Caamano	Technical University of Madrid
	Kenn Frederiksen	Kenergy		Javier Neila Gonzales	
Germany (lead Subtask C)	Helen Rose Wilson	ISE Fraunhofer		Francesca Olivieri	
				Machado Maider	Tecnalia Research & Innovation
France (lead Subtask D and E)	Simon Boddaert	Division Energies Renouvelables / Innovation Photovoltaïque, Centre Scientifique et Technique du Batiment		Román Eduardo	
	Jerome Payet	Cycleco		Ana Belen Cueli Orradre	CENER
	Fanny Grange	Cycleco		Ana Rosa Lugas	
			Sweden (lead Subtask B)	Bengt Stridh	ABB / Mälardalen University
Italy	Francesca Tilli	GSE		Peter Kovacs	RISE
	Alessandra Scognamiglio	ENEA Research Center Portici		Martin Warneryd	RISE
	Laura Maturi	EURAC		Rickard Nygren	White arkitekter
	Stefano Avesani	EURAC		David Larson	Solkompaniet
	Nebosja Jakica	Politecnico di Milano, Architecture Dept.	Switzerland	Francisco Frontini	SUPSI
	Silke Krawietz	Silke Krawietz, SETA Network		Pierluigi Bonomo	
Japan	Hiroko Saito	Photovoltaic Power Generation Technology Research Association (PVTEC)	Egypt	Dr. Mariam Gabr Salim	Environment and Climate change Research Institute
	Hisashi Ishii	Research and Development Division LIXIL Corporation	Lithuania	Juras Ulbikas	PVTP Mirror group national representative
	Seiji Inoue	AGC Glass Building & Industrial General Division ASAHI GLASS CO., LTD	Morocco	Souad Lalami	IRESEN
			Singapore	Dr. Veronika Shabunko	Solar Energy Research Institute of Singapore (SERIS)
			South Africa	Stephen Koopman	CSIR Energy Centre

# AUSTRALIA

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

RENATE EGAN, CHAIR, AUSTRALIAN PV INSTITUTE

WARWICK JOHNSTON, SUNWIZ

Annual Installations by Sector (MW)

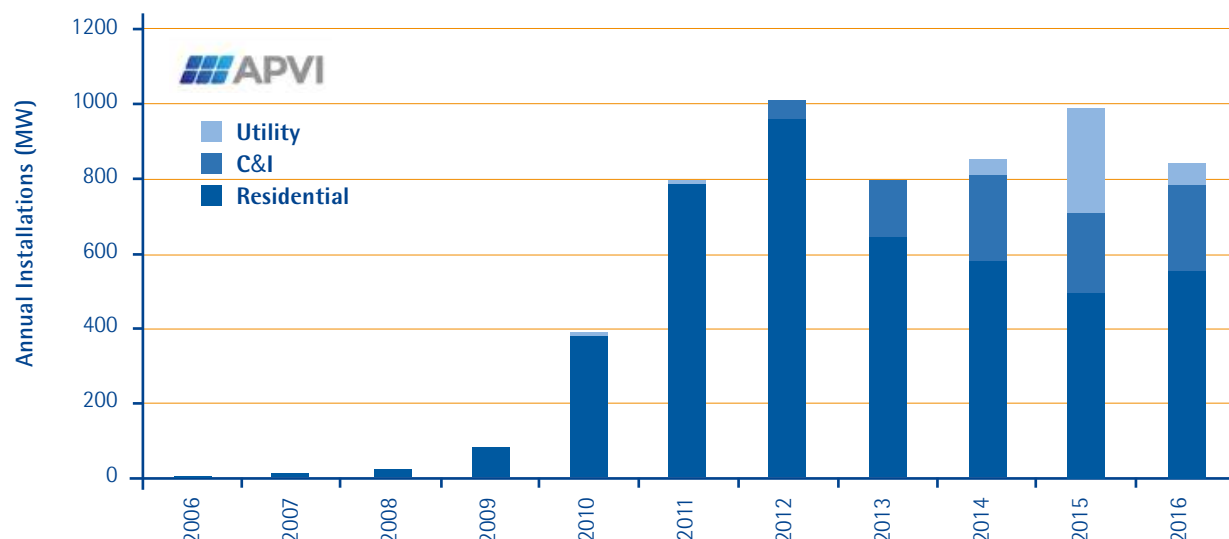


Fig. 1 - Historic trends in annual PV installations in Australia by sector.

## GENERAL FRAMEWORK AND IMPLEMENTATION

After a big year for utility scale solar in 2015 in Australia, the total new installations of solar fell in 2016 to 840 kW. Hidden in the total numbers is a recovery in residential solar installations (installations smaller than <10 kW) with 560 kW installed and continued growth in commercial and industrial (10-100 kW) to 220 kW installed. The ongoing price drops and investment programs by the Australian Renewable Energy Agency (ARENA) and Clean Energy Finance Corporation (CEFC), mean that there are a number of utility scale solar plants under development and a recovery of annual installations to over 1 GW can be expected in future years.

Over 1,6 million Australian homes are now powered by their own PV system. Residential penetration levels average over 20 % of households and reach over 50 % in some urban areas.

At the end of 2016, cumulative installed capacity was at the 5,9 GW mark. Solar continues to be supported with small and large generation certificates, but no new feed-in tariff incentives exist. A number of historic feed-in-tariff agreements have reached the end of their life, which is creating a new market for those early adopters who are looking at new investment opportunities.

A number of coal fired power plants have been retired, or are planned for retirement, leading to reductions in capacity and some instabilities in electricity supply. The lack of a long term energy policy inhibits investment in new generating technologies leading to increasing pressure on existing generators and concern over energy security. An extensive study by industry association Energy Networks Australia (ENA) and the government scientific laboratories CSIRO has concluded that Australia will be 100 % renewables by 2050 and that the energy industry must adapt quickly to accommodate the increased uptake of

renewables. The government has commissioned an independent review, the "Future Security of the National Electricity Market (NEM)", with the preliminary report pointing to a once-in-a-generation opportunity to reform the NEM, to make it more resilient to the challenges of change, and to enable the new and better services Australians want.

With residential electricity prices averaging more than 25 c/kWhr and peaking at over 50 c/kWhr (AUD = 0,7 USD) and ageing cold-fire power plants resulting in plant closures, Australia is well positioned to continue to be a strong market for solar. Battery suppliers have identified a significant opportunity for sales in Australia, owing to the high electricity prices, low feed in tariffs and grid challenges, with over 7 000 batteries installed in 2016 and over 20 000 expected to be installed in 2017.



Fig. 2 - Commissioning of the 2,3 MW Mount Majura Solar Farm Oct 2016 developed by Solar Fields and Solar Choice. The Farm uses horizontal single axis trackers with two x 1MVA transformers to connect into the adjoining 11kV distribution lines.

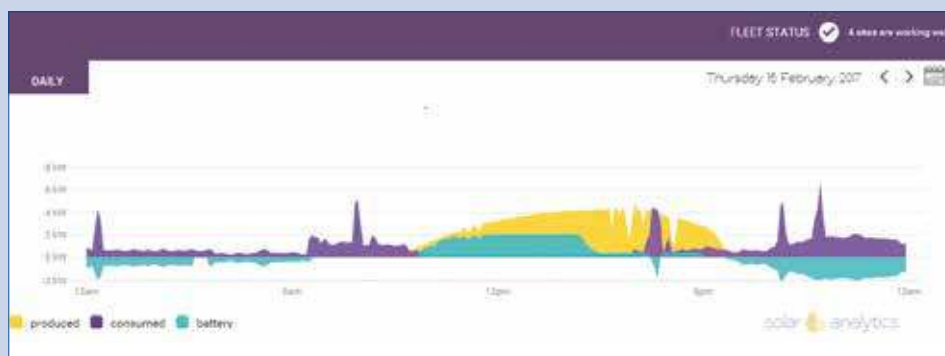


Fig. 3 - Data visibility is enabling new business models around demand management, power purchase agreements and peer-to-peer trading (Image: Solar Analytics).

## 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 ARENA committed 92 MAUD to support for twelve large scale solar farms, expected to result in the commissioning of 480 MW, creating in excess of 2 300 direct jobs. Once complete, the new solar farms will triple the amount of energy produced from big solar in Australia, powering 150 000 average Australian homes and meeting 10 % of the capacity build needed to meet the 2020 RET (renewable energy target), with all new plants expected to be operational by the end of 2017.

Deployment of large scale solar is increasingly being supported by the CEFC, a statutory authority established by the Australian Government. The CEFC works to increase the flow of finance into the clean energy sector by investing in a range of cleaner power solutions which can help reduce Australia's emissions, improve energy efficiency and lower operating costs. This includes large and small-scale solar, grid and storage projects.

## RESEARCH, DEVELOPMENT & DEMONSTRATION

PV research, development and demonstration are supported at the national, as well as the State and Territory level. In 2016, research was funded by the Australian Research Council, Co-operative Research Centres and ARENA. ARENA is the largest funder of photovoltaics research in Australia. 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 Melbourne, and one with the University of Queensland. Major projects supported included the establishment of the Australia-US Institute for Advanced Photovoltaics.

## INDUSTRY AND MARKET DEVELOPMENT

The decline in the PV market seen in 2016 was not unexpected, as the recovery in 2015 arose from the commissioning of the three utility-scale installations, with no significant new utility scale plant planned for 2016. Building on the ongoing reduction in hardware costs and growing local and international experience in utility scale solar, 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 commercial market in the 10–100 kW range had a slow start to the year, but finished strongly with a record 27 MW of systems in the 10–100 kW range installed in the month of December. As a result of the growth in commercial installations, the average system size climbed to a record high, finishing the year at 6,25 kW/system (for sub-100 kW systems) with greatest growth seen in the 75–100 kW range.

Average residential solar PV system prices have remained stable over the 2016 at around 1,62 AUD per Watt including STCs, or 2,40 AUD/Watt without STC support, consistent with 2015.

2017 is expected to see a recovery in large scale solar, with the deployment of projects funded under the ARENA competitive round. Residential solar is expected to remain stable, but may see some growth with interest in storage driving new investment. The commercial PV sector is anticipated to again grow by a modest amount.

Although not yet cost effective for most customers, a significant market for storage is developing in Australia, attracting new technology participants and new business models. 2016 saw 6 750 battery installations, or 52 MWh – up from 500 in 2015 and the 2017 market is expected to treble over the next 12 months.

As solar and solar plus storage becomes increasingly competitive, industry bodies and the government are actively looking at how to navigate the energy transformation that is happening faster than they had anticipated.

New business models around demand management, power purchase agreements and peer-to-peer trading are being tested by new enterprises and the utility sector is moving to new service offerings to maintain customers.

# AUSTRIA

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

HUBERT FECHNER, UNIVERSITY OF APPLIED SCIENCES, TECHNIKUM VIENNA



Fig. 1 - Vacuum Laminator for photovoltaic glass-glass module and smart glass production (Photo: LISEC Austria GmbH).

## GENERAL FRAMEWORK AND NATIONAL PROGRAMME

About 70-75 % of Austria's electricity supply is based on renewable energy, with large hydropower accounting for more than 60 %, wind energy at about 9 %, some bio-electricity and over the last few years there has been a significant increase in photovoltaics; at nearly 2 % in 2015. Austria has never produced electricity from nuclear energy and has a strong policy against nuclear. Austria is aiming at getting completely rid of fossil energy from the 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 has since been revised several times. The official market target is currently set at 1 200 MW in 2020.

A new "Technology Roadmap for Photovoltaics in Austria" published in its "business as usual scenario" a share of 4,8 % of the Austrian electricity demand covered by PV as well as a 15,3 % share in the accelerated scenario until 2030.

Approximately 937 MW of PV power was installed in Austria by the end of 2015. There are no final figures available yet for 2016, but it is expected that the installations in 2016 shall be within the same range as in previous years, leading to about 1,1 GW in total. With current installation rates, the official market target for 2020 will be reached easily within 2017.

Austria's support schemes for photovoltaics are manifold. Two support schemes are still dominating:

- The Feed-in-Tariff system is designed only for systems larger than 5 kWp. The Feed-in-Tariff is provided via the national green-electricity act; The "new RES" are supported by this act mainly through 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 2016, an additional 46 MEUR for all "new renewables" were available. Photovoltaics gets 8 MEUR out of that. 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 2016, the tariff was set at 8,24 EURcents/kWh for PV on buildings (11,5 EURcents/kWh in 2015) and no incentive for PV on open landscape. Higher than in 2015, an additional 375 EUR subsidy per kWp (or 40 % of total invest cost) was offered (2015: 200 EUR, max, 30 %).

In 2016, about 8,7 MEUR were dedicated to PV investment support for small systems up to 5 kWp by the Austrian "Climate and Energy Fund". This additional support scheme has existed since 2008 and is 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 2015. This support has led to about 7 100 new PV systems with a total capacity of



43,9 MWp in 2016. For the second 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) as other private owners, which might have led to approx. 15,3 MWp installed in 2016. Regions that participate in the Programme "Climate and Energy Pilot Regions" are eligible to get funding for PV installations that are in special "public interest". In 2016, 104 PV installations were funded with 1,1 MEUR (ELER + Klima- und Energiefonds). In total, 2,7 MW were submitted.

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 1 658 EUR/kWp (excluding VAT) for a 5 kW system.

In 2016 support schemes for battery-storage systems in combination with PV systems were offered by several provinces and were dedicated for small, mainly private systems. The other support schemes are very different, typically ranging up to storage capacities of up to a maximum of 10 kWh. Up to now, these initiatives have 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 once again experienced very good development in 2016. Initially 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 heightened awareness aiming at further improving the frame conditions for manufacturing, research and innovation in Austria at the level of relevant decision makers.

Research organisations and industrial companies are participating in various national and European projects as well as in the IEA PVPS Programme's various Tasks; the national Energy Research Programme by the Austrian Climate and Energy Fund, as well as the "City of Tomorrow" programme by the Ministry of Transport, Innovation and Technology. Such participation covers quite broad research items on energy technologies including PV. The research budget for PV related projects within these energy research programmes in 2016 was 2,3 MEUR.

The total expenditures of the public sector for energy research in Austria was about 128 MEUR in 2015; out of that, about 22 MEUR was dedicated to renewable energy with a share of 7,2 MEUR for photovoltaics.

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

The national RTD in photovoltaics is focusing on materials research, system integration as well as increasingly on building integration, where integration is seen not only from architectural aspects but from systemic aspects including the local electricity generation for mobility. On European level, the on-going initiative to increase the coherence of European PV RTD programming (SOLAR-ERA.NET Co-fund) is actively supported by the Austrian Ministry of Transport, Innovation and Technology as well as the Austrian Climate and Energy Fund.

"Smart Grid" activities in Austria are ever 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 rising 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, offer this opportunity. Out of that trend, discussions about further financing of the public grid are emerging.

## IMPLEMENTATION

As noted above, self-consumption is increasingly an additional driver of 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 traditionally dominating the Austrian market, 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 size enterprises. 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 at the end of each year all new installed wind and PV systems to the regulator. This might be the basis of a national PV register, which could also serve as important tool in improving the PV power forecasting.

## MARKET DEVELOPMENT

The Federal Association Photovoltaic Austria is a non-governmental interest group of the solar energy and storage industry. The association promotes solar PV at the national and international level and acts as an informant and intermediary among businesses and the political and public sectors. Its focus lies on improving the general conditions for photovoltaic and storage system 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 2016, the association counted 240 companies and persons involved in the PV and storage industry as its members. The 14<sup>th</sup> annual National Photovoltaic Conference took place in Villach/Carinthia in 2016. It was again a three days event, organised by the Technology Platform Photovoltaic and supported by the Ministry of Transport, Innovation and Technology. This strategic conference remains THE annual come together of the innovative Austrian PV community, bringing together about 250 PV stakeholders in industry, research and administration.

Many specific conferences and workshops were organised by the association "PV-Austria". This and other 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 eight courses are planned in 2017. 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 some 10 kWp to a few MW systems have been successfully installed by the utilities as well as by municipalities as "citizen's solar power plants". Several ways to finance these systems are in place, from crowdfunding models to "sale and lease back" models. As previous projects have shown, the demand is very high; e.g. in the province of Lower Austria more than 50 municipalities have already realized such PV systems. Usually, it only takes some hours until a new power plant is sold out. Part of this success is the relatively low interest rates on current bank savings accounts.

## FUTURE OUTLOOK

The low cost system and the ambition to optimise systems for self-consumption purposes might open new opportunities for private owners, as well as for small and medium size enterprises and for the industry.

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.

Electric cars will get federal support from 2017 on. A growing e-vehicle sector might have an influence on the PV sector as well since the origin of the electricity is the parameter for the environmental improvement of this change in the mobility sector.



Fig. 2 – Gunsirichen Environmental Centre, Austria (Photo: "© Fronius International GmbH, 2017").

The fruitful smart grids community in Austria, a lively collaboration between research institutes industry and some national distribution networks operators have 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" which began in 2010 and is led by Austria, is a focal point of the international research activities on 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. 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 an increasing role as a significant and visible sign for a sustainable energy future in urban areas, frequently also in combination with the use of electric vehicles. As an example, PV roof gardens have the potential to improve the city-micro climate, can create convenient living areas on roofs, will store rainwater, etc.; beside the main purpose which is renewable energy generation.

Several renewable energy education courses and trainings are already implemented. A few new ones are currently under development. All of them include PV as an essential part of the future energy strategy. The importance of proper education for installers and planners of PV systems will increase depending on the market situation; 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

## GENERAL FRAMEWORK

Belgium has reached approximatively 3,4 GWp of cumulative installed PV capacity at the end of December 2016, according to the latest figures of the three regional regulators. It represents almost 400 thousand PV installations. The country added more than 170 MWp in 2016, a strong growth compared to 2015 (100 MW).

In Flanders, the small systems (<10 kWp) market was very active despite the "prosumer fee" (~85 EUR/kW). This fee enables DSOs to charge for the cost of grid use by PV owners, without changing the system of net metering. It gives a simple payback time around 15 years for a new PV installation.

This astonishing success is mainly due to the positive communication action made in Flanders to promote PV with a simple message: "You earn more money if you put your savings into PV than to leave it on your bank account."

The market of big systems (>10 kW) wasn't very active in Flanders 2016. They have no net-metering or prosumer fee but 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 about 100 MWp in 2016, reaching 2,45 GWp. The installation of small systems (<10 kW) represents 54 % of the installed capacity. The big plants (>250 kW) and the commercial segments (10-250 kW) represent respectively 25 and 21 % of the total installed capacity.

In Wallonia, the Quali watt support plan for small systems ( $\leq 10$  kW) introduced in 2014 has had a relative success in 2016. It was better than 2015 but the maximum amount of supported installations was not yet reached (~5 300/12 000). Quali watt is a premium spread over five years and is calculated to obtain a simple payback time of 8 years (5 % IRR for a 3kWp installation after 20 years). Besides the financial aspects, this new plan also introduces strong quality

criteria on the equipment (European norms, factory inspection), the installer (RESCERT trainee) and the installation (standard conformity declaration, standard contract) to give back trust to the new investors.

For big systems in Wallonia, 2016 will most probably be one of the best years. Since 2015, there is a system of GC reservation that controls the development of the market. The maximum has been reached with more than 60 MW reserved. About 33 MWp should have been installed in 2016, the rest will be in 2017. The amount of GC/MWh depends of the system size and varies between 2 (130 EUR) if system is smaller than 250 MWp and 1,6 (104 EUR) if system is bigger than 750 MWp.

In terms of installed capacity, Wallonia installed about 63 MWp in 2016, reaching 0,9 GWp. The installation of small systems (<10 kW) represents 84 % of the installed capacity. The big plants (>250 kW) and the commercial segments (10-250 kW) represent respectively 2,5 and 13,5 % of the total installed capacity.

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 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. At the end of the year, an investment plan of 75 MEUR has been announced for energy with a strong focus on PV to reach national objectives.

In terms of installed capacity, Brussels installed about 4 MWp in 2016, reaching 56 MWp. The installation of small systems (<10 kW) represents 18 % of the installed capacity. The big plants (>250 kW) and the commercial segments (10-250 kW) represent respectively 57 and 25 % of the total installed capacity.

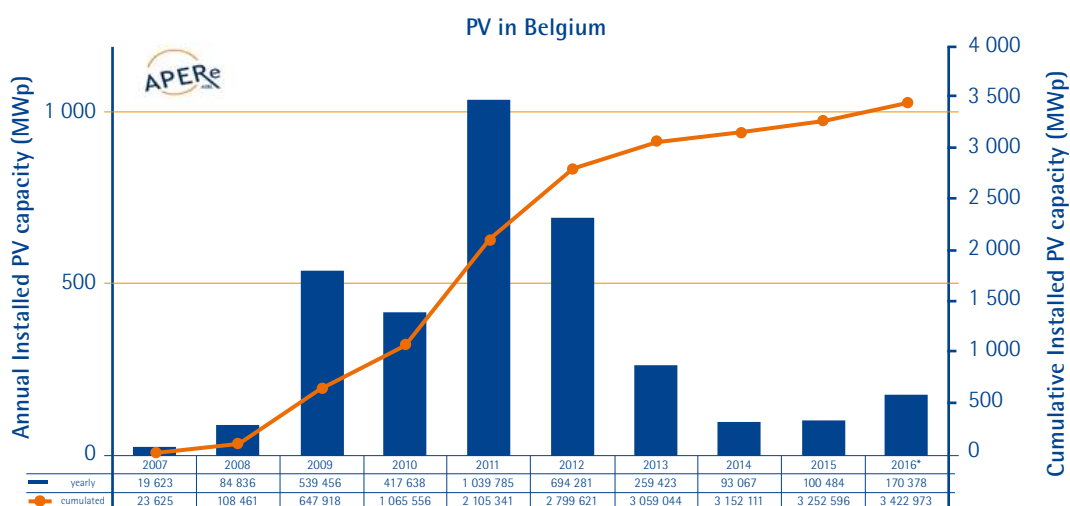


Fig. 1 – Belgium's Annual Installed PV Capacity and Cumulative Installed PV Capacity (MWp).



Fig. 2 – Issol installed 126 kWp on the new Federal Finance Tower in Liège. They have developed glass-glass PV modules with a limited thickness of 10 mm. This installation will produce approximately 100 MWh per year.

## NATIONAL PROGRAMME

The Belgian National Renewable Energy Action Plan fixed a target of 1,34 GWp installed in 2020 in order to reach the national target of 13 % renewables in 2020 set by the European directive. This objective had already been reached in 2011.

Since November 2015, and after long negotiations, this national objective was translated into regional targets. In 2016, each region has adapted their existing roadmaps to reach these objectives.

In Flanders, the government defined indicative production objectives for each renewable energy source with the overall objective to reach a share 10,5 % renewable energy in total final energy consumption by 2020. For PV, the target in 2020 is a production of 2 670 GWh which means about 3 GWp installed. In 2016, about 2 150 GWh are produced by the Flemish PV park. Annual growth should be around 130 GWh/year (145 MWp) to reach the objective in 2020.

In Wallonia, the government wants to source 13 % of its energy consumption from renewable energy sources by 2020. At the end of 2015, the government planned a mean annual growth of 73 GWh (81 MWp) until the end of 2020. This annual objective is split between small systems (43 GWh – 48 MWp) and big systems (30 GWh – 33 MWp).

In 2016, the installation rhythm was 20 % lower than the objective mainly due to small systems.

In Brussels, the objective is to produce 91 GWh of solar electricity at the end of 2020 which means a growth of approximately 10,5 GWh a year (12 MWp) which is a tripling of the installation rhythm of 2016.

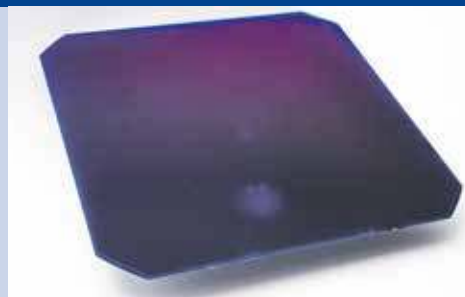


Fig. 3 – In June 2016, Imec demonstrated highly efficient bifacial solar cells with near 100 % bifaciality.

## 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.). More and more research is also active on Smart PV modules that would embed additional functionalities as micro-inverters (mainly Imec Research Center), on smartgrids that includes decentralised production into their models (Energyville) and on recycling (PVSEMA and SOLARCYCLE projects).

## INDUSTRY

There are two producers of classical modules in Belgium: Issol and Final24. But Issol develops mainly BIPV activities. With Soltech and Reynaers, they are the three main companies focusing on BIPV applications. Derbigum is specialized in amorphous silicon. Next to these five 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. (<http://en.rewallonia.be/les-cartographies/solar-photovoltaic>).

## MARKET DEVELOPMENT

Small-scales projects (< 10 KW) account for 61 % of the installed capacity with almost 400 000 installations which represent approximately 8 % of the households. The other 40 % include about 7 400 large-scale projects.

TABLE 1 - BELGIUM'S ANNUAL GROWTH INSTALLED PV AND CUMULATIVE INSTALLED PV (MWP)

YEAR	ANNUAL GROWTH INSTALLED PV (MWP)	ANNUAL CUMULATIVE INSTALLED PV (MWP)
2007	19 623	23 625
2008	84 836	108 461
2009	539 456	647 918
2010	417 638	1 065 556
2011	1 039 785	2 105 341
2012	694 281	2 799 621
2013	259 423	3 059 044
2014	93 067	3 152 111
2015	100 484	3 252 596
2016*	170 378	3 422 973

\*Non-consolidated



# CANADA

## PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

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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. 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.

The Province of Ontario, Canada's most populous and second largest province, leads the country in photovoltaic (PV) investments. As of September 30<sup>th</sup> 2016, the cumulative PV installed capacity stood at 1 926 MWAC embedded within the distribution network and 280 MWAC connected directly to the transmission grid for a total of 2 206 MWAC.

### Utility Interconnected PV Systems 2015

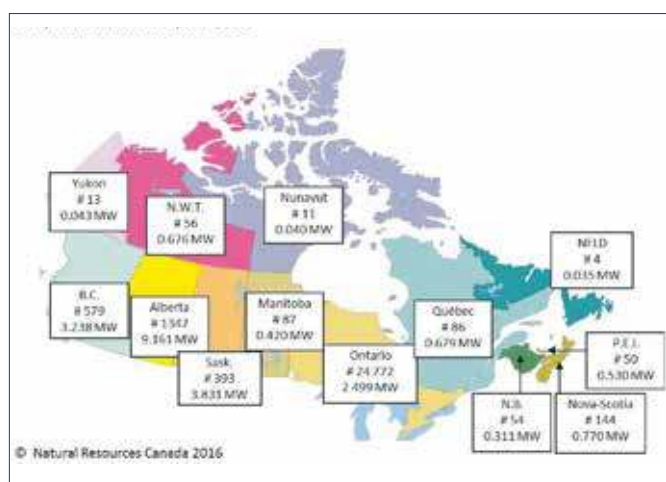


Fig. 1 - Map showing the Canadian provinces, the capacity (in megawatt) and the number of utility interconnected PV Systems as of December 31, 2015.

### 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 2016, 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 addition, research is also led to study the integration of solar PV in remote grids.

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

### 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 ( $\leq 10$  kW) was procured through the microFIT program which has an annual procurement target of 50 MW. Commercial-scale solar ( $>10 \leq 500$  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) [3]. As of September 30<sup>th</sup> 2016, the total amount of PV capacity installed and under development in Ontario was approximately 2 206 MWAC. This now represents more than 1,5 % of the electricity mix and 185 WattsDC 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 [4].

The Northwest Territories (NWT) has launched a Solar Energy Strategy to install solar systems with the capability to supply up to 20 percent of the average load in NWT diesel communities for 2012-2017 [5]. In 2015 a total of 56 systems and 676 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.

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 2000 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 54 % in 2012, 58 % in 2013, 52 % in 2014 and 35 % in 2015 thanks to the Ontario incentive programs. PV module prices have gradually declined from 5,36 CAD/Watt in 2006 to 0,80 CAD/Watt in 2016. This represents an average annual price reduction of 21 % over a 10-year period.



*Fig. 2 - The Leduc Recreation Centre PV system, located in Leduc, Alberta, has 3 622 solar PV modules for a total capacity of 1,14 MW. It is the 2<sup>nd</sup> biggest roof-top PV system in the country, generating approximately 15 % of the centre's annual energy consumption and saving the city some 90 000 CAD each year.*

## 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 MWAC of new contracts to be awarded in 2016 for residential, commercial and utility-scale facilities. Saskatchewan has also committed to the procurement of 60 MWAC 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 4 years [6].

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# CHINA

## PV TECHNOLOGY AND PROSPECTS

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### GENERAL FRAMEWORK

On December 26, 2016, the National Development and Reform Commission issued the new PV Feed-in Tariff for 2017 (NDRC [2016] No. 2729). 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	LS-PV	THE VALUE OF SELF-CONSUMED PV	
	FIT (Yuan/kWh)	For self-consumed PV (Yuan/kWh)	Excess PV electricity Feed-Back to Grid (Yuan/kWh)
I	0,65	Retail Price of Grid Electricity + 0,42	Wholesale Coal-Fire Tariff + 0,42
II	0,75		
III	0,85		

NDRC also announced in the Tariff Document, the FITs of PV will be regulated every year and for the projects the FIT are set by bidding, the tariff level should be never higher than the published level. For self-consumed PV projects, the subsidy level is kept the same as before.

The subsidy money is come from surcharge. The surcharge level is 1,9 USDcents/kWh. By this surcharge, about 60 BCNY (about 10 BUSD) can be collected every year to subsidy PV, wind and biomass power.

### NATIONAL PROGRAM

On November 7, 2016, China's 13th Five-Year (2016-2020) Plan for Power Generation was published jointly by NDRC (National Development and Reform Commission) and NEA (National Energy Administration). On December 8, 2016, China's 13<sup>th</sup> Five-Year Plan for Solar Energy was published by NEA.

**TABLE 2 – ENERGY AND POWER STRUCTURE IN CHINA (2015, 2020)**

ENERGY AND POWER STRUCTURE IN CHINA	2015	2020
Total Installed Power (GW)	1 530,0	2 000,0
Total Power Requirement (TWh)	5 690	~ 7 000
The Share of Electricity in Total Energy Consumption (%)	25,7	27,0
Installed Power per Capita (kW/p)	1,11	1,4
Power Consumption per Capita (kWh/p)	4 142	~ 5 000
Share of Non-Fossil Fuel Energy (%)	12 %	15 %
Share of Fossil Fuel Power (%)	65 %	61 %
Share of Coal-Fire Power (%)	59 %	55 %

**TABLE 3 – 2020 TARGETS OF POWER CAPACITY BY SECTORS**

POWER SECTORS	2015	2020
Hydro Power (GW)	297	340
Nuclear Power (GW)	27	58
Wind Power (GW)	131	210
Solar PV (GW)	42	≥ 105
CSP (GW)	0	5
Coal Fire Power (GW)	900	≤ 1100
Gas Power (GW)	66	110
Others (GW)	67	72
Total	1 530	2 000

1,05 GW installed solar PV capacity is only the lowest level and the number could be higher. The PV Committee of China estimates that the installed capacity of PV will be at least 150 GW by the year of 2020.

### TECHNOLOGY PROGRESS AND RESEARCH & DEVELOPMENT (R&D)

In 2015, the first "Leading Runner" project at Datong (Shanxi Province) was started, total capacity is 1 GW. The main requirements of the "Leading Runner" program are as follows:

**TABLE 4 – SPECIFICATION REQUIREMENTS FOR PV MARKET ENTRY AND LEADING RUNNER PROGRAM**

TYPE	PV CELLS	PV MODULES	MARKET ENTRY		LEADING RUNNER	
	Size of Cells (mm)	Cell Number in one Module	15,5 % Effi- ciency (Wp)	16 % Effi- ciency (Wp)	16,5 % Effi- ciency (Wp)	17 % Effi- ciency (Wp)
Multi-Si	156*156	60	255	/	270	/
	156*156	72	305	/	325	/
Mono-Si	156*156	60	/	260	/	275
	156*156	72	/	315	/	330
a-Si	All Thin-Film (TF)		Efficiency ≥ 8 %		Efficiency ≥ 12 %	
CIGS			Efficiency ≥ 11 %		Efficiency ≥ 13 %	
CdTe			Efficiency ≥ 11 %		Efficiency ≥ 13 %	
Other TF			Efficiency ≥ 10 %		Efficiency ≥ 12 %	
HCPV	500 concentrating times		Efficiency ≥ 28 %		Efficiency ≥ 30 %	
DC/AC Inverter	Grid-connected Inverters		Efficiency ≥ 96 % with transformers;			
			Efficiency ≥ 98 % without transformers.			

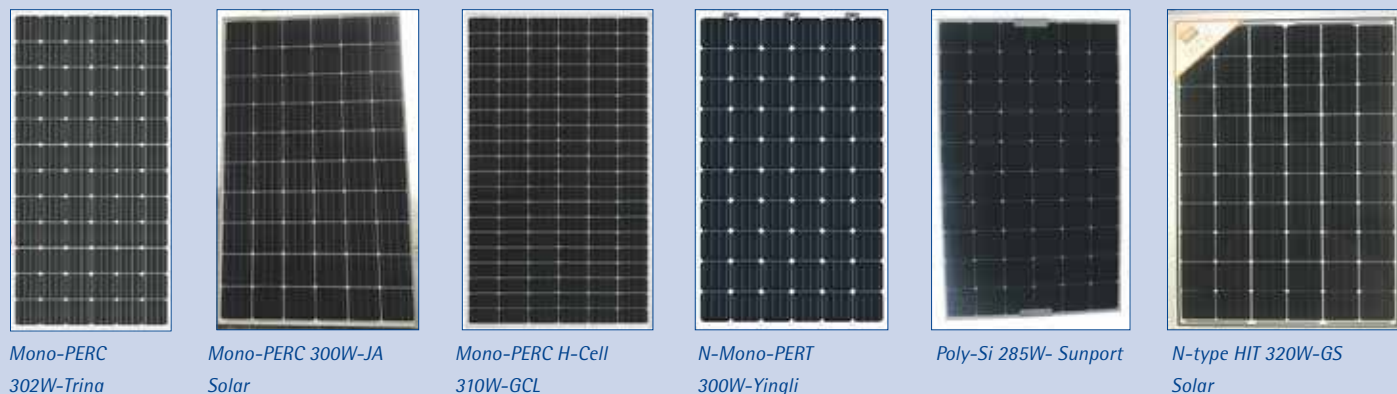


Fig. 1 - Typical High-Efficiency PV Modules (all modules are 60-156 x 156 cells). The high-efficiency PV modules produced by top-PV companies all meet the specification requirement of the "Leading Runner" program.

In 2016, the "Leading Runner" program has been expanded; 5 additional "Leading Runner" projects were launched in Shanxi, Hebei, Inner-Mongolia, Anhui and Shandong provinces and total capacity is 5,5 GW. The specification requirements are the same as above.

Stimulated by the "Leading Runner" program, PV technologies have made great progress and the cost has also been going down significantly. The selling price of PV modules is around 2,8 CNY/Wp to 3,3 CNY/Wp (USD:CNY = 1,0:7,0) and the system price is about 7 CNY/W.

The module efficiency of industry products has increased and the manufacturing capacity for the "Leading Runner" PV modules in China is more than 10 GW already. Table 5 and the following pictures show the highlights of the modules produced by different companies in mass production:

TABLE 5 - THE HIGH EFFICIENCY PV MODULES IN MASS PRODUCTION FOR THE TOP CHINESE PV COMPANIES

PV COMPANY	MODULE TYPE	TECHNOLOGIES	CELL EFF. (%)	MODULE EFF. (%)	MODULE POWER (WP)
Trina Solar	P-Poly-Si	PERC, highest efficiency	21,25	19,86	/
	P-Poly-Si	PERC, average efficiency	19,50	17,16	277,00
	P-Mono-Si	PERC, highest efficiency	22,61	/	/
	P-Mono-Si	PERC, average efficiency	21,30	18,45	302,00
JinKo	P-Poly-Si	Black Cell + PERC	20,00	18,02	295,00
	P-Mono-Si	PERC	21,20	18,94	310,00
JA Solar	P-Poly-Si	Black Cell	19,25	16,82 %-17,12 %	275 W-280 W
	P-Mono-Si	PERC	21,05	18,04 %-18,35 %	295 W-300 W
Yingli	P-Poly-Si	Ordinary	18,80	16,80	275,00
	N-Mono-Si	N-PERT	21,00	18,22	300,00
GCL	P-Poly-Si	Black-Cell + PERC + white EVA	19,80	18,00	292,80
		Black-Cell + PERC + white EVA + Half-Cells	19,80	18,00	298,53
	P-Mono-Si	PERC + White EVA	21,00	18,70	304,28
		PERC + White EVA + Half-Cells	21,00	18,70	310,22
Sunport Power	P-Poly-Si	MWT	19,60	17,50	285,00
GS Solar	N-Mono	HIT	21,20	19,00	320,00

Remarks: All modules in Table 5 are single-side 60 pieces 156x156mm PV cells.

## INDUSTRY AND MARKET DEVELOPMENT

### PV Industry in China

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

In 2016, China was also the top country in PV production in the world, covering whole manufacturing chains: PV grade poly-silicon, silicon wafers, PV cells and PV modules. The situation of PV production of whole manufacturing chain in China is shown below:

**TABLE 6 – POLY-SILICON PRODUCTION IN CHINA AND THE WORLD (2011-2016)**

YEAR	2011	2012	2013	2014	2015	2016
World (Tons)	240 000	235 000	246 000	302 000	340 000	370 000
China (Tons)	84 000	71 000	84 600	136 000	165 000	194 000
Share (%)	35,00	30,21	34,39	45,03	48,53	52,43

**TABLE 7 – SOLAR SILICON WAFER CAPACITY & PRODUCTION IN THE WORLD AND CHINA (2011-2016)**

YEAR	2011	2012	2013	2014	2015	2016
World Capacity (GW)	56,0	60,0	50,0	68,0	84,0	90,0
World Production (GW)	36,0	36,0	45,0	50,0	60,3	71,0
China Capacity (GW)	40,0	50,0	35,0	50,0	64,3	70,0
China Production (GW)	24,5	26,0	28,0	38,0	48,0	63

**TABLE 8 – PV CELL PRODUCTION IN THE WORLD AND CHINA (2011-2016)**

YEAR	2011	2012	2013	2014	2015	2016
World Production (MW)	35 087	31 898	39 500	50 300	62 100	69 000
China Production (MW)	20 592	19 961	23 000	33 000	41 000	49 000
Share (%)	58,69	62,58	58,23	65,61	66,02	71,01

**TABLE 9 – PV MODULE PRODUCTION IN THE WORLD AND CHINA (2011-2016)**

YEAR	2011	2012	2013	2014	2015	2016
World Production (MW)	36 996	38 750	39 987	52 000	63 500	72 000
China Production (MW)	22 798	25 214	25 610	35 000	43 900	53 000
Share (%)	61,62	65,07	64,05	67,31	69,13	73,61

### PV Market in China

China's PV installation in 2016 is shown in Table 10:

**TABLE 10 – DOMESTIC PV INSTALLATION BY SECTORS IN 2016**

2016 DOMESTIC PV MARKET BY SECTORS				
No.	MARKET SECTOR	ANNU. INS. (MWp)	CUM. INS. (MWp)	SHARE (%)
1	Rural Electrification	2	182	0,23
2	Communication & Industry	5	90	0,12
3	PV Products	3	88	0,11
4	Distributed and Building PV	4 230	10 290	13,18
5	Ground Mounted LS-PV	30 310	67 430	86,36
	<b>Total</b>	<b>34 550</b>	<b>78 080</b>	<b>100,00</b>

During 2011-2016, the cost of PV has been reduced sharply. It is estimated that PV prices will reach grid-parity with traditional coal-fire power on the user-side by the year of 2020 and reach to grid-parity on the generating side by the year 2025.

**TABLE 11 – PV PRICES GOING DOWN DURING THE LAST 6 YEARS**

YEAR	2011	2012	2013	2014	2015	2016	2017 (E)
Cumulative (GWp)	3,50	7,06	17,74	28,38	43,38	78,08	100
Module Price (CNY/Wp)	9,00	4,50	4,00	3,80	3,50	3,10	2,80
System Price (CNY/Wp)	17,50	10,00	9,00	8,00	7,50	7,00	6,50
PV Tariff (CNY/kWh)	1,15	1,00	0,9-1,0			0,8-0,98	0,65-0,85

# COPPER ALLIANCE

THE COPPER ALLIANCE'S ACTIVITIES

FERNANDO NUNO, PROJECT MANAGER, EUROPEAN COPPER INSTITUTE



Fig.1 - Cable and connectors for photovoltaic modules.



Fig. 2 - Copper rod used for manufacturing copper cables.

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;

# A framework for prosumers is needed

	Bill breakdown by percentage	Grid injection	Self-consumption	Grid Consumption
Tax Category	Non government			
	General Taxes (19%)	Through consumer	VAT PV plant	++
Government	Green taxes (23%)	Premium as other RES	RES, exempt	++
	Energy cost (36%)	Wholesale	No charge	++
T&D Grid	Grid charges (22%)	<ul style="list-style-type: none"> <li>• Capacity charge (€/kW)</li> <li>• Injection tariff if needed</li> </ul>		

Fig. 3 - Proposed regulatory framework for prosumers - Leonardo Energy.

- 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](http://www.leonardo-energy.org/photovoltaic-grid-parity-monitor)), which also contributes to improving public acceptance. Also, Copper Alliance has defined a possible regulatory framework to address properly self-consumption.
- 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 and Task 1 activities. In addition to the publication of IEA PVPS reports and summaries on the Leonardo ENERGY website, Copper Alliance successfully held two PV webinars, on self-consumption regimes and on market trends, reaching an audience of about 650 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.



# DENMARK

## PV TECHNOLOGY STATUS AND PROSPECTS

FLEMMING KRISTENSEN, ENIG LTD., DENMARK

PETER AHM, PA ENERGY LTD., DENMARK



Fig. 1 - Roof integrated system developed and delivered by Gaia Solar and Steni.



Fig. 2 - Close up photo of the PV roof slate.

### GENERAL FRAMEWORK

The Danish government launched its energy plan in November 2011 called Our Energy 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 in March 2012 by a broad coalition of parties in- and outside the government. The plan, which reaches up to 2020, was further detailed in the government's energy statements. In the latest statement of November 2016, the Public Service Obligation (PSO), which based on a small levy on each kWh sold has financed most of the Danish green energy interventions for years, was decided to be phased out over some years and replaced by funds from the state budget. Expansion of wind energy was included again, energy R&D programmes were combined and various minor adjustments introduced, however nothing specific on PV. With regard to renewable energy (RE) the plan sets target for the overall contribution from RE by 2050, but the previous in-between targets leading up to 2050 are no longer in the plan.

Renewable energy is very much a present and considerable element in the energy supply: by end of 2016 more than 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 in principle high priority in the energy plan, however the amount of R&D funding allocated to RE has been reduced. Renewable energy technologies, in particular wind, play an important role with PV still seen as a minor option suffering from go-stop political interventions; thus, preventing a stable market development despite a proven growing degree of competitiveness.

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 municipal PV, and several municipalities have presently reduced or stopped PV deployment.

### NATIONAL PROGRAM AND IMPLEMENTATION

Denmark has no unified national PV programme, but during 2016 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, targeted R&D in the field of green electricity producing technologies including a few PV projects.

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 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 approximately 0,30 EURcents/kWh primarily because of various taxes – combined with dropping PV system prices proved in 2012 to be able to stimulate PV deployment seriously, as the installed grid connected capacity during 2012 grew from about 13 MW to approximately 380 MW, a growth rate of about 30 times. For PV systems qualifying to the net-metering scheme, grid-parity was reached in 2012 for the sector of private households.

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 politically; this because the consequences of the new regulations were not fully clear to the decision makers at the time of decision and follow up measures were found to be necessary. By June 2013 the new regulations were finally in place including transitory regulations, effectively putting a cap on future PV installations under the net-metering scheme in terms of an overall maximum installed capacity of 800 MW by 2020; for municipal PV installations the cap was set at an additional 20 MW by 2020. In 2016, PV was summarily excluded from the long existing standard FIT for both wind and PV set at 0,60 DKK/kWh (8,05 EURcents) for the first 10 years and 0,40 DKK/kWh (5,4 EURcents) the following 10 years.

An additional result of Denmark harmonizing its support mechanisms for RE and PV produced electricity to EU state aid regulations has in 2016 been a shared German-Danish auction scheme for large scale PV meaning that under certain limitations German developers could enter bids for German located PV plants under the Danish auction and vice versa. Danish developers succeeded in both the German auction of 50 MW and the Danish one of 20 MW; the winning bids were around 0,40 DKK/kWh (5,4 EURcents/kWh) and thus very close to lowest ever Danish off-shore wind price of 0,375 DKK/kWh at the 600 MW Kriegers Flak.



*Fig 3 – Copenhagen International School is a new building located in Copenhagen's new district Nordhavn. The school building's facade will be covered in 12 000 solar individually angled panels, which will supply more than half of the school's annual electricity consumption. The PV will cover a total area of 6,048 square meters making it one of the largest building integrated solar PV plants in Denmark (photo: Anne Lilke Krag Hansen). Architect: C. F. Møller. Solar Cells: SolarLab.*

The above mentioned market uncertainties combined with reduced R&D funding has effectively put the PV market on hold in 2016; only about 60 – 70 MW [1] installed capacity was added leading to a total installed capacity of just above 800 MW by end of 2016. The amount of PV installations not applying for the additional support 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 photovoltaics 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, in 2015, of the National PV Strategy; the revision which has been carried out in consultation with a broad range of stakeholders including the Danish PV Association was completed in the first half of 2016 and can be found on the website of the Danish Energy Agency; however the revised strategy has not received any official recognition.

In early 2016 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); these figures are part of a periodically revised general energy sector forecast, the so called Energy Catalogue. There seems so far to be little if any political impact of these forecasts.

## RESEARCH & 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 electronics but also for other custom made components.

Penetration and high penetration of PV in grid systems are as a limited effort being researched and verified by small demonstrations, and network codes are reported to be under revision to accommodate a high penetration of inverter-based decentral generation and to conform to the EU wide harmonisation under development in Entso-E/EC.

As mentioned above, R&D funding for RE and PV appears to exhibit lower political priority after 2016.

## INDUSTRY AND MARKET DEVELOPMENT

A Danish PV Association (Dansk Solcelle Forening) was established late 2008. With about some 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 household coming from

PV by 2020, but is now revising this target but being hampered in the process by the regulatory uncertainties. The association played 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 since 2013, most upstarts have disappeared again.

Danish investors have entered the PV scene acting as holding companies, e.g. for cell/module manufacturing in China and acting as international PV developers.

Consultant engineering companies specializing in PV application in emerging markets report a slowly growing business volume.

The total PV business volume in 2016 is very difficult to estimate with any degree of accuracy due to the small market of around 60 – 70 MW and to the commercial secrecy of the PV sector both domestically and internationally. By end of 2016, the cumulative installed PV capacity in Denmark (including Greenland) was estimated at a bit more than 800 MW.

## FUTURE OUTLOOK

The present liberal minority government has announced the intention to reduce the annual government funds allocated to R&D into energy and renewable, and has shown little interest in PV except for creating barriers for a stable market development.

The emerging market sector of PV installations for own consumption appears to be growing, however there is little firm data on this relative new sub-market.

[1] At time of writing, the official Danish statistics on grid connect PV only covered up to mid November 2016. The figure of about 20 MW is thus the authors estimate.

# 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* sets out the strategic vision to prompt the transition to a low-carbon, secure and competitive economy in the European Union. It consists of five interrelated dimensions: security of energy supply; internal energy markets; energy efficiency; decarbonisation of the energy mix; and research and innovation [1].

On 30 November 2016, the European Commission presented a package of measures on energy composed of eight legislative proposals and three non-legislative proposals. The "*Clean Energy for All Europeans*" package aims to keep the European Union competitive -as the clean energy transition is changing the global energy markets- implement the 2030 climate and energy framework, and advance the *Energy Union* [2].

The legislative proposals concern energy efficiency, renewable energy, the design of the electricity market, security of electricity supply and governance rules for the Energy Union. The package also includes actions to accelerate clean energy innovation and renovate Europe's buildings. It provides measures to encourage public and private investment, promote EU industrial competitiveness and mitigate the societal impact of the clean energy transition, protecting the most vulnerable consumers (*energy poverty*).

The proposals place a special emphasis on consumers, as active and central players on the energy markets. Increased transparency and better regulation should give more opportunities for civil society to become more involved in the energy system and respond to price signals.

The legislative procedure for the adoption started with the Commission's submission of the legislative proposals to the European Parliament and Council of the EU (representing the national governments of EU Member States). The "*Clean Energy for all Europeans*" package is included among the EU's legislative priorities for the year 2017 [3].

## DEPLOYMENT

The annual maximum deployment of PV installations was reached, in Europe, in the year 2011, when more than 22 GW were installed. After that year, a great reduction in annual installations has been observed. Different reasons (phasing out of support schemes, restricted access to credit, introduction of caps, and retroactive changes) might have reduced the demand. In the year 2015, about 7,7 GW of new photovoltaic capacity was installed in the European Union, bringing the cumulative PV capacity to about 95 GW. The EU market share, which was about 72 % of the global market in 2011, decreased to 15 % in 2015. The cumulated PV capacity installed in some EU countries (with more than 1 GW at the end of 2015) is reported in Figure 1. UK (3,69 GW), Germany (1,46 GW), France (0,88 GW) the Netherlands (0,45 GW) and Italy (0,30 GW) represent about 90 % of the whole yearly installed capacity in 2015 [4].

Solar is now supplying, on average, nearly 4 % of electricity demand in Europe. Italy, Greece and Germany are producing each more than 7 % of their electricity demand by solar power.

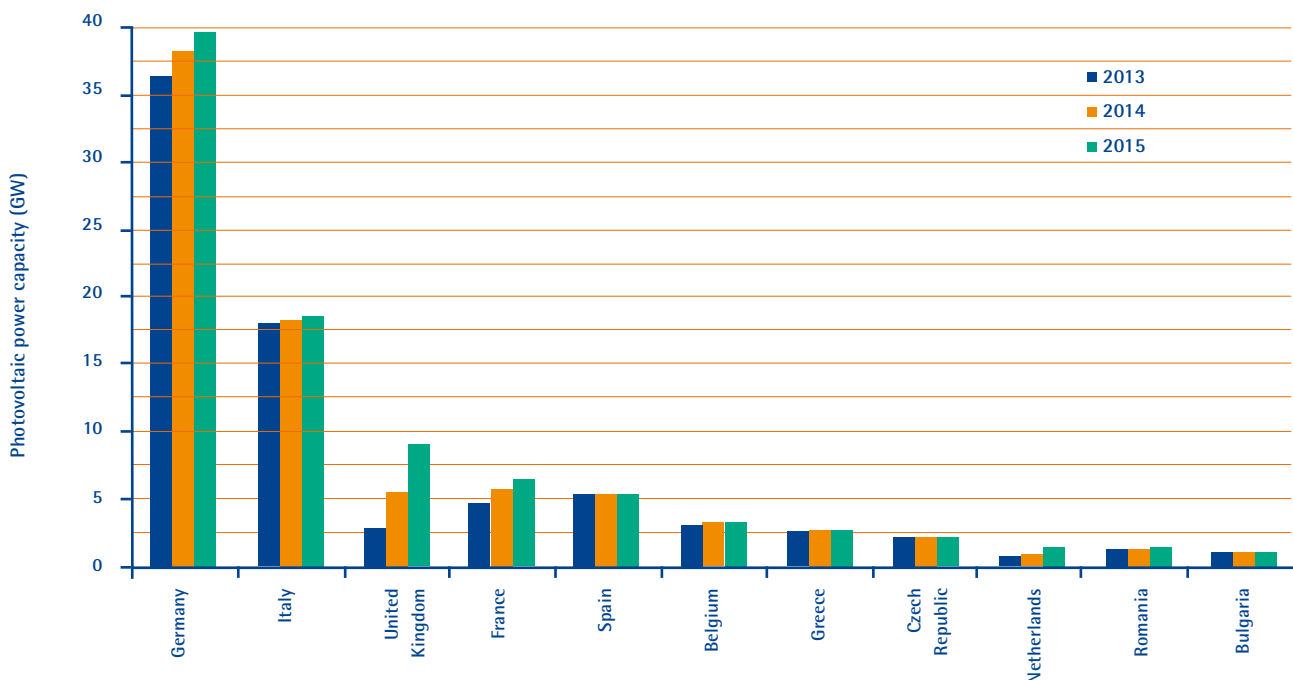


Fig. 1 - Cumulated installed photovoltaic capacity in some EU countries.

## RESEARCH AND DEMONSTRATION PROGRAMME Horizon 2020 – The EU Framework Programme for the Years from 2014 to 2020

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' [5].

A view of the budget which is currently being invested on PV activities, under Horizon 2020, is provided in Figure 2, broken down by the kind of funding action.

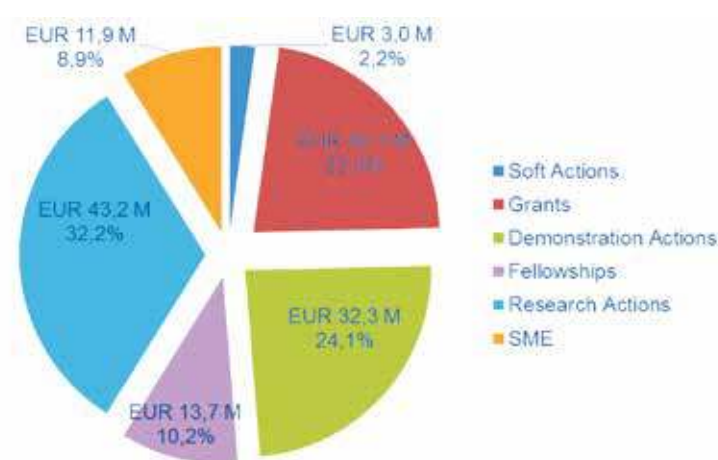


Fig. 2 – Ongoing photovoltaic activities funded under Horizon 2020.

The overall contribution of 134,3 MEUR is mostly spent for research actions (32,2 %), demonstration actions (24,1 %) and grants to researchers provided by the European Research Council (22,4 %). Fellowships, provided under Marie Skłodowska-Curie actions, absorb more than 10 % of the budget while actions for the small and medium enterprise (SME) instruments are at 8,9 % of the overall investment.

## SET-PLAN ACTIONS AND INITIATIVES

### The European Technology and Innovation Platform on Photovoltaics (ETIP PV)

Following the Communication "Towards an Integrated Strategic Energy Technology (SET) Plan: Accelerating the European Energy System Transformation" [6], the SET Plan governance has been 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 and the Commission services. The ETIPs are a continuation of the European Technology Platforms and European Industry Initiatives in a single platform, with the freedom of self-organisation [7]. The ETIP

PV has been launched in January 2016, encompassing the former PV Technology Platform (PV TP) and the Solar European Industry Initiative (SEII).

### 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 strategic targets for different areas of the energy sector (including PV) has been defined. The strategic targets for PV are indicated in a Declaration of Intent agreed by the representatives of the European Commission services, of the SET-Plan countries and of the PV stakeholders in December 2015 [8]. 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.

Selected stakeholders and interested SET-Plan countries have agreed to develop, by September 2017, a detailed Implementation Plan for the delivery of these targets, describing the technological and non-technological activities to be undertaken. Discussions are held within an ad hoc Temporary Working Group (TWG) whose composition is currently under definition. SET-Plan countries which have expressed their interest in contributing to this exercise are Belgium, Cyprus, Estonia, France, Germany, Italy, the Netherlands, Norway, Spain, and Turkey. Stakeholders have mostly been proposed by the ETIP PV. The PV TWG is expected to start its activities in January 2017.

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# FINLAND

## PV TECHNOLOGY STATUS AND PROSPECTS

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JERO AHOLA, PROFESSOR, LUT, LAPPEENRANTA UNIVERSITY OF TECHNOLOGY



Fig. 1 - Hybrid wind and solar PV power plant of Suomen Voima Oy in Hamina (Photo: Jero Ahola).



Fig. 2 - Kivikko rooftop solar PV plant in Helsinki (Photo: Helen Oy ([www.helen.fi](http://www.helen.fi))).

## GENERAL FRAMEWORK AND IMPLEMENTATION

A long-term objective of Finland is to be a carbon-neutral society. In 2014, a national roadmap was published with the aim of finding means to achieve 80–95 % greenhouse gas reductions from the 1990 level by 2050. In the energy sector, the challenge of transformation is particularly great. Approximately three-quarters of all greenhouse gas emissions in Finland come from power generation and direct energy consumption, when energy use of transportation is included.

## NATIONAL PROGRAMME

Currently, there is no national strategy nor objectives for photovoltaic power generation in Finland. Instead, the solar PV is mainly considered an energy technology that can be used to enhance the energy efficiency of buildings by producing electricity for self-consumption. However, it is becoming widely accepted that PV will be one of the least-cost power generation technologies also in Finland. 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 25 % of the total project costs. Agricultural companies are also eligible to apply an investment subsidy of 40 % 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 is 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, allocations or programs for solar energy R&D 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 Finnish PV market 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 approximately 10 MW. Since 2010, the number of grid-connected PV systems has gradually increased. Presently, the market of grid-connected PV systems heavily 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 2016, the installed grid-connected PV capacity was estimated to be approximately 20 MW.



# FRANCE

## PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

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

### GENERAL FRAMEWORK AND IMPLEMENTATION

The year 2016 saw the publication of 71 application decrees for 2015's Energy Transition Act for Green Growth, of which 17 directly impact the photovoltaics sector. These include a number of complementary decrees in May defining power thresholds, separation distances, and technology-specific conditions for RES systems, determining eligibility for Power Purchase Obligations or Additional Remuneration Contracts.

Designed to encourage RES integration into energy markets, these texts introduced Additional Remuneration Contracts and limit Feed-In Tariffs (FIT) to small building mounted systems (although the tariff levels determined by the Feed-In Tariff Order remain unchanged under this threshold). Systems over 100 kW must either candidate in public tenders or sell their production in private purchase agreements – system size limits and remuneration mechanisms are detailed in Table 1.

Access to the Electricity as a Public Service Contribution Fund (CSPE) was officially opened, allowing private energy suppliers to acquire Power Purchase Obligation contracts.

An ordinance defining individual and collective self-consumption operations was published, however the application decrees were not yet published in early 2017.

It is expected that 2017 will see changes to financing models for small to medium systems, with a new Feed-In Tariff Order expected in the first quarter, and precisions concerning grid access and regulatory considerations for individual and collective self-consumption photovoltaic systems.

National photovoltaic capacity grew by 559 MW for a cumulative capacity of 7 134 MW.

TABLE 1 – NEW SUPPORT MECHANISMS, PUBLISHED IN MAY 2016 AND NOVEMBER 2016

SYSTEM TYPE AND SIZE	BUILDING MOUNTED SYSTEMS UNDER 100 KW	BUILDING MOUNTED SYSTEMS AND PARKING CANOPIES 100 KW TO 500 KW	BUILDING MOUNTED SYSTEMS 500 KW TO 8 MW	GROUND BASED SYSTEMS 500 KW TO 17 MW AND PARKING CANOPIES 500 KW TO 10 MW	SYSTEMS 100 KW TO 5 MW IN NON-INTER-CONNECTED ZONES (ZNI**)	BUILDING MOUNTED SYSTEMS FOR SELF-CONSUMPTION
SUPPORT MECHANISM	Feed in Tariff Order	Call for Tenders 2017-2019	Call for Tenders 2017-2019	Call for Tenders 2017-2019	Call for Tenders 2017	Call for Tenders** 2016-2017
VOLUME	No volume cap	675 MW in 9 calls of 75 MW	675 MW in 9 calls of 75 MW	3 GW in 6 calls of 500 MW	50 MW with storage in 1 call	40 MW in 2 calls of 20 MW (continental) 20 MW in 1 call (ZNI*)
REMUNERATION TYPE	FIT Power Purchase Agreement *conditions and tariff under revision	Power Purchase Agreement at tendered rate	Market sales + Additional Remuneration Contract at tendered rate	Market sales + Additional Remuneration Contract at tendered rate	Power Purchase Agreement at tendered rate	Self-consumption + market sales + bonus on self-consumption + bonus on grid injections at tendered rate

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

\*\* Call for Tender is not limited to photovoltaic systems, other RES technologies are eligible

### NATIONAL PROGRAMME

National target volumes for photovoltaics were published in the Energy Programme Decree (PPE) in November. Targets are set to increase from 6,6 GW cumulative capacity mid-2016 to 10,2 GW by the end of 2018, and between 18,2 GW and 20,2 GW by the end of 2023. The decree provided a provisional calendar for future Calls for Tenders for RES capacity, with 1 GW per year planned in ground based photovoltaic plants and 0,45 GW per year planned on building mounted photovoltaic systems over 100 kW.

The French government has demonstrated its strategy for large centralised systems to meet the PPE targets, as shown by the volumes in the provisional Call for Tenders calendar, with 1,45 MW per year planned from early 2017 until mid-2019. The 2023 targets could be reached by new photovoltaic power plants operating exclusively on the electricity market, after the Additional Remuneration Contract / Call for Tenders transition period. Small systems are expected to contribute only small volumes to the targets. The inclusion of carbon footprint for frameless modules as a determining factor in the Calls has also demonstrated the state's firm support for low-carbon systems.



Fig. 1 - Biocoop Melesse: Self-consumption system on a logistics building, financed by a citizen RES investment fund and a green electricity supplier (photo: © mrw zeppeline bretagne / armorgreen).

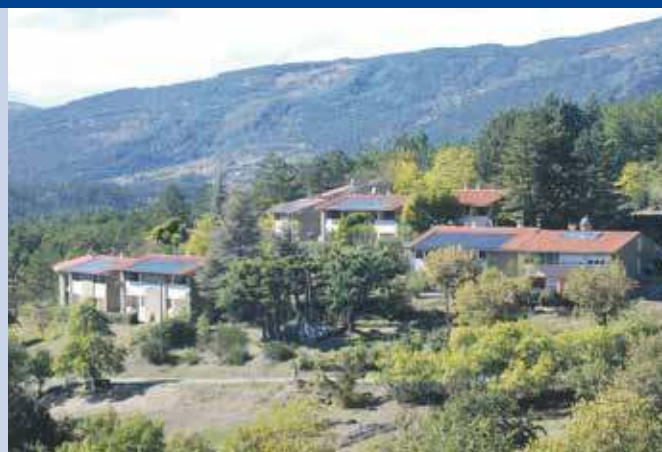


Fig. 2 - Rosans Village with systems installed by local citizen RES investment company (SAS Centrales Villageoises Rosanaïses) (photo: PNRBaronniesProvençales).

In 2016, 240 MW of building mounted systems between 100 kW and 250 kW were awarded in the Simplified Call for Tenders whilst in December 2015 more than 800 MW of systems over 250 kW were awarded. Given local industry lead times, most of these systems will not be commissioned until early or mid-2017. A further 50 MW for systems with storage in the French overseas territories and Corsica were awarded in June 2016, where high penetration requires storage, close monitoring and special disconnect provisos to maintain grid stability.

With photovoltaic system costs continuing their slow reduction, self-consumption has attracted attention. An experimental Call for Tenders for self-consumption systems of 100 kW to 500 kW on the mainland was launched with 20 MW of projects retained. A similar Call for Tenders for overseas territories was published in December 2016. Whilst the French government supports the generalisation of self-consumption models, as it would reduce the burden on the CSPE Fund for new production capacities, the relatively low cost of electricity in France will mean slower uptake compared to neighbouring countries. The model is being developed for medium size systems on buildings such as supermarkets and cold storage facilities on the mainland, with a wider deployment in overseas territories where security of supply can be an issue.

Increased demand by building and homeowners for highly energy efficient and positive energy buildings, combined with revisions to thermal regulations (RT2018 and European-led nZEB targets for all new public buildings), are expected to drive growth of photovoltaics on new buildings.

Many industry actors believe that within the next few years France could see a generalisation of partial self-consumption models (self-consumption with injection of surplus production) for domestic photovoltaic systems. Whilst no hard data is available yet to document this, the combination of rising domestic electricity prices and grid connection costs for total injection, and the Linky meter deployment are the source of this industry forecast. The Linky communicative meter, capable of simultaneously measuring consumption and production is to be deployed on all production sites from 2017 onward and will allow for lower connection costs.

However, the expected change to the FIT Order in early 2017 will also impact the development of self-consumption in domestic systems, as it may actively encourage or limit self-consumption (the draft text of the Order has been submitted to France's Higher Energy Council (Conseil Supérieur de l'Energie) for consultation before signature).

Strong public support for citizen investment has complemented the government's updated crowdfunding regulation. This update creates exceptions to national financing rules for RES projects, facilitating citizen-led and participative financing projects. In parallel, the French Environment and Energy Management Agency (ADEME) published two studies: one documenting the legal framework for citizen investment in RES and another concentrating on the social and local interactions and benefits of citizen investment in RES. Tariff bonuses (3 EUR/MWh) for participative and municipal investment are offered in Call for Tenders since early 2016, and have proven popular (28 of the 72 winning bids in the Self-consumption Call).

TABLE 2 - PV FEED-IN TARIFFS FOR THE 4<sup>TH</sup> QUARTER OF 2016 (EUR/KWH)

TARIFF CATEGORY AND PV SYSTEM TYPE	POWER OF PV INSTALLATION (W)	TARIFF Q4 2016 (EUR/KWH)
T1 - Full building- integration (IAB)	$P \leq 9 \text{ kW}$	0,239
T4 - Simplified building- integration (ISB)	$P \leq 36 \text{ kW}$	0,124
	$36 \text{ kW} < P \leq 100 \text{ kW}$	0,118
Call for Tenders	100 kW to 250 kW	Average selling price (EUR/AveraMWh) 131,25

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

## R&D

Research and Development in France ranges from fundamental materials science to pre-market development and process optimisation. The principal state agencies financing research are:

- the National Research Agency (ANR), that finances projects through topic-specific and generic calls and also through tax credits for in-company research.

Programmes accepted in the ANR Calls with a photovoltaic component operating in 2016 were spread across 70 laboratories. Many of these laboratories are joint university/research institute facilities linked to the national research institutes CNRS, CEA, INES or IPVF. Topics are predominantly materials science-based, with growing interest in III-V semiconductor/silicon and Perovskites/silicon tandems cells. Process improvements for mainstream technologies were well represented. Photovoltaics as an energy source for embedded applications was also present in several projects (road surfaces, drones, etc.).

- the French Environment and Energy Management Agency (ADEME), that manages the State "Investing in the Future" programme (Investissement d'Avenir) financing innovative pre-industrial technologies. ADEME also runs its own Calls for R&D on RES and has an active policy supporting PhD students with topics related to PV cells, as well as being the French relay for the IEA PVPS and SOLAR-ERA.NET pan-European network.

Mid-2016, the second "Investissement d'Avenir" programme was launched with two dedicated Renewable Energy Calls. The first provides support for the development of advanced or innovative manufacturing equipment and processes, photovoltaic cells and modules as well as for experimental trials of innovative photovoltaic systems and building integration equipment. The second Call, "SME Initiatives" (Initiatives PME), targets SME innovation with funding for the development-to-market stage of innovations. Beneficiaries have been primarily in software, design and supervision sectors of the photovoltaics market. Grid and energy production management tools were also supported through a specific section, demonstrating a clear increase in support for smart energy management systems, energy storage interfaces and mobile solutions.

French participation in European SOLAR-ERA.NET projects has focused on applied research targeting technological improvements for manufacturing processes and cost reductions.

- Bpifrance (a French public investment bank) that provides, amongst others, low-cost financing and subsidies for research-to-enterprise technology transfers and technology innovation-to-market deployment, feasibility studies and accompaniments.

Industrial applied innovation was also encouraged through the Innovation component of 2015's Call for Tenders for photovoltaic systems over 250 kW. Eligible contributions to innovation were opened in three domains: component performance, photovoltaics system design and operations and maintenance (including ancillary grid services). The winning bids were announced in December 2015. However, with no official publications for commercial confidentiality reasons, it may be difficult to evaluate the success and added value.



*Fig. 3 - Farmers group Agrisoleil87 system on custom-designed building (photo: Agrisoleil87).*

Industrial development projects were financed through various different measures, including tax credits and research Calls, and include the integration of photovoltaics into specific applications (glazing, cloths, roads, floating elements, etc.), as well as mobile electronics.

The major showcases for photovoltaics research in France are the PVTC (PhotoVoltaic Technical Conference) in April with a focus on materials and advanced processes to innovative applications, and the National PV Days (JNPV) in late December at the initiative of the Fed-PV, (CNRS PV research federation) and IPVF.

## INDUSTRY AND MARKET DEVELOPMENT

Market interest in total or partial self-consumption remuneration schemes has been the focal point of the year in the small to medium system size sectors, with conferences, workshops and an experimental Call for Tenders speeding industry comprehension and appropriation. Existing market players have reinforced their capacity and offers in energy management and supervision systems, supported by the government's "SME initiatives" and the "GreenTech" awards for innovation.

The market for 100 kW to 250 kW systems, regulated by the "simplified" 3-phase Call for Tenders that ran through 2016 was highly concentrated, with 4 actors sharing more than 25 % of the volumes attributed. A significant proportion of systems were developed for, or by, the agricultural sector, with a demonstrated capacity to develop commercially competitive systems in the lower irradiation northern areas of France.

When it comes to megawatt-scale systems, industry representatives are satisfied with the government's three-year calendar for Call for Tenders, published in the Energy Programme Decree (PPE) in November. This calendar provides photovoltaics plant developers and industry the ability to plan ahead and is expected to bring stability to the local photovoltaics industry.

The provision for Additional Remuneration contracts instead of fixed Power Purchase Agreements in Calls for Tender has stimulated market actors to a better understanding of the complexities of the electricity market. With a limited initial volume of electricity and the creation of a new role for actors (aggregators), it is not yet clear whether a sufficient number of purchase offers from market aggregators (buyers) will be available to guarantee a competitive market when the first contracts become operational in late 2017 or early 2018.

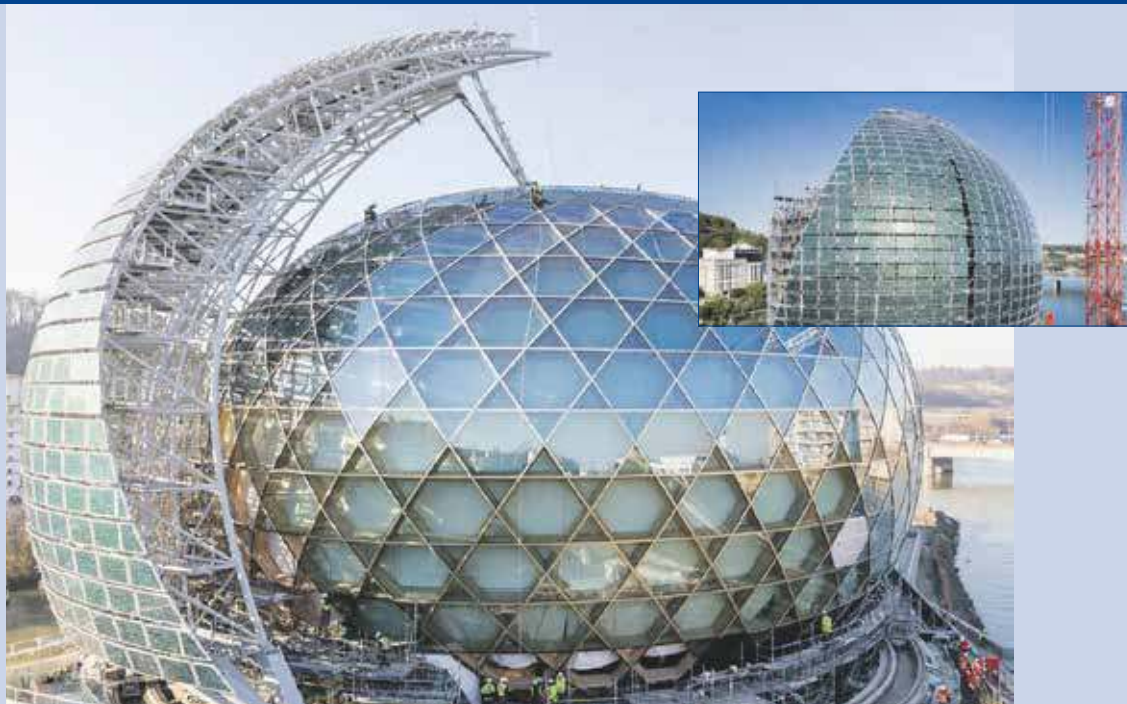


Fig. 4 - Cité Musicale, Ile de Séguin. Its solar sail is a successful model of BIPV. The "music city's" wooden and glass sphere is adorned by 1000 m<sup>2</sup> of bi-glass modules (photo: ISSOL for TCE Solar and Bouygues Constructions - Architect: Shigeru Ban).

However, actors on the local market will benefit from European experiences with market sales of photovoltaic electricity and Additional Remuneration contracts, although specificities such as administrative complexities and the restricted size of the market in France may require some adjustments to operational methods.

The French government's strategy to develop photovoltaic capacity has been built on competitive Tenders to accelerate cost reductions. Selection criteria included the carbon footprint of the photovoltaic modules used to reduce the environmental impact of commissioned systems. The carbon footprint notation has favoured regional industries, due to the generally lower carbon content of Europe's electricity, as compared to other major manufacturing countries (nearly all 80 MW of winning bids of 2016's last phase of the simplified Call for Tenders included European assembled modules, of which half were assembled in France).

France's ten photovoltaic cell or photovoltaic module manufacturers have struggled to stay profitable with no clear timetable for previous Calls, reducing their ability to plan manufacturing volumes. It remains to be seen how the fixed time frame and target volumes of 2016's PPE Tenders calendar will strengthen the position of regional manufacturers.

Grid connections over most of 2016 were lower than 2015 for multi-MW systems – a necessary result of the previous Call for Tenders for large systems calendars. However, approximately 1,5 GW was awarded through Tenders from December 2015 to the end of 2016, most of which will be connected to the grid in the first semester 2017. Overall, grid-connected volumes grew an estimated 559 MW (compared to 894 MW in 2015 and 955 MW in 2014). Of this, 14 % was by systems of or under 9 kW, 14 % by systems from 9 kW to 100 kW, and systems commissioned within the framework of Call for Tenders, all over 100 kW, 72 %.

TABLE 3 – GRID CONNECTED CAPACITY AT THE END OF DECEMBER 2016 (PROVISIONAL)

POWER CATEGORY	CUMULATIVE POWER (% , MW)	CUMULATIVE NUMBER OF SYSTEMS (% , NUMBER)
Up to 9 kW (T1 FiT)	16 %	90,8 %
9 kW to 100 kW (T4 FiT)	19 %	7,4 %
Above 100 kW	65 %	1,8 %
Total (provisional)	7 134 MW	382 382 installations



# GERMANY

## PHOTOVOLTAIC BUSINESS IN GERMANY – STATUS AND PROSPECTS

KLAUS PRUME, CHRISTOPH HÜNNES, PROJEKTRÄGER JÜLICH (PTJ), FORSCHUNGSZENTRUM JÜLICH GMBH

### GENERAL FRAMEWORK AND IMPLEMENTATION

The German Energy Transition - "Energiewende", the transformation of the energy system, is a core task for Germany's environmental and economic policy. The overall objective is an environmental friendly, reliable and economical feasible energy supply. Germany has set itself ambitious goals: by 2050 it intends to reduce greenhouse gas emissions by 80 – 95 % compared with 1990 levels, with intermediate goals set out for 2020, 2030 and 2040. Together, all sectors of the national economy will help contribute to delivering on these goals [1]. The energy transition is an enormous modernisation and investment programme. Electricity generation plants, power grids, heat networks, heat storage systems, electric vehicles and appropriate recharging infrastructures will be built, high-efficiency heat pumps installed and buildings retrofitted for energy efficiency. While electricity will become the most important source of energy in the energy system the majority of the electricity will be derived from wind and solar power. The costs of wind power and photovoltaic installations are decreasing continuously. They offer enormous potential [1].

In 2016 a capacity of 1,5 GW PV power has been newly installed in Germany (see Figure 1). This results into a total installed PV capacity of 41,3 GW connected to the German electricity grid.

### NATIONAL PROGRAMME

The responsibility for all energy related activities is 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. The 2017 revision of the Renewable Energy Sources Act rings in the next phase of the energy transition: from 2017 onwards, funding rates for renewable electricity systems with more than 750 kW installed power will no longer be fixed by government, but will be determined via a market-based auction scheme – a fundamental change in funding renewable energy. This will permit the further expansion of renewables in a controlled manner, synchronize their expansion with the upgrading of the grid, and set the level of subsidies for them in market-based auctions [2]. A total volume of 600 MW photovoltaic systems will be released in three auctions per year from 2017 on.

In 2016, within the "market integration model" three auctions with a total volume of 410 MW installation capacity have taken place for ground-mounted photovoltaic installations. The calls were characterized by a high degree of competition. The proposed capacity was significantly over-subscribed and the price level decreased

from call to call (7,41 EURcents/kWh -> 7,25 EURcents t/kWh -> 6,90 EURcents /kWh) which shows a good efficiency of the process [3]. Small and medium size photovoltaic systems below 750 kW are continuously eligible with a guaranteed Feed-in-Tariff (FiT) for a period of 20 years. The most important change for PV in 2016 is that new installations > 100 kW power capacity (before > 500 kW) 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 < 100 kWp, a fixed FiT is paid which depends mainly on the system size and the date of the system installation. The FiT is adapted on a regular basis, depending on the total installed PV capacity of the last twelve months. Details on the development of the FiT can be found in the reference section below [4]. Table 1 shows the development of the FiT for small rooftop systems (< 10 kW) installed since 2001.

Moreover, investments in PV installations are getting attractive even without financial support by a Feed-in-Tariff. First offers for PV rooftop system of 10 kW with a price of 10 000 EUR are offered [5]. The Levelized Costs of Energy (LCOE) for these systems are around 0,13 EURcents / kWh whereas the average electricity price for a private household is around 0,29 EURcents / kWh [6]. Therefore, self-consumption of the generated electricity is getting more and more attractive.

This development is fostered by the continuation of a market stimulation program for local stationary storage systems in conjunction with small PV systems (< 30 kWp) [7]. The program is equipped with a sum of 30 MEUR and is designed to run from March 2016 until end of 2018. Around 26 500 decentralized local storage systems have been funded already.

### RESEARCH AND DEVELOPMENT

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

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*	2017*
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	12,31

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



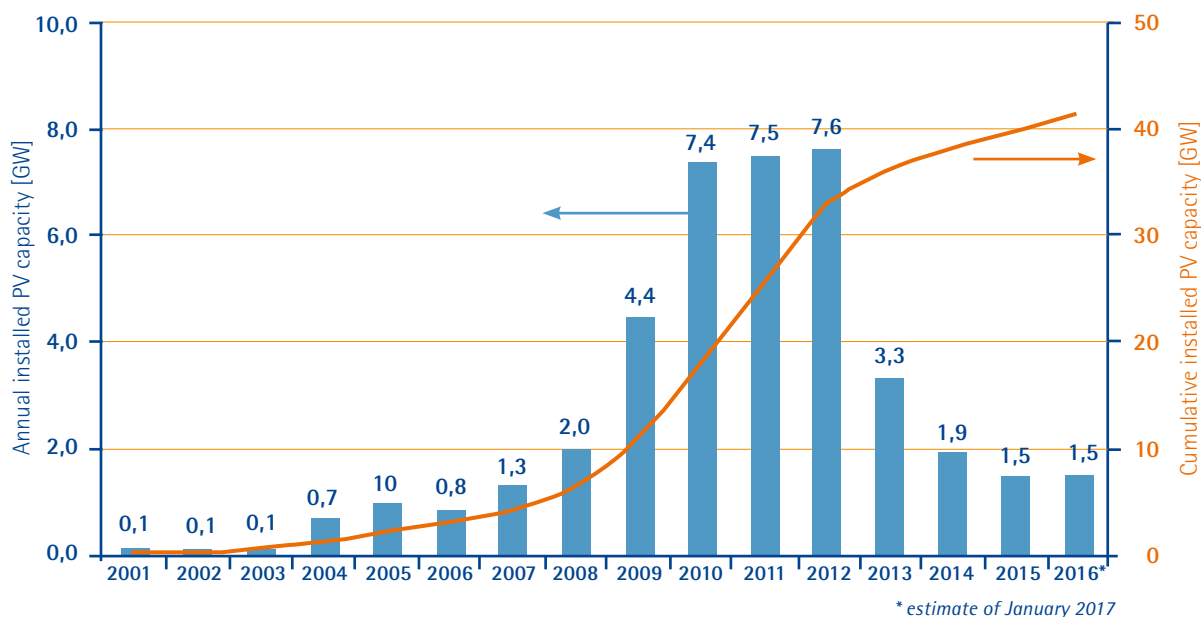


Fig. 1 – Development of grid connected PV capacity in Germany, 2017.

### Funding Activities of the BMWi

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

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

In 2016, the BMWi support for R&D projects on PV amounted to about 57,8 MEUR shared by 368 projects in total. That year, 166 (2015: 97) new grants were contracted. The funding for these projects amounts to 116,6 MEUR (2015: 78,6 MEUR) in total. The development of funding activities is summarized in Figure 2. The German contributions to the PVPS Tasks 1, 9, 12, 13 and 14 are part of the programme. Details on running R&D projects can be found via a web-based database of the Federal Ministries [9].

### Network on Research and Innovation in the field of Photovoltaics

The energy transition will only succeed if all stakeholders work together especially in the field of research and innovation. Therefore, the BMWi coordinates the close and ongoing dialogue between the relevant stakeholders by initiating high-level energy transition platforms. This also creates a high level of transparency, contributing to greater public acceptance of the energy transition. The Research and Innovation Platform acts as an advisory body for the BMWi, hosting a dialogue on the strategic direction of energy research with the national stakeholders in the Federal Government and the business and scientific communities. [10]

Underpinning the Research and Innovation Platform the Network on Research and Innovation in the field of Renewable Energies was founded in 2016. PV and wind power are the two pillars of this network. The network serves as an information and discussion platform for players from industry, universities, research institutes and politics. It is a source of inspiration for the future focus of research on renewable energies to the BMWi and gives concrete ideas for the implementation of thematic topics or support concepts. The members of the network also develop research roadmaps and inform the public about the progress made in the field of renewable energies. The Research Network is an open expert forum for all interested stakeholders.

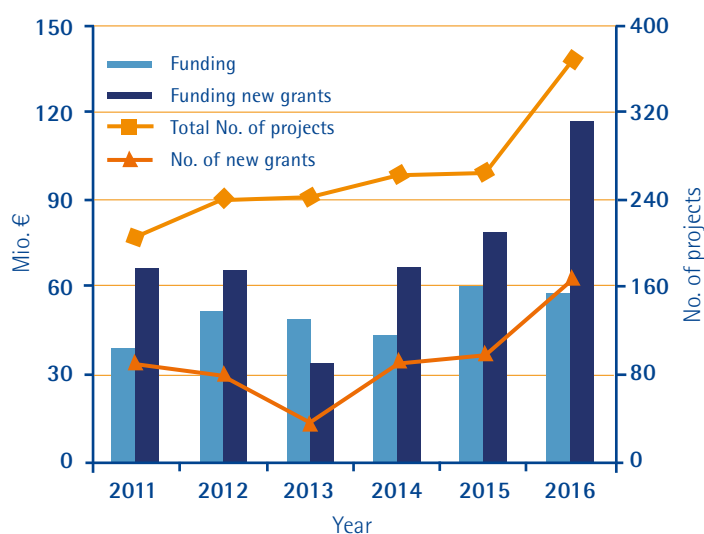


Fig. 2 – R&D support and quantity of PV projects funded by BMWi (BMU) in the 6<sup>th</sup> EFP.



Fig. 3 – Outdoor PV module efficiency and energy yield test facility (Photo: © Fraunhofer CSP, Halle).



Fig. 4 – Ground mounted PV plant along highway (Photo: © IBC Solar AG).

### Funding Activities of the BMBF

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 German Energy Transition are 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.

The program "FuE for Photovoltaik", a joint initiative of BMWi and BMBF, has been launched in 2013. The aim of this activity 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, efficient and cost effective production concepts and the introduction of new PV module concepts with a special focus on quality, reliability and life time. A mid-term evaluation of the running 13 joint projects which are funded by the ministries BMWi (8 projects, 43 MEUR) and BMBF (4 projects, 6 MEUR) [11] has taken place in early 2016.

### INDUSTRY AND MARKET DEVELOPMENT

2016 was once again an ambivalent year for the German PV industry. On the one hand, a significant drop in module prices requested for additional cost savings in the manufacturing processes puts the PV industry under pressure again. On the other hand, manufacturers of components, machines and plants for photovoltaics in Germany benefited from a continued investment of the solar industry in photovoltaic-equipment. The VDMA (Verband Deutscher Maschinen- und Anlagenbau- Mechanical Engineering Industry Association) specialist group on PV reported that orders in the equipment market significantly exceed the number of delivered equipment. Incoming orders after the first three quarters 2016 were higher than 2015 in total. Although sales posted a decline in the third quarter 2016, compared to the same period of the previous year companies in Germany, which are particularly active in the new markets such as India, the Middle East and North Africa, are expecting a new momentum in the coming year [12].

Together with a strong research community and a high number of system installers, a workforce of more than 50 000 people are employed in the PV industry [13].

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# ISRAEL

## PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS: AN UPDATE

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### GENERAL

Following the 2015 Paris Agreement on Greenhouse Gas Emissions Reductions, which Israel ratified before the 2016 Marrakesh meeting, the Israeli government decided on a series of steps to ensure the achievement of the target of 17 % Renewable Energy (RE) electricity production (in energy terms) set for 2030, with interim targets of 13 % in 2025 and 10 % in 2020. This included funds allocated to encourage energy efficiency projects for which a target of 17 % energy efficiency improvement was previously set, and a long series of procedural steps to promote RE and energy efficiency. In light of the continuing fast decline in the cost of PV systems, it is expected that significantly more than 50 % of the renewable energy in Israel will come from the PV sector.

Approximately 905,6 MW of PV power systems were working by the end of 2016, of which 130 MW were connected in 2016. Overall RE capacity was about 970 MW, of which 22 MW is Biogas, 28 MW wind, and about 7 MW hydro. It is worth noting that 22 MW of wind energy connected in 2016, are the first in modern era. PV installations in 2016 were lower than in previous years, due to a halt in quotas allocation during 2014-2016, in expectation for new government policy. For example, in 2014 a quota of 340 MW for PV was issued, to be evenly spread during 2015-2017. This quota did not yet turn into actual PV projects due to various legal issues, which are expected to be overcome soon. The promise for new policy finally materialized, and the Energy Ministry allocated, toward the end of 2016, a new quota of 1 000 MW of PV projects for the years 2017-2018, and declared year 2017 as the RE year. The above-mentioned quotas will hopefully be connected before 2020. The overall electricity production from renewables in 2016 (overwhelmingly PV) was close to 2,5 % - 1,46 TWh. The capacity factor in Israel for PV is considerably higher than in Europe and stands around 19 %-20 % for actual production on an annual average.

Government support is given in the form of guaranteed Feed In Tariff (FIT) for 20 years. FITs varied by project nature, size, installation year and other parameters. FIT have decreased considerably over time.

Worth mentioning is a land auction for a 60 MW project, that was closed during 2016. In this auction the price of electricity was set at the end of 2014 at 0,32 ILS/KWh (0,08 USD/EU), and the bidders competed for the price of the land (the highest offer wins). If one subtracts the price of the land from the winning bid, it translates to a price for the electricity of approximately 0,19 ILS (0,05 USD/EU). The high price offered for the land in this auction, may cause trouble for future pricing of land plots for PV projects.

In order to reduce the costs of RE installations, Israel is now trying a new bidding system for the FIT in medium to large PV projects. The first bidding process for at least 150 MW (out of the aforementioned 1000 MW) is now in progress (beginning of 2017). Under this system, a quota is set by the Public Utilities Commission, and bids are taken. The FIT for all winners will be determined by the price of the lowest bid that did NOT enter the quota (2<sup>nd</sup> price auction or the Vickrey auction).

2015 has seen a dramatic decline in the electricity cost in Israel (around 15 %), which stayed stable during 2016. Thus, the competition to renewable energy has become tougher. Gas prices have gone slightly lower, with the implementation of the supply agreement from Tamar and Leviathan fields. At the same time, the price of coal has risen significantly over the second half of 2016. It now looks quite probable that electricity production from gas will increase to at least 70 % within 3-4 years. At the same time, the Energy Ministry took a historic decision to close a major coal power station, Hadera, with 1 600 MW, within 5-6 years. It is thus clear that PV systems must play an important role in the electricity production supply mix. This can certainly be done as PV electricity costs are around grid parity, even considering additional costs required for backup and balancing. For example, the estimated cost, without externalities, of an open cycle gas turbine in Israel is about 0,25 ILS per KWh, which is most probably higher than the expected closing price of the current PV auction.

### GOVERNMENT POLICY CONSIDERATIONS

2016 marked a significant change in Israel's energy policy, which shifted towards cleaner energy. 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. Israel is now starting to experiment with large scale battery storage, as was evident by the RFI published by the PUA for battery storage solutions in the last quarter of 2016.

At the same time, it now becomes clear that in order to be able to support a high percentage of electricity production from variable RE, Smart Grid is required. Initial steps in this direction are supported by the Chief Scientist Office of the Ministry of Energy.

### 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 was increased in 2016 to 700 MW overall. This quota is applicable to all renewable generation up to 5 MW. Currently around 100 MW of this quota has been used, and with the decline of the FIT, it is becoming more popular.
- As Israel is densely populated in cities, and apartment buildings are the most common way of living, work is now done to enable shared net metering in such buildings, where the roof is shared by the tenants.
- Real-time self-consumption simply reduces the electricity bill.





Fig. 1 - Solar Decathlon: Israel Team's concept of net zero energy co-housing building, and actual model design for the competition (insert).



Fig. 2 - The municipality of Eilat, a pioneer in renewable energy in Israel, develops a smart system to encourage and help local authorities, citizens and commercial building owners to install PV systems on their rooftops.

- 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 0,26 ILS/KWh).
- All the electricity fed into the grid is subject to Grid and Services charges.
- A back-up fee that aims to cover the need to back-up PV systems with conventional power plants. This fee is technology dependent and will grow for solar from 0,03 ILS/kWh when the installed capacity will reach 1,8 GW and then 0,06 ILS/kWh when 2,4 GW will be installed.
- A balancing fee (0,015 ILS/kWh) for variable renewable sources has also been introduced.
- Finally, a grid fee that depends on the time of day and day of the week and connection type (to transmission, distribution, or supply grid) and ranges from 0,01 and 0,05 ILS/kWh has been introduced.

## RESEARCH AND DEVELOPMENT

The Ministry of National Infrastructure, energy and Water 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 supported projects are:

- **Solar Decathlon China 2017** is an international competition where students from 20 international teams compete to plan and build the best and most innovative sustainable net-zero energy house (see Figure 1).  
The Israeli team from **Afeka Tel Aviv Academic College of Engineering** and the **College of Management Academic Studies** have been accepted as finalists for the upcoming competition in China in August 2017. Team Israel plans to build an affordable and sustainable net-zero energy co-housing building by implementing innovative Israeli Solar and energy efficiency technologies.
- **The municipality of Eilat**, a pioneer in renewable energy in Israel, develops a smart system to encourage and help local authorities, citizens and commercial building owners to install PV systems on their rooftops. As the process of installing solar systems has gotten less expensive, more building owners are turning to it as a possible option for decreasing their energy bill (see Figure 2). The system will simplify the process and encourage more building owners to install PV systems. A web interface will allow a building owner to enter his address, and receive an aerial photo of his roof together with PV planning and the financial feasibility of the system. If attractive, he would be able to review a list of the contractors and vendors and choose one to work with. If he needs financing, he will also receive proposals according to his financial situation. Lastly, the city will also create a "fast-track" for permitting and building the system. The goal is to build a system that will be a One-Stop-Shop for solar installations as well as to encourage the owners and shorten the time needed to start producing electricity.  
This project is a collaboration between Eilat City and SolView, who developed a software system to analyze a roof photo for PV installation.
- **Utilight** invented and developed a non-contact Pattern Transfer Printing (PTP™) technology and equipment for printing narrow (30 um width) finger lines on PV solar cells. With the existing interconnection technology (3-5 bus bars and tabs per wafer) it enables savings of silver paste and cell conversion efficiency gain. Theoretical simulation shows that it is possible to significantly

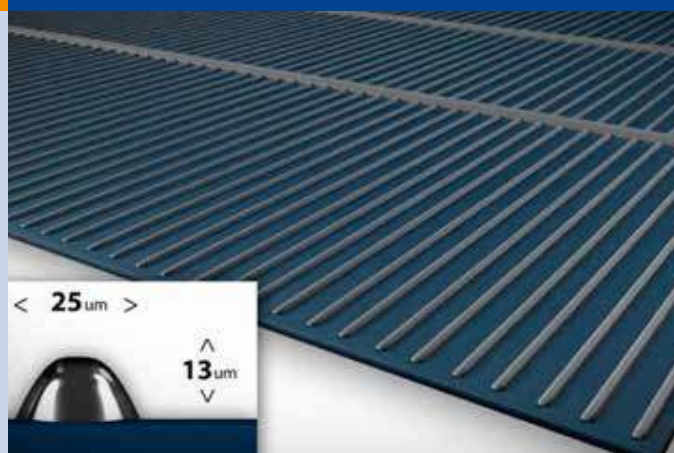


Fig. 3 - Utilight invented and developed a non-contact Pattern Transfer Printing (PTP™) technology and equipment for printing narrow (30 μm width) finger lines on PV solar cells.

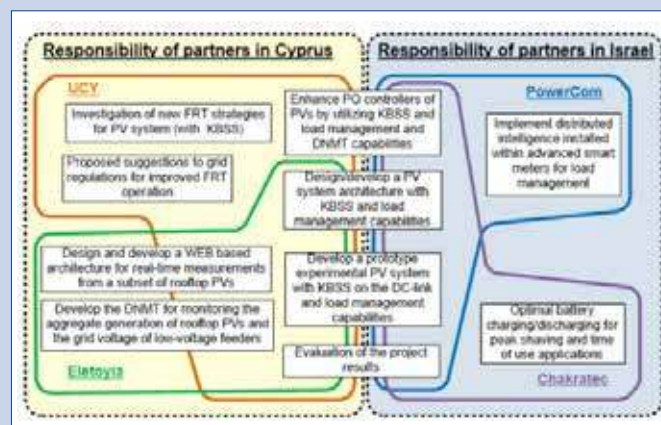


Fig. 4 – SOLAR.ERA-NET collaboration on a MicroGrid project of several rooftop PV systems with storage. Powercom contributes the control system, and Chakratec, the mechanical battery storage system.

increase both cell efficiency gains by about 1 % abs. and silver paste saving down to 30 mg/wafer (see Figure 3). This is achieved by combining PTP ultra-fine finger lines of 15-20 μm width, and 0,5-0,6 aspect ratio, and multiple bus bars interconnections (e.g. 18 as in Smart Wire Connection Technology).

This project is planned as a SOLAR-ERA.NET Consortium "Refined PV" led by ISC Konstanz Institute together with Utilight and several European industrial companies that will provide the needed innovative solutions for implementing the concept. The goal is to design, manufacture and test a novel PV module comprising the novel silicon PV cells and to provide production worthy processes and equipment ready for proliferation in the PV industry.

- In this project, **Powercom** and **Chakratec** will develop, in a SOLAR-ERA.NET collaboration, a managed MicroGrid system that supports a combination of photovoltaic energy and storage. This microgrid system will use a unique flywheel storage system developed by Chakratec with unlimited charge/discharge cycles, high power discharge, deep discharge and other benefits. The combined system will have the ability to manage resources, at the level of generation, and supply the MicroGrid with optimal management of electricity using solar energy and storage. The companies will integrate the MicroGrid components, and run a pilot control and monitoring of different network elements.



# ITALY

## PV TECHNOLOGY STATUS AND PERSPECTIVES

SALVATORE CASTELLO, ENEA

SALVATORE GUASTELLA, RSE



Fig. 1 - Roof integrated 106 kW PV plant at Arsago (VA), Polycrystalline modules (Photo: Solmonte [www.solmonte.it](http://www.solmonte.it)).



Fig. 2 - Roof integrated 4,5 kW PV plant at Solferino (MN), Polycrystalline modules with red cells and frame (Photo: Solmonte [www.solmonte.it](http://www.solmonte.it)).

### GENERAL FRAMEWORK AND IMPLEMENTATION

In 2016, the Italian PV sector continued to grow, but the market remained stable at a rather limited level of PV installations if compared to recent past years when the national incentive programme was active. The PV sector confirms the changed approach while trying to capture new opportunities in distributed generation.

First estimates for 2016 show total new PV capacity installed of about 370 MW; thus underlining a small increased growth compared to 2015 (300 MW) but reduced if compared with 2014 (424 MW). The residential segment of small size plants continued to perform better thanks to tax deductions; medium and large plants did not grow despite the possibility to be installed with a specific grid configuration in order to be recognized Sistemi Efficienti di Utenza (SEU, see below National Programme).

The PV off-grid sector for domestic and not-domestic applications confirmed the slow growth and with about 14 MW installed it remained as a marginal sector.

On the whole, it can be estimated that a total cumulative capacity of around 19,3 GW was reached at the end of 2016.

As a consequence of the above-mentioned information, Italy can be considered a mature PV market with a positive public perception towards PV technology. Moreover, recent preliminary statistics report that PV energy production represents an important part of the electric production: in 2016 PV energy production reached 22,59 TWh (almost equal to the value of 2014) and this represents 8,2 % of the total Italian net electricity production.

According to the recent preliminary statistics, the contribution of "new renewables" (solar, wind and geothermal) reached 16,6 % of the total net electricity production in Italy; a share that reached 32,0 %, that includes hydroelectric. In this frame, PV represented 26 % of all net electricity from renewable sources in Italy.

### 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 the Feed in Tariff law in 2013, two mechanisms are continuing to be applied in Italy: the first, "Scambio Sul Posto" (SSP),

deals with the value of energy exchanged with the grid, given the real time self-consumption allowed for all PV system sizes) and the second relates to Tax breaks. Moreover, a third mechanism, the so-called "Sistemi Efficienti di Utenza" (SEU), has been adopted.

The experience so far has outlined (as confirmed in 2016) that SSP plus tax breaks are the most effective mechanisms in boosting new PV installations, especially in the residential sector.

#### 1. "Scambio Sul Posto" (SSP) and "Ritiro Dedicato" (RID)

This mechanism consists in two schemes:

- net billing system, the so-called "Scambio Sul Posto" (SSP), valid for existing plants with a capacity below 200 kW and from 2015 for new plants up to 500 kW; under the SSP scheme, 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.

#### 2. Tax Breaks and White Certificates

The scheme of tax breaks allows some or all expenses associated with small PV installation (power less than 20 kW) to be deducted from taxable income streams. This scheme has been extended through 2016 and is still available.

Moreover, companies and public institution could benefit from white certificates but only for small size PV plants.

#### 3. Sistemi Efficienti di Utenza" (SEU)

The so-called "Sistemi Efficienti di Utenza" (SEU) consists of a scheme 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. This scheme is becoming widespread, especially among existing medium size 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), RSE (a research company owned by GSE), CNR (the National Council for Scientific Research), EURAC, several universities and other research institutes, including companies' organizations.



Fig. 3 – 14,4 kWp PV plant with 16 kWh Li-Ion Energy storage system, connected to the grid of Lampedusa island (Photo: ENEA, [www.enea.it](http://www.enea.it)).



Fig. 4 – Roof integrated 60 kW PV plant at Lamezia Terme (CZ), 250 W Polycrystalline modules (Photo: SunCity Srl).

ENEA is the most relevant research organization operating in PV in Italy. Most of its activity is in innovative materials, solar cell design, as well as in 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 cells. Moreover, ENEA is focused on an innovative approach for the architectural integration of PV elements in buildings and concentrators technologies. Regarding PV systems ENEA is developing 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 the emerging technologies of energy storage and management also into account. In this context, ENEA has been testing grid-connected PV plants equipped with different storage technologies on Lampedusa Island (see Fig. 3) and at its experimental facilities during 2016. 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 (i.e. CPC Match). In this field, RSE is also involved in the development of new SiGeSn ternary material for four junction solar cells, in the design of new optics, in outdoor and indoor concentrating module characterization and in the development of advanced solar tracking control. Moreover, RSE is engaged in the development of new quaternary chalcogenides PV thin film cells made of chemical elements abundant in the earth's crust to ensure a potential large penetration of PV technology. Furthermore, RSE carries out performance evaluations of innovative flat modules and plants, as well as in research and demonstration activities for electrification of remote communities, such as small islands not connected to the national electric grid.

The PV Energy Systems Group of the Institute for Renewable Energy of EURAC is active in three core areas. In the first area "Performance and Reliability", the activities are focused on the definition of various methodologies for the calculation of degradation rates in PV performance using data from PV systems installed in Italy, Cyprus, and Australia. In the second area of "BIPV Field", the activities have involved the creation of a handbook about success stories and best practices in BIPV projects and the set-up of an outdoor test field dedicated to BIPV. In the frame of the third area "PV Grid Integration", EURAC has investigated the forecasting of PV production by supporting the PV European Technology and Innovation Platform in preparing a related white paper and by analysing, with the local DSO Edyna, data coming from over 2 000 PV plants. Finally, for the

coordination of the project H2020 Solar Bankability, EURAC is involved in the elaboration of methodologies for the calculation of the economic impact of technical risks on the LCOE and on the business models in PV projects.

## INDUSTRY AND MARKET DEVELOPMENT

Italian production of PV modules continues to be in a difficult period, with a gap between actual output, and production capacity. After the end of FiT scheme, the sector became independent from financial support that compromised the proper functioning of the market. Several manufacturers are producing new models, which reached a relevant quality and an efficiency comparable with the best worldwide production, even if the actual output remains lower than their production capacities.

In the sector of power conditioning systems (mainly inverter), the Italian manufacturers confirmed their wide production and their ability to remain among the leading manufacturers around the world. In fact, the Italian inverter manufacturers, taking into account their capacity and the size of the low annual national market, realized that the internationalization is their obliged path. Thanks to the know-hows acquired during the PV boom years, these companies are continuing to reposition in other markets, providing interesting developments for the future growth of this technology. New initiatives on energy storage have been implemented and others have been announced in 2016. They consist mainly on 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 (i. e. a storage system installed by ENEL at Ventotene island).

Moreover, the high level of capacity built in the past helped the growth of companies that provide operation and maintenance activities. Large Italian companies, in the past EPC contractors, and system integrators are mainly focused on large size plant management and maintenance services. Generally, they aim at optimizing performances and reducing costs through integrating management, control and maintenance of big ground plants into single platforms.

In conclusion, it has to be highlighted that some barriers are still conditioning the penetration of PV plants to the electric grid in Italy. The overcoming of these limitations with appropriate governmental decisions on new effective authorization procedures for the installation of centralized ground plants (starting through the use of abandoned industrial areas and of areas not usable for agriculture) can allow to supply a significant share of electric energy economically.

# JAPAN

## PV TECHNOLOGY STATUS AND PROSPECTS

HIROYUKI YAMADA, NEW ENERGY AND INDUSTRIAL TECHNOLOGY DEVELOPMENT ORGANIZATION (NEDO)

OSAMU IKKI, RTS CORPORATION



Fig. 1 - Fujigane PV Power Plant at the foot of Mt. Fuji (Fujikawaguchiko Town, Yamanashi Prefecture) 1,512 kW. Single crystalline silicon PV module (by Hansol Technics) (250 W x 6 048 modules).

### GENERAL FRAMEWORK

The Ministry of Economy, Trade and Industry (METI) revised the Act on Special Measures Concerning Procurement of Renewable Energy Sourced Electricity by Electric Utilities (Renewable Energy Act), in order to realize both the balanced introduction of renewable energy and the reduction of financial burden on the nation. Thus, the "Revised Renewable Energy Act" was enacted. The legal revision brought about a drastic revision of the Feed-in Tariff (FIT) Program in Japan and it was decided to change the approval scheme, change the method to set Feed-in tariffs (FITs), change entities who are obliged to purchase electricity generated under the FIT program, improve transparency of the issues related to electric grids, and to review a scheme for exemption of surcharge payment, toward the scheduled enforcement of the revised Act in April 2017.

Toward a sound development and expanded introduction of PV power generation, METI presented the necessity of increasing competitiveness of PV power generation as a power source and international competitiveness of PV as an industry. Also, METI set out a plan to realize stable and reliable PV power generation and to accelerate autonomous PV introduction in the era of a future-oriented solar life, as its future direction. As for the technology deployment policy, METI formulated the "Innovative Energy Strategy" and presented targets and directions to achieve them based on the following four pillars: 1) thorough energy conservation; 2) expansion of renewable energy; 3) establishment of a new energy system and 4) overseas expansion of energy industries. As for renewable energy, not only the expansion of introduction but also creation of the low-carbon market, reestablishment of the renewable energy industry and expansion of the renewable energy business in overseas markets are stipulated in the strategy.

The national government held a cabinet meeting of the ministers related to renewable energy, etc. and agreed to strengthen the governmental efforts through collaboration among the Cabinet Office, related ministries and agencies and to accelerate the expansion of deployment. The Cabinet Office, related ministries and agencies will promote collaborative projects, revitalization of local economies taking advantage of renewable energy, as well as establishment of a common infrastructure toward expanding introduction of renewable energy.

Regarding the approved and the installed capacities of PV systems under the Feed-in Tariff (FIT) program which took effect in July 2012, a total of 80,3 GW<sub>AC</sub> (as of the end of August 2016, including cancelled and revoked projects) of PV systems have been approved, of which 30,2 GW<sub>AC</sub> started operation. Annual PV installed capacity in 2016 is expected to be at the level of 8 to 9 GW<sub>DC</sub>, and Japan's cumulative PV installed capacity is expected to reach the level of 40 GW<sub>DC</sub>.

### 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 2016, the FIT levels for PV systems were set lower than those of the previous fiscal year. The tariffs and periods of purchase were set as follows: 1) 24 JPY/kWh (excl. tax) for PV systems with a capacity of 10 kW or more for the period of 20 years and 2) 33 JPY/kWh for PV systems with a capacity of below 10 kW (31 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. In the period from July 2012 when the FIT program started to the end of August 2016, 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 5,0 GW, 35,6 GW and 39,6 GW, respectively, amounting to 80,3 GW<sub>AC</sub> in total. Also, METI has been actively working on cancelling the approved PV projects which have not started operation for a long time. Accordingly, the cumulative approved capacity of PV systems decreased by around 1,7 % year on year. However, since it takes time for many PV projects to start operation after they obtained approval due to the issues of permission and electric grids, only 30,2 GW<sub>AC</sub> of PV systems started operation under the FIT program and 5 023 MW of PV systems out of them started operation between January and August 2016, a 25,9 % decrease year on year.

METI revised the Renewable Energy Act in May 2016 and the revised Renewable Energy Act is scheduled to take effect in April 2017. Major points of the revision include the following: 1) drastic changes in the approval scheme, including setting up a requirement to sign a connection contract with a relevant electric utility; 2) introduction of a tender scheme for 2 MW or larger PV projects; 3) review of a method to set FITs; 4) change of off-takers (from electric utilities)



to power transmission and distribution operators in line with the full liberalization of the electricity market; and 5) revision of a scheme for exemption of surcharge through reflecting the energy-saving efforts, etc.

Regarding the changes in the approval scheme, a scheme to sort out a large number of approved PV projects which have not started operation for a long time is included. For example, approval of the projects for which connection contracts are not signed between the developers and the electric utilities by April 1, 2017 will be cancelled. Against the backdrop of the cases where negative impacts were imposed on the neighborhoods of PV power plants, such as flying off or spattering of PV modules due to wind or water damages in recent years, or collapse of developed land, METI set out a plan to focus on security as well as operation and maintenance (O&M). Meanwhile, discussions on the regulatory reform to realize a smarter security of power generation facilities have advanced based on the recent progress in information and communication technologies. It is hoped that the regulations suitable for PV power generation will be formulated.

Following the increase in installations of variable renewable power source such as PV and wind power generation systems, there emerged some cases where forecasted output exceeded the demand. Accordingly, output curtailment was conducted. Currently, output curtailment was conducted only in remote islands with isolated electric grids, but it has been indicated that output curtailment is likely to be conducted in the electric grids of mainland Japan. Electric utilities released their prospects of output curtailment and METI presented guidelines regarding fairness of output curtailment to electric utilities. Basically, it is required to conduct a fair output curtailment even if the projects fall under different rules of output curtailment. The guideline stipulates that the results of output curtailment may differ as long as the fairness of procedures is secured. In addition, when conducting output curtailment, information disclosure is required, including disclosure of a rational reason for output curtailment and information on verification at the Organization for Cross-regional Coordination of Transmission Operators (OCCTO).

It is planned that the electricity generated under the FIT program will be basically traded on the wholesale electricity exchange. In this case, however, the original environmental value will be evaluated. Therefore, it is also proposed to establish the "non-fossil value exchange market," where this environmental value is actualized and traded. In order that electricity retailers respond to the Act on the Promotion of Use of Nonfossil Energy Sources and Effective Use of Fossil Energy Materials by Energy Suppliers and achieve the target of the Act on Promotion of Global Warming Countermeasures (ratio of non-fossil power source by 2030: 44 %, equivalent to 0,37 kg-CO<sub>2</sub>/kWh), as well as to appeal to customers, efforts to separately trade the value of non-fossil power sources from electricity and use the gained compensation to curb the financial burden of the nation are planned.

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

After the enforcement of the FIT program, the focus of METI's budget for the dissemination of PV power generation has shifted from supporting the introduction with subsidy to establishing the environment toward a large-scale dissemination of renewable energy including responses to grid restriction issues and subsidy for storage batteries to adjust the grid. A new demonstration project "Subsidy for projects to establish virtual power plants (VPP)" was established with the budget amount of 2,95 BJPY. Under this project, renewable energy scattered over the electric grid will be functioning as if it constitutes a single power plant (VPP) with a high level energy management technology. As for new programs for PV dissemination, the following budget items were newly established: "Subsidy for projects to support renewable energy operators" (4,85 BJPY) and "Subsidy for projects to promote multifaceted use of renewable energy for local production and local consumption" (4,5 BJPY). The former budget item is designed to provide subsidy for installation of PV systems for self-consumption as well as storage batteries. The latter one is designed to support energy systems for local production and local consumption which share and use renewable energy among multiple facilities. Meanwhile, the budget amount was increased from 45,6 BJPY to 48,3 BJPY for the "Subsidy for project to implement the Feed-in Tariff (FIT) program for renewable energy," which is designed to reduce the amount of surcharge for high power-consuming industries, mainly due to the growing introduction of PV power generation.

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

The **Ministry of the Environment (MoE)** terminated the "Project to promote introduction of renewable energy, etc. in public facilities (Green New Deal project)" and started several new projects in collaboration with other ministries including the following, depending on different purposes: 1) "Project to promote self-sustainable dissemination of renewable energy-based electricity and thermal energy" (6,0 BJPY); 2) "Model project for advanced measures to reduce CO<sub>2</sub> emissions for public facilities, etc." (2,55 BJPY); 3) "Project to promote CO<sub>2</sub> saving in commercial buildings, etc." (5,5 BJPY); 4) "Model project to promote CO<sub>2</sub> saving in water and sewage systems" (2,40 BJPY) and 5) "Model project to promote CO<sub>2</sub> saving in rental housing" (2,00 BJPY). Also, in order to strategically promote technology innovation, demonstration and commercialization, MoE has continued the "Project to promote a hydrogen society using renewable energy" (6,5 BJPY) and the "Project to promote establishment of independent and distributed low-carbon energy society" (1,3 BJPY). MoE also newly established the "Project to promote efficient introduction of renewable energy in national parks, etc." (0,7 BJPY), aiming to introduce renewable energy in national parks.

The **Ministry of Land, Infrastructure, Transport and Tourism (MLIT)** obliged the buildings to conform to the energy conservation standards, in response to the "Act on Improvement of Energy Consumption Performance of Buildings" which took effect in April 2016, 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 the scale larger than 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. As a budget item to realize these efforts, the budget was allocated to the "Green housing in local community" (11,0 BJPY), etc. Moreover, 9,14 BJPY was allocated for the "Enhancement of disaster prevention functions of governmental facilities which act as disaster prevention bases," and 5,4 BJPY was allocated for "Expenses related to sewage projects" which is designed to promote disaster prevention and reduction measures for sewage facilities. In these efforts, introduction of renewable energy is also a significant issue.

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 the introduction of renewable energy to 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 0,6 BJPY in the FY 2016 budget for this project.

The **Ministry of Education, Culture, Sports, Science and Technology (MEXT)** has been actively promoting the introduction of renewable energy in relation to promoting measures to improve quake resistance of educational facilities and measures against aging buildings. According to the result of surveys conducted every other year on the installation status of renewable energy-based power generation systems, etc. 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, etc. 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.

Among **local authorities**, a large number of municipalities formulated action plans to expand the introduction of renewable energy such as PV power generation. Some of them are promoting local production and local consumption of electricity while others are continuously installing PV systems and wind turbines on their own or providing land for project development. Meanwhile, in order to set up certain regulations on the installation of PV systems, which has been rapidly growing across the nation, some municipalities formulated ordinances and guidelines on the installation of PV systems.

## R&D, D

### R&D

As for R&D activities of PV technology, the New Energy and Industrial Technology Development Organization (NEDO) conducts technology development towards commercialization, which is administered by METI, and the Japan Science and Technology Agency (JST) conducts fundamental R&D, which is administered by MEXT.

NEDO advances the "Development of high performance and reliable PV modules to reduce levelized cost of energy" (FY 2015 to FY 2019) toward cost reduction of PV systems as a five-year project from FY 2015 based on the NEDO PV Challenges, a guidance for technology development that was formulated in September 2014. Under this project, four technological development topics were determined in line with the NEDO PV Challenges: 1) "R&D for silicon solar cells employing advanced complex technologies and high performance CIS PV modules"; 2) "R&D for solar cells with innovative new structures"; 3) "Technological development of common infrastructure for PV cell/module" and 4) "Development for common infrastructure technology". Regarding these four topics, a total of 19 R&D topics and three trends survey are underway, aiming to realize the power generation cost of 14 JPY/kWh by 2020 and 7 JPY/kWh by 2030. As for technology development, as well as promoting technological development of infrastructure for commercialization using technology development of high-efficiency solar cells and pilot mass-production lines for various types of PV cells/ modules, development of reliability measurement technology of solar cells and output evaluation technology for PV system are conducted, thus the achievement of the world's highest conversion efficiency of 26,33 % on a practical-sized crystalline silicon solar cell was reported at the results report workshop held in October 2016. Furthermore, in 2016, two new research topics under the "Project for development of PV recycling technologies" and a new study project concerning building-integrated PV (BIPV) were conducted.

As for R&D activities administered by MEXT, development on PV-related technology is continued under "PV cells /modules and solar energy utilization system", as one of the technological fields under the "Advanced Low Carbon Technology Research and Development Program (ALCA)" promoted by JST. In 2016, one research topic was selected respectively for silicon tandem solar cells and perovskite solar cells as new research agendas and fundamental technology development is conducted. R&D activities were promoted as their last fiscal year under "Photoenergy Conversion Systems and Materials for the Next Generation Solar Cells" and "Creative Research for Clean Energy Generation using Solar Energy", which were basic R&D programs through JST, and "FUTURE-PV Innovation Projects", which were implemented by JST in association with reconstruction from the Great East Japan Earthquake.

### Demonstration

Demonstration research related to PV technology is mainly promoted by NEDO. Under the "Demonstration project for diversifying PV applications (FY 2013 to FY 2016)" aiming to extend PV utilization





Fig. 2 - PV System on the Farm of the Graduate School of Agriculture, Kyoto University (Kizugawa City, Kyoto Prefecture). PV system on a plastic greenhouse: 2.15 kW, Organic thin-film PV module (by Mitsubishi Chemical, 25 W x 86 modules). Ground-mounted PV system: ca. 400 kW, Crystalline silicon PV modules (by Toshiba).

areas, validation of installation technologies for building walls, agricultural applications, slopes and water surfaces, etc. and power generation performance at these sites was conducted. Development and demonstration of solar thermal/ PV hybrid modules and systems as added value technologies including functions other than power generation or adding new applications are being conducted. Under "Technological development project for improvement of system efficiency and operation and maintenance (O&M) (FY 2014 to FY 2018)", development and demonstration are being conducted on technologies to increase power generation amount by improving functions of BOS, technologies to reduce BOS cost including installation cost. In 2016, under this project, NEDO solicited new proposals for research topics regarding demonstrations on structure of PV system and ensuring electrical safety. In order to ensure safety against disaster risks, development of design method and technology, demonstration test and research of facilities are conducted. Under "New Energy Venture Business Technology Innovation Program (from FY 2007)", NEDO newly established a phase D for "Large-Scale Demonstration Study" in 2016. Large-scale demonstration study towards small and medium enterprises' commercialization of extremely prospective technology, whose fundamental technology has been already established, though the commercialization risk is high, will be implemented.

Demonstration activities on technologies for utilization of PV system are conducted home and abroad by METI or NEDO in demonstration projects aiming at realizing smart communities and improving storage technology of PV electricity. These projects are aiming at global market development by the localization of technologies to meet the diverse needs of different countries and regions. Major domestic demonstration projects on smart community terminated in FY 2015. The following are major demonstration projects conducted abroad in FY 2016:

- Smart Community Demonstration Project: Lyon, France (FY 2011 to FY 2016), Java Industrial Park, Indonesia (FY 2012 to FY 2017), Manchester, UK (FY 2014 to FY 2016), Speyer, Germany (FY 2015 to FY 2017)
- Demonstration Project for World-leading Remote Island Smart Grid (FY 2011 to FY 2016): Maui Island, Hawaii, USA
- Smart Grid Demonstration Project (FY 2015 to FY 2018): Haryana, India
- Model Project for a Microgrid System Using Large-scale PV Power Generation and Related Technologies (FY 2012 to FY 2019): Neemrana Industrial Park, Rajasthan, India
- Demonstration for Hybrid Solar Inverter & Battery System with Monitoring and Control (FY 2015 to FY 2016): Oshawa, Ontario, Canada

- Demonstration Project for Validation of Redox Flow Battery Performance (FY 2015 to FY 2020): California, USA
- Demonstration project of High-Voltage Direct Current (HVDC) feeding system, etc. for data center (FY 2015 to FY 2016): Texas, USA

Furthermore, in Japan, demonstration projects on large-capacity storage systems are conducted by electric utilities as part of support programs by METI and MoE, aiming to expand possible grid connection capacity of renewable energy and to control the grid. Also, demonstration test on remote output curtailment of PV electricity, demonstration projects towards formulation of VPP as well as development and demonstration, etc. of hydrogen energy technology utilizing PV electricity started as well.

#### INDUSTRY STATUS AND MARKET DEVELOPMENT

In the PV cell/ module and PV system business, the number of new domestic PV projects decreased due to the reduction in FITs and domestic companies actively promoted overseas expansion, preparing for the expected shrinkage of the domestic PV market. Amid the fierce global competitions, these companies are working on further cost reduction, and major domestic manufacturers are seeking business expansion by introducing new products for overseas markets. Domestic manufactures are considering the expansion of production capacity in parallel with development of overseas markets. Panasonic agreed to construct a factory of PV modules in New York, the USA as a joint venture with Tesla (USA) (they are collaborating in production of storage batteries in the USA as well). Solar Frontier and the government of Saudi Arabia agreed to conduct a joint feasibility study into the possibility of CIS PV module production in Saudi Arabia.

In the domestic market, manufacturers are increasingly launching products for the robust residential PV market and domestic PV manufacturers appealing their strength in high performance and high reliability are competing fiercely with overseas manufacturers that aggressively appeal price advantage and long-term guarantee. Domestic manufacturers are focusing on the energy management business and technology development of electric power control, as well as proposing a whole energy system in order to respond to full liberalization of electricity retailing and development of the overseas market.

In the components manufacturing industry, components and processes are under increasing pressure to reduce cost due to the price decline of PV cell/ module and PV system. Under such circumstances, manufacturers started to appeal added values such as ionomer-based encapsulants, thin cover glass, stain-proof coating and wavelength conversion materials, etc.



Fig. 3 - PV System for Parking Lot (AMI PREMIUM OUTLETS PV System Self-consuming All the Generated Power) (Ami-Machi, Inashiki Gun, Ibaraki Prefecture) 1,043 kW. Multicrystalline silicon PV module (by Kyocera, 265 W x ca. 4 000 modules).

In the silicon feedstock industry, Tokuyama decided to sell its manufacturing facility in Malaysia to rapidly rationalize its business. Manufacturers of manufacturing equipment are promoting the proposals towards development and mass production of next-generation PV cells/ modules.

In the manufacturing industry of supporting structures and foundations, in addition to the effort to reduce cost through expansion of business scale and development of simple construction methods, etc., different approaches were reported including proposals of new construction method and supporting structure for low-voltage industrial PV systems and development of new construction method which enables installation of additional PV modules to the existing PV power plants, etc.

In the PV inverter industry, companies are diversifying business in preparation for the expected shrinkage of the domestic PV market in the years to come and emphasizing the overseas market. Major domestic manufacturers such as Toshiba Mitsubishi-Electric Industrial Systems (TMEIC) enhanced production capacity following increase of orders abroad. Adoption of string inverters are advancing for large-scale PV projects. New entries and new product releases are following one after another in the domestic market. For residential applications, activities to launch products for energy generation and storage systems, products adopting GaN power semiconductors and products for outdoor installations were reported.

In the storage battery industry, due to the increase in demand for PV systems for self-consumption at home and abroad, cost reduction, enhancement of production capacity and development of new products have continued. For residential applications, installation of storage batteries as a standard for houses built for sale, small products and products for V2H (Vehicle to Home) were offered. Also, new products of storage batteries for public and industrial facilities have been developed and launched with expectation for demand in the application of input and output levelization of PV electricity, etc., in addition to application for disaster prevention. In Japan, demonstration projects for VPP are promoted and energy-saving services combining PV and storage batteries are offered for cluster housing.

In the housing and construction industry, efforts on zero energy houses (ZEH) are growing with the aim of curbing net energy consumption to zero or below through the combination of energy saving and energy creation. Following the improvement of the surrounding environment such as subsidy program by the government, builder registration and labeling systems, major companies are making effort to launch products while conducting demonstrations. Efforts

on zero energy condominiums and zero energy buildings (ZEB) are also in progress. Establishment of VPP is promoted and Sekisui Chemical is developing a system which enables coordination of storage batteries among households.

In the EPC and PV power generation business sectors, construction of large-scale PV projects with a capacity of more than 10 MW made progress and many large-scale projects started operation in full scale. In order to respond to the reduction in FITs, some companies are constructing mechanism to secure profits by cost reduction of building materials while others are promoting floating PV systems on reservoirs, etc. and solar sharing which aims to achieve compatibility of PV power generation business and agriculture. Amid the fierce environment for investment in Japan, major companies are actively expanding their overseas business and receipt of orders for large-scale projects with capacity of several dozens of MW are reported.

In the area of the PV power generation business support service, following the policy to emphasize long-term stable operation of PV systems formulated by the government and the PV industry, major companies are increasingly strengthening and streamlining operation and maintenance (O&M) service by utilizing a nationwide network. Maintenance of smaller-scale ground-mounted PV systems, etc. which have been increasingly installed nationwide became a major challenge and more companies are aiming to receive more orders through enhancement of the O&M service for low-voltage projects. For large-scale PV projects, various services are being developed including round the clock monitoring at monitoring center of large-scale PV systems, monitoring service using cloud and inspection using drones, etc. At the same time, following the enhancement of functions of monitoring systems, systems automatically corresponding to output curtailment and systems for remote monitoring and electricity storage control were released. Services to forecast PV electric power generation are offered to PPS. These services provide real-time data on electric power generation amount and are utilized for the operation of transmission lines. Reuse and recycling business of PV modules started to be addressed in full scale.

As for the finance-related business, listing on the Infrastructure Fund Market established under the Tokyo Stock Exchange (TSE) became active. The listing of two issues (Takara Leben Infrastructure Fund and Ichigo Group) was realized and several companies are now preparing for the listing. As a result, the secondary market for PV power plants becomes active and the importance of asset management is also increasing. Investment in overseas markets is promoted and large-scale financing for businesses in emerging markets started by the Japan Bank for International Cooperation (JBIC), etc.

# REPUBLIC OF KOREA

## PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

JONGHYUN HAN, KOREA ENERGY AGENCY



Fig. 1 – 2 MW Floating PV system at Boryeong Dam, Boryeong-si, Chungcheongnam-do, Korea.

### GENERAL FRAMEWORK AND IMPLEMENTATION

The Korea government set its 4<sup>th</sup> basic plan for new and renewable energy (NRE) in 2014 which is domestic/international resource development and the long-term (2014-2035) basic plan for the NRE. Visions and targets of 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 shift from the 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, the FIT was terminated at the end of 2011. RPS replaced the FIT scheme from 2012. Under the RPS scheme, Korea's PV installation marked a tremendous jump to 1 134 MW in 2015. At the end of 2015, the total installed capacity was 3 615 MW.

### NATIONAL PROGRAMME

Korea has been making an effort to increase the renewable energy portion of "National energy mix". The new goal was announced in 2014. In the target scenario, 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 4,6 % of the total primary energy supply in 2015.

#### (1) RPS Programme

The 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, 18 (in 2016) obligators (electricity utility companies with electricity generation capacity of exceeding the 500 MW) are required to supply 10 % of their electricity from NRE (New and Renewable Energy) sources by 2023, starting from 2 % in 2012. In 2016, 804 MW of PV system was installed under this programme. In a cumulative amount, about 68,7 % of the total PV installations in Korea were made under RPS scheme, while a total of 500 MW (about 14 %) was installed under the 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 selecting PV electric operator (50 % of the total capacity is selected by less than 100 kW facilities).

#### (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 a certain portion (depending on the size, region and electricity consumption) of the initial PV system cost for single-family and multi-family houses. The maximum PV capacity allowed is 3 kW/household. In 2016, 28 MW was installed under this programme.

#### (3) Building Subsidy Programme

The Government supports a certain portion (depending on the building type) of installation cost for PV systems (below 50 kW) in buildings, excluding homes. Various grid-connected PV systems were installed in schools, public facilities, welfare facilities as well as universities. In 2016, 6,3 MW was installed under this programme.

#### (3) 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 systems 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 installation cost for NRE (including PV) systems owned and operated by local authorities. In 2016, 12 MW was installed under this programme.

#### (4) 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 owners 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 2016, 7,1 MW was installed under this programme.

#### (5) 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 18 % (in 2016) 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 2016, 42 MW was installed under this programme.

#### Production of Feedstock and Wafer:

OCL achieved its total production capacity of poly-silicon feedstock up to 52 000 ton. Woongjin Energy is operating a 1,15 GW silicon ingot capacity plant. Nexolon has a capacity of 1,75 GW in the silicon wafer.

#### Production of Photovoltaic Cells and Modules:

Hanwha Q CELLS Korea has 1,5 GW of photovoltaic cell plants and 1,5 GW of module plants in the province of Chungcheongbuk-do. LG Electronics has a capacity of 1,1 GW and 1,1 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.

TABLE 1 – OBLIGATION SHARE FOR PUBLIC BUILDING OBLIGATION PROGRAMME

YEAR	2011~2012	2013	2014	2015	2016	2017	2018	2019	2020~
OBLIGATION SHARE (%)	10	11	12	15	18	21	24	27	30

#### (6) PV Rental Programme

This is a new NRE subsidy programme launched in 2013. The PV rental programme fully began in 2014. Household owners who used more than 350 kWh of electricity can apply for this programme. Owners pay a PV system rental fee (maximum of 70 000 KRW monthly which is on the average less than 80 % of the electricity bill) for a minimum of seven 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 the REP (Renewable Energy Point), having no multiplier. In 2016, 8,0 MW was installed under this programme.

#### R&D, D

The total PV R&D budget from the Korean government in 2015 was 103,9 BKRW. (MOTIE-Ministry of Trade, Industry & Energy, MSIP-Ministry of Science, ICT and Future Planning, SMBA-Small and Medium Business Administration).

#### INDUSTRY AND MARKET DEVELOPMENT

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

Since the new installation of 276 MW in 2008, the PV market remained stagnant in Korea over the next three years (with new installations of 372 MW during 2009~2011). This was mainly due to limited FIT scheme which played an important role in the early stage Korean PV market expansion. However, 295 MW in 2012, 531 MW in 2013, 925 MW in 2014 and 1 134 MW in 2015 respectively, were installed due mainly to the newly introduced RPS scheme with mandated PV requirement. At the end of 2015, the total installed PV capacity was about 3 615 MW, among them the PV installations that were made under RPS scheme accounted for 68,7 % of the total cumulative amount.

The RPS scheme was again the main driver for PV installation in 2016; 804 MW were recorded under this programme. This is 53 % of the total RPS scheme installation in 2016.

TABLE 2 – CAPACITY OF PV PRODUCTION CHAIN AS ON NOVEMBER 2016

POLY-SI (TON)	INGOT (MW)	WAFERS (MW)	CELLS (MW)	MODULES (MW)
95 000	2 900	2 380	3 705	5 800



# MALAYSIA

## PV TECHNOLOGY STATUS AND PROSPECTS

DATIN BADRIYAH BINTI ABDUL MALEK, MINISTRY OF ENERGY, GREEN TECHNOLOGY & WATER (KETTHA)

CATHERINE RIDU, SUSTAINABLE ENERGY DEVELOPMENT AUTHORITY MALAYSIA

### GENERAL FRAMEWORK AND IMPLEMENTATION

Since 2011, the grid-connected photovoltaic (PV) market in Malaysia is largely driven by the implementation of the feed-in tariff (FiT) mechanism by Sustainable Energy Development Authority Malaysia ("the Authority"). The FiT is framed by the Renewable Energy (RE) Act 2011 [Act 725] whilst the establishment of the Authority is under the SEDA Act 2011 [Act 726]. PV allocation under the FiT will be coming to an end post 2017, due to limitation of the Renewable Energy (RE) Fund. 2016 marked the dawn of new programmes beyond the FiT with the implementation of Large Scale Solar (LSS) and Net Energy Metering (NEM) programmes by the Energy Commission (EC) of Malaysia and the Authority respectively. The main actors involved in the FiT, LSS and NEM are the Ministry of Energy, Green Technology and Water, the Authority, the EC, the distribution licensees, RE developers, and the PV service providers.

### NATIONAL PROGRAMME & MARKET DEVELOPMENT

In Peninsular Malaysia, the electrification rate is almost 100 % while in East Malaysia, the electrification rate is just slightly above 90 %. In this respect, the PV market in Malaysia is dominated by grid-connected PV systems whilst off-grid PV applications are miniscule compared to grid-connected ones. This report only focuses on grid-connected PV market in the country of Malaysia save for the state of Sarawak. This is because the three prevailing PV programmes (i.e. FiT, LSS and NEM) are not applicable to Sarawak as the state is governed by its own electricity supply ordinance.

**FiT Update:** In 2016 alone, a total of 3 794 applications for PV were approved with a total capacity of 101,60 MW. The breakdown of approved applications is as follows: individuals (3 449 applications 32,13 MW), community (126 applications 3,39 MW), and non-individuals (219 applications 66,08 MW). As at 31 December 2016, a cumulative installed capacity of **284,34** MW of PV projects were operational of which the 58,56 MW was for the individuals, 3,47 MW was for the community and 222,31 MW was for the non-individual PV projects. This translated to 6 289 individuals, 183 communities, and 382 non-individuals feed-in approval holders. The **installed PV**

**capacity in 2016 alone was 53,86 MW;** 7,77 MW from individuals, 1,79 MW from communities, and 44,30 MW from non-individuals. More information on PV quota, FiT rates and operational capacity can be viewed at [www.seda.gov.my](http://www.seda.gov.my).

**LSS Update:** The total quota allocated for the LSS from 2017 to 2020 is 1 250 MW [1] <sub>ac</sub>. 250 MW<sub>ac</sub> was granted directly, awarded under the fast track programme and these projects will achieve commercial operation in 2017. The remaining 1 000 MW<sub>ac</sub> will be under a bidding mechanism. At the end of 2016, the EC announced the winners of its LSS bidders who participated in the March 2016 call for tender for Peninsular Malaysia and Sabah. The capacity will reach commercial operation between 2017 and 2018. For Peninsular Malaysia, the capacity was divided into three categories – P1 (1 to 5 MW<sub>ac</sub>), P2 (6 to 29 MW<sub>ac</sub>) and P3 (30 to 50 MW<sub>ac</sub>). For the Sabah region, there were two packages – 1 to 5 MW<sub>ac</sub> (S1) and 6 to 10 MW<sub>ac</sub> (S2). A total of 450,896 MW<sub>ac</sub> was awarded to 19 bidders, the result can be viewed at [http://www.st.gov.my/images/highlight/2016/Announcement\\_RFP\\_Results.pdf](http://www.st.gov.my/images/highlight/2016/Announcement_RFP_Results.pdf).

**NEM Update:** On the 1<sup>st</sup> November 2016, the Authority opened the NEM application for domestic, commercial and industrial sectors. The NEM permits an eligible electricity consumer to install a PV system primarily for own use and the excess energy to be exported to the grid. The credit on the excess energy is based on prevailing Displaced Cost and credit can be rolled over for a maximum of 24 months. A total of 100 MW per year has been allocated from 2016–2010 making a total of 500 MW. As the NEM only started towards the end of 2016, only 27,4 kW of applications were approved and none have achieved operational status in 2016. The digital dashboard on quota availability and allocation of the NEM can be viewed at <https://services.seda.gov.my/nem/auth/login>.

### R&D, D

R&D activities in PV are largely under the purview of the Ministry of Science, Technology and Innovation. Figure 1 shows the main R&D areas of Malaysian universities and research institutions.

Local University and Research Institutions	3 <sup>rd</sup> Gen Cell/ Wafer		4 <sup>th</sup> Gen	Module	BOS			PV System	Radiation Monitoring	Review on Technology / Policy	Social/ Technology/ Economy/ Environment Analysis & Evaluation	PV Application
	CPV	Organic PV, Dye Sensitized Solar Cell			Mounting Structure, racking, tracking system	Inverters, Cables, Charge controller	Energy Storage (battery)					
Universiti Kebangsaan Malaysia		P		P		P	P	P	P	P	P	P
University Malaya					P	P	P	P		P	P	

P – Journal publications

Fig. 1 – Main Solar PV Researches by Local Universities and Research Institute (Source: Malaysian Industry-Government Group for High Technology).

[1] Unless specified, all PV capacities in this report are dc-rated.



Local University and Research Institutions	3 <sup>rd</sup> Gen Cell/ Wafer		4 <sup>th</sup> Gen	Module	BOS			PV System	Radiation Monitoring	Review on Technology / Policy	Social/ Technology/ Economy/ Environment Analysis & Evaluation	PV Application
	CPV	Organic PV, Dye Sensitized Solar Cell			Mounting Structure, racking, tracking system	Inverters, Cables, Charge controller	Energy Storage (battery)					
Universiti Sains Malaysia	P		P									
Universiti Teknologi Malaysia				P		P		P	P	P		
Universiti Putra Malaysia	P				P	P		P	P	P	P	
Universiti Teknologi MARA						Patent		P				
Universiti Teknikal Malaysia Melaka								P			P	
Universiti Tenaga Nasional											P	
Universiti Malaysia Perlis		P							P			
Universiti Malaysia Pahang		P						P				
Multimedia University				P				P		P		
Universiti Tunku Abdul Rahman	P	P			P		P					
Universiti Malaysia Trengganu				P					P			
Universiti Teknologi PETRONAS		P						P	P			P
Universiti Malaysia Sabah									P			
SIRM Berhad									P			Patent
MIMOS Berhad					Patent							Patent

P – Journal publications

Fig. 1 – Main Solar PV Researches by Local Universities and Research Institute (Source: Malaysian Industry-Government Group for High Technology).



Fig. 2 - Showcase of 48 kW PV system as part of Community Project (Photo credit: Choong Wen Chinese Primary School, Kuala Lumpur).

## INDUSTRY DEVELOPMENT

On the PV manufacturing front, Malaysia remains a significant PV producer (after China and Taiwan). According to the Malaysia Investment Development Authority (MIDA), in 2016, export and local sourcing activities undertaken by the top solar companies in Malaysia were valued at 2,5 BUSD and 320 MUSD respectively. It was estimated that over 80 % of the PV products were exported to Europe, the USA and Asia. MIDA also reported that in 2016, Malaysia

has attracted seven more solar manufacturing projects in the solar industry worth 400 MUSD.

In 2016, the total metallurgical grade silicon (MGS) and polysilicon manufacturing nameplate capacity remained at **53,4** kilo tonnes with employment of 840. For ingot, wafer, solar cells and PV modules manufacturing, the total estimated nameplate capacity was 8 284 MW with employment of 15 550.

Figure 3 shows the major PV manufacturing statistics in Malaysia classified under 4 categories for 2016 and 2017 (estimate): Metallurgical and Poly Silicon, Ingot and Wafer, Solar Cells, and PV Modules.

Within the PV industry, there were 106 PV service providers active in the market in 2016. The list of these registered PV service providers for 2017 can be found at [www.seda.gov.my](http://www.seda.gov.my).

METAL SI & POLY SI		2016		2017 (ESTIMATE)	
No.	Company Name	Capacity (kilo ton)	Employment	Capacity (kilo ton)	Employment
1	Elpion Si (Metal Si)	33,4	160	NA	NA
2	Tokuyama (Poly-Si)	20	680	12	NA
	<b>Total</b>	<b>53,4</b>	<b>840</b>	<b>12</b>	<b>0</b>
INGOT/WAFER		2016		2017 (ESTIMATE)	
No.	Company Name	Capacity (MW)	Employment	Capacity (MW)	Employment
1	LONGI (ingot)	0	0	293	217
2	LONGI (wafer, P-type mono)	124	571	426	380
3	Comtec (Ingot, N-type & P-type, mono)	278	434	278	434
	<b>Total</b>	<b>402</b>	<b>1 005</b>	<b>997</b>	<b>1 031</b>
CELL		2016		2017 (ESTIMATE)	
No.	Company Name	Capacity (MW)	Employment	Capacity (MW)	Employment
1	AUO-SunPower (N-type Mono-Si)	685	2 109	745	2 107
2	Hanwha Q-Cells (P-type Multi-Si)	260	-	20	-
3	TS Solartech (Mono & Multi-Si)	500	450	550	550
4	Jinko Solar (Multi-Si)	1 300	4 200	1 300	4 300
	LONGI	NA	NA	227	653
5	JA Solar (Multi-Si)	500	536	500	536
	<b>Total</b>	<b>3 245</b>	<b>5 186</b>	<b>3 342</b>	<b>6 039</b>
MODULE		2016		2017 (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 crystalline)	1 100	2 000	900	910
3	Panasonic (HIT N-type mono crystalline)	425	1 250	430	1 250
4	MSR (Mono & Multi-crystalline)	85	130	100	140
5	Solartif (Multi-crystalline)	10	20	80	20
6	PV HiTech (Multi-crystalline)	5	15	5	15
	LONGi	0	0	254	633
MODULE		2016		2017 (ESTIMATE)	
No.	Company Name	Capacity (MW)	Employment	Capacity (MW)	Employment
7	Endau XT (Mono & Multi-crystalline)	0	0	0	0
8	Hanwha Q-Cells	1 319	900	1 800	1 033
9	Jinko Solar (Multi-crystalline)	450	914	450	914
10	Nanopac (Thin Film)	12	30	12	30
11	Promelight (Mono & Multi-crystalline)	150	200	200	250
12	LONGi	NA	NA	600	2 360
	<b>Total</b>	<b>4 637</b>	<b>9 359</b>	<b>7 231</b>	<b>11 455</b>

Fig. 3 - Major PV Manufacturing Statistics in Malaysia (Source: Malaysian Industry-Government Group for High Technology).

# MEXICO

## PV TECHNOLOGY: STATUS AND PROSPECTS IN MEXICO

AARON SANCHEZ-JUAREZ AND ANTONIO DEL RIO PORTILLA, INSTITUTO ENERGIAS RENOVABLES, UNIVERSIDAD NACIONAL AUTONOMA DE MEXICO

### GENERAL FRAMEWORK AND IMPLEMENTATION

The new Law for the Electricity Industry (LEI) and the Law for Energy Transition (LET) approved last December 2015 has been set the legal framework for the massive deployment in Mexico of PV, along with other renewables. These legal frameworks also included the mechanism for the long terms auctions of clean electricity, clean power and clean energy certificates (CEC).

So, based on the legal framework, the Energy Ministry (Secretaria de Energia, SENER) has carried out two electric auctions in Mexico, one at the end of 2015 that ended in July 2016, and the other that began in June 2016 and ended in September 2016.

The results obtained from the first electric auction, were the following:

- The winning bids were only Wind and Photovoltaic technology.
- 18 clean energy offers were accepted, 12 of which were for PV.
- Start dates for operations were set during and until 2018.
- The contribution of PV projects on the total clean energy capacity to be installed was 3 141 MW.

The average cost per Megawatt-hour was estimated at 51,32 USD.

The results of the second electric auction in Mexico (September 2016) were the following:

According to the results published by SENER on September 28, 2016 (Press Bulletin No. 114) [1], 56 clean energy offers were awarded, giving a total of 1 187 MW of installed capacity, of which 184 MW comes from PV. The share of photovoltaic technology in the total annual energy production corresponds to 54 %. In turn, the average price of the package per Megawatt of clean energy plus certified clean energy had a value of 33,47 USD/MWh. Table 1 shows the main data of the second auction.

On the other hand, a great interest by decision makers at government level, public institutions, private institutions and the general public has been observed for the implementation and operation of photovoltaic systems interconnected to the national electricity system. This interest has allowed the broadening of the panorama on the potential market of users of this technology to the degree that groups of investors have considered that making photovoltaic modules in Mexico is a great opportunity to do business. To date, there are 8 Mexican companies manufacturing photovoltaic modules with a global annual production about 150 MW although the production capacity is almost 1,0 GW.

### NATIONAL PROGRAMME

Except for the new laws enacted within the Mexican Energy Reform, which contemplate the inclusion of renewable energy in the electricity sector to achieve a penetration of 35 % of electricity produced with clean energy, to date there is no defined national program that encourages the massive use of photovoltaic technology. However, this has not prevented a great interest from private investors, developers and energy companies to install, operate and manage photovoltaic plants, whose interest can be verified by the results of the second auction (see Table 1).

### R&D, D

The National Council of Science and Technology through the Sectoral Energy Funds of the Ministry of Energy has promoted the creation of the Mexican Centers of Innovation focused on Research, Technological Development and Innovation on Renewable Energies. Thus, the Mexican Center for Innovation in Solar Energy, CeMIESol, has been created and put in operation since 2014. With 22 projects under development (<http://www.cemiesel.mx/home/>), consulting services, training, incubation of companies, research, innovation and

TABLE 1 – TECHNOLOGIES PARTICIPATION ON THE SECOND AUCTION

Technology	QUANTITIES ASSIGNED BY TECHNOLOGY			TECHNOLOGY PARTICIPATION		
	CEC	Energy (MWh)	Power (MW-year)	CEC	Energy	Power
Solar PV	4 933 382	4 836 597	184	53 %	54 %	15 %
Eolic	3 828 757	3 874 458	128	41 %	43 %	11 %
Geothermal	198 764	198 764	25	2 %	2 %	2 %
Hydroelectric	314 631	-	-	3 %	0 %	0 %
<b>Total</b>	<b>9 275 534</b>	<b>8 909 819</b>	<b>1 187</b>	<b>100 %</b>	<b>100 %</b>	<b>100 %</b>

CEC: Clean Energy Certificate

[1] <http://www.gob.mx/sener/prensa/con-las-primeras-dos-subastas-electricas-mexico-triplico-su-capacidad-en-energias-renovables-pjc-70670>





Fig. 1 - Team members of LANEV at IER-UNAM facilities, Temixco, Morelos, Mexico (photo: LANEV IER-UNAM).

technological development are being offered to the Mexican solar industry, both thermal and photovoltaic. One of the projects, the P-29 "National Laboratory for the Evaluation of Modules and Photovoltaic Systems, LANEV", which has been consolidated and has received its technical accreditation as a Testing Laboratory, is offering the conformity assessment services for modules and photovoltaic systems based on standards IEC61215 and IEC 61730 for the Mexican photovoltaic industry, integrators, developers and users of photovoltaic technology (Figure 1 shows the team members of LANEV).

Although the current photovoltaic projects related to the research and technological development on solar cells within this initiative are in the middle phase, there are very satisfying results in the development of solar cells with conventional semiconductors and new materials.

## INDUSTRY AND MARKET DEVELOPMENT

The Energy Regulatory Commission (CRE) has granted a total of 319 interconnection contracts [2] for PV in the period of 2011-2016, giving a total of 9 408,86 MW, of which 115,6 MW are in operation, 9 277,63 MW are in the process of being installed or are about to start works and in addition, a plant in the state of Durango of 15,62 MW has an inactive status.

A summary of the projects in operation, under construction and inactive by federative entity can be observed in Figure 2. The states with the highest PV power in the construction process are Chihuahua and Sonora, with more than 2 000 MW each, followed by Coahuila, Guanajuato and Jalisco, with projects totaling around 500 MW for each entity. For its part, the states that currently have PV in operation are: Durango, Baja California Sur, Estado de México, Baja California, Sinaloa, Guanajuato and Aguascalientes.

Photovoltaic systems with capacities less than 500 kW do not require a generation permit from CRE, just enough to request the interconnection contract with the Federal Electricity Commission (CFE). PV systems for residential use (<10 kW), general purpose (<30 kW) at low voltage (less than 1.0 kV), as well as users with PV up to 500 kW that do not need to use CFE transmission or distribution lines for bringing energy to their loads fall into this category. The diagram shown in Figure 3 give us the classification of these users according to the power and the supply voltage.

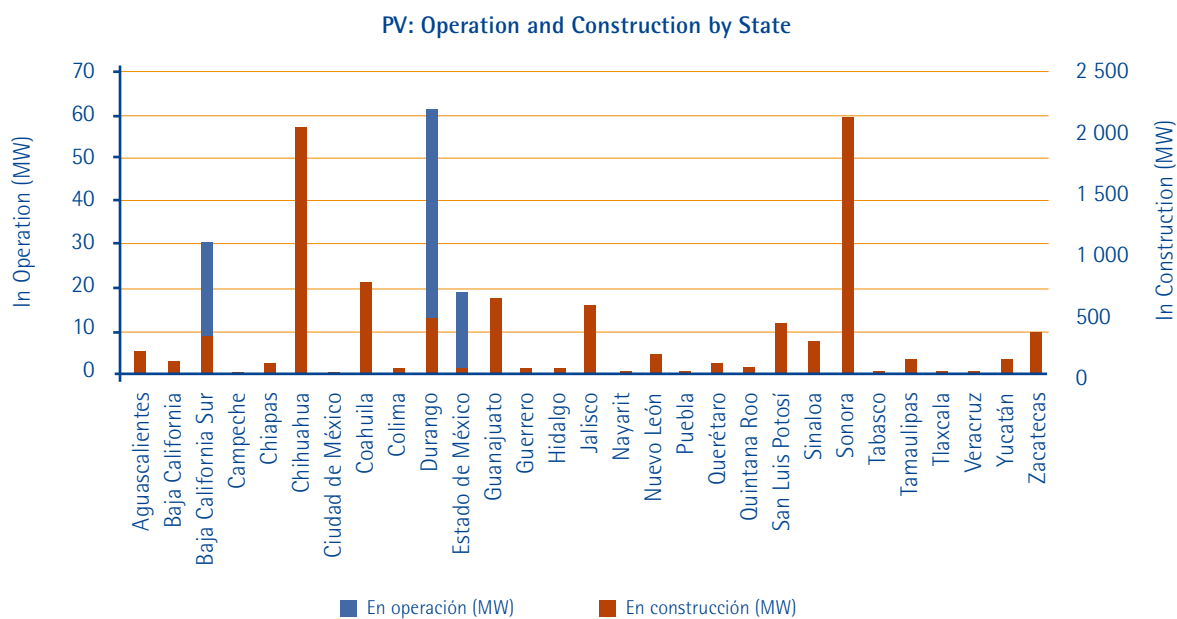


Fig. 2 - Photovoltaic power installed and under construction.

[2] <http://datos.gob.mx/busca/dataset/permisos-vigentes-de-generacion-electrica-por-tipo-de-tecnologia>

INTERCONNECTION AGREEMENT		
SMALL SCALE		MEDIUM SCALE
Residential use up to 10,0 kW	General or commercial use up to 30,0 kW	General use up to 500,0 kW
Electrical voltage <1,0 kV	Electrical voltage <1,0 kV	Electrical voltage <69,0 kV

Fig. 3 - Classification of PV systems less than 500.0 kW that do not need permission from CRE.

According to the report published by the CRE, the number of interconnection contracts awarded until the end of 2015 for power plants with renewable energy was 16 977. In terms of power, it is estimated that 92,4 MW correspond to photovoltaic systems in small and medium scale, while the rest correspond to biomass, biogas and wind energy generation projects.

Although there are no official data on the national development of photovoltaic modules, experts from the National Solar Energy Association (ANES) have estimated that during 2016 the national production was approximately 130,0 MW distributed in 8 companies. Three of these companies have an installed production capacity of more than 50,0 MW, and the remaining ones, in the order of 12,0 MW, which have planned to increase their production capacity. 15 % of the PV national production has been estimated for exportation.

To date, there is no government report on the photovoltaic capacity installed in 2016, which should include those systems that were put into operation and those that were installed but are not operating. One of these systems that has already installed the PV arrays but is not in operation is the 1,0 MW PV plant installed on the top of the Citizen Care Building of the State of Guerrero (CEDAC). This PV plant is located on the seafront in the city of Acapulco Guerrero, a unique system in Mexico that is installed in a structural lattice of steel at 33 meters of height above sea level (a photograph of such systems is shown in Figure 4).

With the projection provided last year, it is thought about 150 MW was installed that during 2016.

The Shared Risk Trust (FIRCO), a technical entity of the Ministry of Agriculture (SAGARPA), as well as the Trust Funded in Relation to Agriculture (FIRA), have continued to support the development of agricultural production projects with photovoltaic systems, and according to data of FIRCO, in the year 2016, 1,25 MW were installed in projects ranging from 20,0 kW to 150,0 kW. Figure 5 shows a photograph of one of the projects mentioned.

Also, academic institutions such as the National Autonomous University of Mexico (UNAM), in terms of its research, teaching and dissemination function, have considered promoting the use of



Fig. 4 - Building of the Government of the Guerrero State; CEDAC Citizen Care Center; Acapulco, Gro., Mexico. 1,0 MW installed on the top of the building at 33,0 m above sea level (photo: Ing. José Luis Castellanos Gómez).



Fig. 5 - Agro Industria Productos y Representaciones, Mazatepec, Morelos, Mexico. Power installed of 64,0 kW (photo: Cryplant, Energías Renovables).



Fig. 6 - 150,0 kW: Instituto de Ecología, UNAM; Ciudad de México, Mexico (photo: Cryplant, Energías Renovables).

photovoltaic systems in their educational campus since it has been determined to become an example at the national level in the development of the energy transition. Thus, several photovoltaic plants have been installed in the main campus of Mexico City as well as in its foreign campus, such as at the Instituto de Energías Renovables which is in the process of installing 150,0 kW at its facilities in the city of Temixco, Morelos. Figure 6 shows a photograph of a PV plant installed in the Instituto de Ecología in the University City, at Mexico City.

#### Acknowledgements

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# THE NETHERLANDS

PV TECHNOLOGY STATUS AND PROSPECTS

OTTO BERNSEN, RVO, ENERGY INNOVATION



Fig. 1 - Combined Solar and Wind (Photo: RVO Image Bank).

## GENERAL FRAMEWORK

The Dutch PV market showed sustained growth in 2016 with an estimated yearly growth of 525 MWp (see Nationaal Solar Trend Rapport 2017, published January 2017). However, there is still room for improvement in the different market segments. The total installed capacity surpassed the 2 GWp in 2016. The trend for larger solar systems, of 15 kWp to up and above 30 MWp, has set in definitely and in the Netherlands. The National Action Plan Solar (NAZ) foresees a growth of total installed capacity in 2023 of 10 Gigawatt. The national goal "Climate Goals" are set at 16 % renewable energy sources (RES) in 2023 and no emissions in 2050. Progress is being made and according to the Dutch Central Bureau for Statistics (CBS press release 29-02-2017), the total amount of renewable electricity production has risen from 11 % to 13 % of total electricity production in 2016 (preliminary figures), of which solar accounts for approximately 11 %. More definite figures follow in May 2017.

In 2016, an evaluation and discussion started concerning the effects and continuation of the existing net metering scheme and what could follow after in combination with local storage (see report PwC "The Historical Impact of Net Metering", 2016). In 2017 a final decision will be taken by the government.

## NATIONAL PROGRAMMES

The national effort on energy innovation is led by the Top Consortium for Knowledge and Innovation (TKI) for Solar which 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, as well as to ensure that the added value to the Dutch economy is maximized.

Supporting schemes for exploitation of solar power are varied and complementary. For small systems, a national net metering scheme exists which is guaranteed until 2020. For systems over 15 kWp, the SDE plus scheme is available which is basically a reversed auction system. For collective PV systems, a tax reduction system is in place called the "Postcoderoos", covering members that live nearby with a similar postal code. Several schemes are in place to stimulate investments by private companies and SMEs. A subsidy scheme exists especially for the replacement of asbestos roofs that targets both households and companies with larger roofs (over 35m<sup>2</sup>). Finally, an energy label is mandatory (the EPC) for houses coming on the market, which stimulates the installation of roof top PV panels. As of 2020 all new buildings will need to be almost "energy neutral".

Apart from these instruments, several regional programmes exist and the so called "Green Deals" can still be closed concerning public-private partnerships that contribute to the 2020 energy goals.

An interesting scheme is the "HE" or renewable energy subsidy, with a 50 MEUR budget per year. It is a generic innovation scheme for all renewable energy sources, including combinations with storage for example, targeting the Dutch Climate Goals for 2030 and that saves on the SDEplus expenses in future years. The goals are the accelerated introduction of new products to the market in order to reach the climate goals with lower expenses.

## RESEARCH AND DEVELOPMENT ACTIVITIES

In 2017, much as in previous years, there exists a R&D budget for solar of 12 MEUR divided over the two programme lines of the TKI "solar technologies" and "multifunctional building parts". In addition, there are separate programmes for fundamental research (NWO and STW), for renewable energy and technical innovation, in general, and specific programmes for SMEs.





Fig. 2 - Roof top application (Photo: RVO Image Bank).

The key research partnerships in these main 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 Tempres, 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 and the TUDelft has a very successful free massive online course (MOOC) "Solar Energy" by Prof. Arno Smets that will be expanded in 2017.

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/> and DIFFER <https://www.differ.nl/research/solar-fuels>.

## INDUSTRY STATUS

In 2016, the manufacturing industry of machinery (led by Tempres, Eurotron, Levitech and VDL) has maintained their market position. From the chemical industry, the multinational DSM has become a worldwide market leader; specifically in encapsulation of solar cells with antireflective and anti-soiling coatings.

There exist several smaller solar production lines in the Netherlands; most notably, Exasun, Kameleon Solar and Hyet, amongst others. The installation of solar has already led to the creation of some 10 000 jobs in the building and installation sector over the last few years (source: Nationaal Solar Trendrapport 2016). 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.tksolarenergy.nl/>

## DEMONSTRATION PROJECTS

Still new market segments are being explored, notably in floating panels, on both fresh and salt or brackish water and integrated solar panels in buildings, transportation and infrastructure. The multi-functional use of these surfaces opens up new business models beyond merely the energy yield of the panels.

Apart from the technical aspects, the demonstration phase of integrated solar projects has moved into the areas of the legal and local planning procedures, as well as system integration. Solar power has become a forceful driver of social change in the Netherlands.

## IMPLEMENTATION AND MARKET DEVELOPMENT

The PV market showed sustained growth in 2016 with an estimated added amount of 525 MWp.

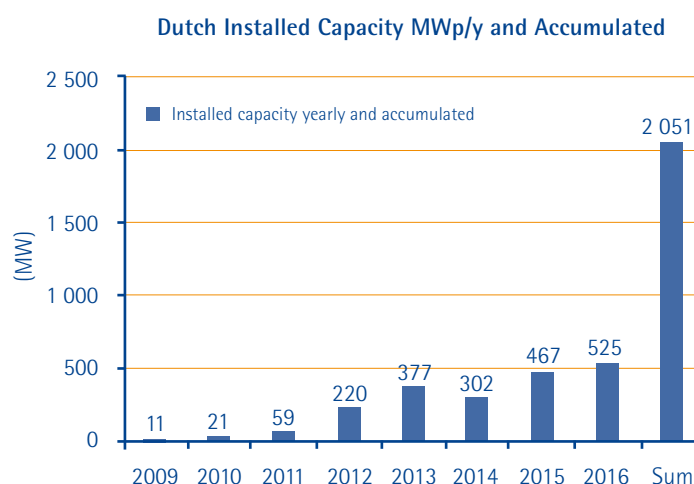


Fig. 3 - Preliminary estimation for the installed capacity in 2016 and the accumulated/sum based on CBS Statline. (Source for 2016: Nationaal Solar Trend Report 2017). CBS Statline, has not yet been published over 2016).

Of this total accumulated amount, some 356,2 MWp is installed under the SDE Plus (over 15 kWp systems), see (Figure 4) and roughly a third (180,7) of all new panels in the last year 2016. This trend for larger systems has definitely set in and is expected to continue over the next years. The exact amount of yearly growth however is depending on several factors, such as the availability of private financing and competition with other (cheaper) technologies under the SDE plus scheme.

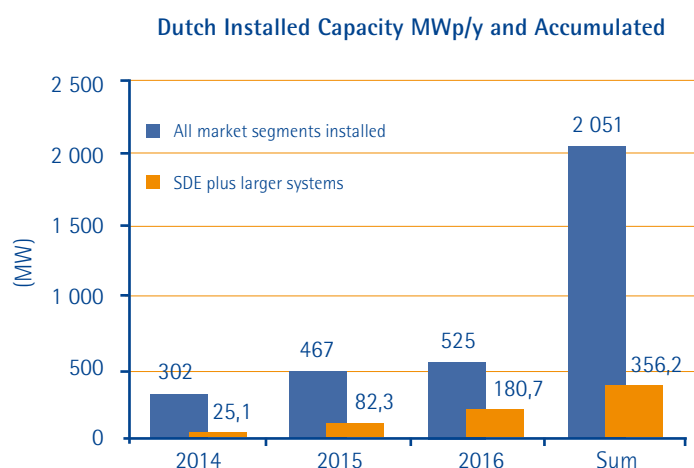


Fig. 4 - Installed capacity yearly, in all market segments and accumulated/sum in SDE Plus (Source: RVO, SDE Plus Facts & Figures).



# NORWAY

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

TROND INGE WESTGAARD, THE RESEARCH COUNCIL OF NORWAY



Fig. 1 - 1322 kW rooftop/wall PV system installed in 2016 at UNIL's distribution center in Våler, Norway. (Photo: Leif Skorge, MultiConsult AS).

## GENERAL FRAMEWORK

Norway's electricity production is already based on renewable energy due to the availability of hydropower. In normal years the electricity production from hydropower exceeds the domestic electricity consumption by a significant margin. In 2016, hydropower generated 96 % of the total electricity production of 149 TWh, while the gross domestic electricity consumption was 132 TWh. The hydropower generator capacity can under normal circumstances satisfy peak demand at any time.

Norway and Sweden operate a common electricity certificate market in order to stimulate new electricity generation from renewable energy sources. This market-based support scheme is in practice not accessible for small scale producers due to the registration fees.

In this situation where electricity already is provided from renewable energy sources, PV systems are predominantly installed on residential and commercial buildings for self-consumption of the electricity produced by the systems.

## NATIONAL PROGRAMME

Norway has no defined goals when it comes to implementation of PV technology. The electricity certificate market is technology neutral, and it has so far only been relevant for hydropower, wind power, and in 2016 a few commercial rooftop PV installations. To compensate for this, Enova SF subsidizes up to 35 % of the installation costs for grid connected PV systems at a rate of 10 000 NOK per installation and 1 250 NOK per installed kW maximum capacity up to 15 kW. Enova SF is a public agency that supports new power generation and energy saving technologies.

In 2016 it was decided to introduce mandatory rules for access to the grid for sale of surplus electricity from privately operated PV systems, and these new rules take effect from 2017 onwards. These rules exempt small suppliers of surplus electricity for some specific grid connection fees.

Enova has a support program for "Buildings with High-Energy Performance". This program offers financial support to buildings where the energy performance goes beyond standard technical norms. E.g. combinations of PV roof top installations and advanced energy saving technologies in buildings may be eligible for this type of support. The municipality of Oslo had a capped support scheme for PV systems on residential buildings. The municipality gave financial support limited to 40 % of the investment cost for systems on buildings with less than four apartments. The reimbursement takes place when the installation is completed. The total support of 6 MNOK (0,8 MUSD) for 2015 and 2016 combined was fully allocated. The same support level was available for multi-apartment buildings and commercial buildings in Oslo if the planned installations were of sufficient quality. Oslo also has targets for investments in PV installations on buildings owned by the municipality.

## RESEARCH AND DEVELOPMENT

The Research Council of Norway (RCN) is the main agency for public funding of research in Norway. Within the energy field, it funds industry oriented research, basic research, and socio-economic research.

The total RCN funds for solar related R&D projects, mostly in PV, were approximately 110 MNOK (13 MUSD) for 2016. 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.

The Norwegian Research Centre for Solar Cell Technology has completed its last full year of operation ([www.solarunited.no](http://www.solarunited.no)) before the transition to a new center takes place in the first half of 2017. Leading national research groups and industrial partners in PV technology participate in the center. The research activities have been within silicon production, mono- and multi-crystalline silicon,

next-generation modeling tools for crystallizing silicon, solar cell and solar panel technology, new materials for next-generation solar cells, and new characterization methods. In addition, the center has a value-chain project that applies the results of the other activities in production of working solar cell prototypes. The total center budget is ~350 MNOK (42 MUSD) over its duration (2009–2017).

RCN approved the application for a new solar cell technology FME-center from 2017. The new center will have its focus on up-stream activities (silicon feedstock, ingots and wafers), but it will also include research that is relevant for use of PV systems with Norwegian building codes in northern European climate conditions.

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

- Institute for Energy Technology (IFE): 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, there are a characterization laboratory and a polysilicon production lab, featuring three different reactor types.
- University of Oslo (UiO), Faculty of Mathematics and Natural Sciences: The Centre for Materials Science and Nanotechnology (SMN) is coordinating the activities within materials science, micro- and nanotechnology.
- Norwegian University of Science and Technology (NTNU) Trondheim: Focuses on production and characterization of solar grade silicon. Some activities on PV systems took place in the FME-center ZEB (Zero Emission Buildings), which ended in 2016.
- SINTEF Trondheim and Oslo: Focus on silicon feedstock, refining, crystallisation, sawing and material characterisation.
- Norwegian University of Life Sciences (NMBU): 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 Solar. Renewable Energy demonstration facility with PV-systems, solar heat collectors, heat pump, heat storage and electrolyser for research on hybrid systems.

The Northern Research Institute (Norut) in Narvik also has a research group that is active in silicon solar cell research and testing of PV systems under arctic conditions.

## INDUSTRY AND MARKET DEVELOPMENT

The Norwegian PV industry is divided between "upstream" materials suppliers and companies involved in the development of solar power projects. The industry supplies purified silicon, silicon blocks, and wafers in the international markets. Solar power project development is to a large extent oriented towards emerging economies.

**REC Silicon** is noted on the Oslo stock exchange, but the company's production of high purity silicon takes place in the United States.

**Elkem Solar** operates a production plant for solar grade silicon (ESS) in Kristiansand in southern Norway. This plant uses a proprietary

metallurgical process that consumes much less energy than other processes for purification of silicon. The production capacity is approximately 6 000 tons of solar grade silicon per year. In addition, Elkem Solar produces multicrystalline silicon blocks at Herøya in eastern Norway for its subsidiary REC Solar. REC Solar has a yearly solar panel production capacity of 1 300 MW at its integrated wafer, cell, and solar panel manufacturing plant in Singapore.

**NorSun** manufactures high performance monocrystalline silicon ingots and wafers at its plant in Årdal in western Norway. Annual ingot production capacity is equivalent to 350 MW of solar panel capacity. The major part of this ingot production is converted to wafers utilizing diamond wire sawing at the Årdal plant.

**Norwegian Crystals** produces monocrystalline silicon blocks in Glomfjord in northern Norway. The capacity of the factory is equivalent to 200 MW per year. The company also supplies wafers to its customers.

**The Quartz Corp** refines quartz at Drag in northern Norway. Parts of this production are special quartz products that are adapted for use in crucibles for melting of silicon.

**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. The present portfolio of power plants has a capacity of 322 MW and is located in the Czech Republic, South Africa, Rwanda, Honduras, and Jordan. The company has a project pipeline that includes new projects in Malaysia, Brazil, and Mozambique.

## IMPLEMENTATION

Although the Norwegian PV market is small on an international scale, there was a steep increase in PV installations in 2016. In total, 10,7 MW of grid-connected PV capacity and 0,8 MW of off-grid PV capacity were installed in 2016, while the total PV generation capacity installed before 2016 was approximately 15 MW. This upwards shift in the installation rate is obviously linked to the fact that reduced installation costs made it more economically attractive to use the support schemes for PV installations.

8 of the 10 largest PV installations in Norway were connected to the grid in 2016, with a combined maximum capacity of 6,2 MW for the 8 new installations. These installations were all on commercial buildings, and the largest installations are placed on refrigerated warehouses where maximum electricity consumption matches well with maximum insolation. A driver for the increased installation rate of large commercial systems was that the rules for electricity certificates with respect to self-consumption were clarified.

The higher installation rate of 2016 is expected to continue, given the reduced installation costs for PV systems. The uncertainties are related to whether owners of commercial buildings consider the investment in PV systems financially attractive, and to the extent municipalities will offer more attractive subsidies for residential installations than the nationwide Enova subsidy scheme.

# PORTUGAL

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

ANTONIO JOYCE, LNEG (LABORATORIO NACIONAL DE ENERGIA E GEOLOGIA)



Fig. 1 - The new Fatima Sanctuary Church's PV system.

## GENERAL FRAMEWORK AND IMPLEMENTATION

The policy framework for renewable energies in Portugal has led Portugal to a very good position on the topic of renewable integration on the electricity sector. The actions described in the National Renewable Energy Action Plan (PNAER) together with the actions of the National Energy Efficiency Action Plan allow Portugal to comply with the Overall and National Objectives of the European Renewable Energies Directive 2009/28/EC on the promotion of the use of energy from renewable sources.

The PNAER was defined by the Council of Ministers' Resolution nº 20/2013, published in the Portuguese Official Journal, 1<sup>st</sup> Series, Nº 70 from 10<sup>th</sup> of April 2013. This official document foresees, that the contribution of Solar PV for 2020 is 670 MW of installed capacity and 1 039 GWh of energy generation, respectively. Solar energy is expected to have an important role in the increase of decentralized power production. Moreover, it is expected a contribution of concentration PV for 2020 of 50 MW installed capacity and 100 GWh of energy generation.

By the end of 2016, according to the monthly reports of DGEG the installed capacity was mainly in the framework of the legislation for Self-Production (Decree-Law 153/2014 of 20 October) with a total of 48,7 MW including:

- Self-Production Units (UPAC): 37,5 MW (5,2 MW of which were PV systems below 1,5 kW with no need for a licensing process);
- Small Production Units (UPP), up to 250 kW: 11,2 MW.

To these values, 9 MW of new Utility Scale Power Plants (PRE) have to be added giving a total of 57,7 MW of PV power installed in 2016 giving rise to a cumulative PV power installed in Portugal in 2016 of 512,7 MW.

In terms of PV energy produced in 2016 the total value is 781 MWh representing 1,6 % of the total consumption (49 269 MWh).

## NATIONAL PROGRAMME

The PNAER, defined by the Council of Ministers' Resolution nº 20/2013, foresees for 2020 a PV installed capacity (including CPV) in Portugal of 720 MW and a yearly produced energy of 1 139 GWh.

The new regulatory framework (Decree-Law 153/2014 of 20 October) is applicable to small-scale RES generation with grid injection and with a FIT (up to 250 kW) and to generation based on any kind of source for own consumption (no capacity limit), though the great majority of installations already completed are photovoltaics.

This Decree Law provides the same simplified licensing procedures as the previous programmes of micro- and mini-generation for local grid-connected energy producers. In effect, licensing is conducted online via Internet, using the Electronic System of Registration of Generation Units (SERUP), allowing two regimes:

- The small generation is applicable to any type of systems up to a limit of 250 kW, where a reference FIT is established and applied to each RES according to a different percentage: 100 % for solar, 90 % for biomass and biogas, 70 % for wind and 60 % for hydro. The reference FIT for new producers, valid for 15 years, has a value of 95 EUR/MWh, to which an amount of 5 EUR/MWh is added if at least 2 m<sup>2</sup> of solar thermal panels are used in the consumer's installation or an amount of 10 EUR/MWh is added if there is an electric vehicle charging power outlet connected to the mobility grid in the consumer facility.
- Self-consumption is applicable to any kind of source since it does not benefit from a FIT, and has the possibility of injecting the surplus into the grid, which is paid by the last-resort supplier at 90 % of the average monthly Iberian market (MIBEL) price. Optionally, renewable energy generators in self-consumption (either grid connected or off-grid) can also trade the electricity surplus or the generated electricity by green certificates.

## R&D, D

In the last years, PV R&D in Portugal has had a strong development, which includes an important scientific community with a significant number of researchers working in different aspects of photovoltaics. These are mostly public research groups related to universities and national research centres but some important private companies in Portugal are also addressing the innovation process in PV.

Some of the most important players in R&D activities are:

**The University of Minho**, working on PV conversion materials namely on thin film; amorphous/nanocrystalline silicon solar cells; silicon nanowire solar cells; oxygen and moisture protective barrier coatings for PV substrates; and photovoltaic water splitting.

**INL (International Iberian Nanotechnology)**, working on solar fuel production; Inorganic-organic hybrid solar cells, sensitized solar cells, perovskite solar cells,  $\text{Cu}_2\text{O}$ ,  $\text{Cu}(\text{In,Ga})\text{Se}_2$  solar cell devices and materials, quantum dot solar cells, thin film Si, encapsulation barrier and Si-NW solar cells.

**The University of Oporto (Faculdade de Engenharia da Universidade do Porto)**, working on Solar PV cells and modelling processes.

**The University of Aveiro**, working on semiconductor physics; growth and characterization of thin films for photovoltaic applications.

**The University of Coimbra (Faculdade de Ciências e Tecnologia)**, working on dye-sensitized solar cells, perovskite solar cells, bulk heterojunction organic solar cells and metal oxide photo-electrodes for solar fuel applications.

**The University of Lisbon (Faculdade de Ciências)**, working on silicon technologies namely ribbon cells, and modelling.

**The University of Lisbon (Instituto Superior Técnico)**, working in organic cells.

**The New University of Lisbon (UNL) (Faculdade de Ciências e Tecnologia, UNINOVA and CENIMAT)**, working on thin film technologies and tandem cells.

**LNEG (Laboratório Nacional de Energia e Geologia)**, working on conversion technologies namely organic cells, perovskites, kesterites (CZTS) and CTS and also on new PV/T modules and modelling.

Also private companies, for example, **EFACEC**, **Martifer Solar**, **Open Renewables** and **MagPower** have their own research and innovation groups.

## INDUSTRY AND MARKET DEVELOPMENT

Production of photovoltaic cells and modules (including TF and CPV) is taking place in Portugal.

There is a considerable experience in module production in Portugal with some factories highly automated, mainly on crystalline silicon technologies. Examples are:

**Open Renewables** – The oldest manufacturer of PV modules in Portugal with a 60 MWp/year rate.

**Martifer Solar** – with a production rate of 50 MWp/year.

**Jinko** – with a production rate of 30 MWp/year.

Thin film technologies, such as amorphous silicon, had some industry development during a few years but are no longer operating.

An important PV industry development in Portugal is related with concentrated photovoltaics, CPV, along with a totally Portuguese engineering developed product on HCPV at **Magpower** with a production rate of 54 MWp and with an internationalization process; which has several projects installed abroad.

The power electronics industry is important in Portugal namely through **EFACEC**, a well-known and internationally established company. For the PV sector it is important to mention grid-connected inverters and also controllers.

Several manufactures of supporting structures exist.

There is also a considerable amount of expertise in Portuguese companies on planning and engineering PV plants; with already an important portfolio of installations in Portugal and abroad.



# SOLARPOWER EUROPE

SOLARPOWER EUROPE'S ACTIVITIES

ALEXANDRE ROESCH, POLICY DIRECTOR, SOLARPOWER EUROPE



Fig. 1 - James Watson (SolarPower Europe CEO) with Maroš Šefčovič (European Commission Vice-President for the Energy Union).

SolarPower Europe, formerly known as EPIA (European Photovoltaic Industry Association), is a member-led association representing organisations active along the whole value chain.

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.

2016 was an important year for the energy sector in Europe. Indeed, the European Commission presented on 30 November 2016 the so-called "Clean Energy for All Europeans" package, which sets the scene for the evolution of the European energy mix for the decade 2020-2030 and proposes important adaptations to the power market rules.

Through a constant interaction with policy-makers over the last year, SolarPower Europe secured several policy asks in that package which are crucial for the further development of solar in Europe and in particular:

- A proactive European framework for self-generation and consumption
- An obligation for EU countries to provide visibility on national support schemes for at least three years ahead by publishing a long-term schedule
- An "anti-retroactivity clause" to ensure the stability of financial support to renewables
- Mandatory one stop-shops in all countries for permitting and grid connection procedures, with clear time limits
- Minimum shares of renewables in all new buildings and buildings undergoing major renovation

- The guarantee that all projects built up to 2020 will benefit from priority dispatch and access after 2020
- A framework limiting the use of capacity mechanisms which includes an emissions target to avoid coal generation qualifying under such schemes
- The guarantee that EU countries cannot go below their 2020 RES targets and that they must collectively deliver on the 2030 RES target
- An enabling framework for solar + storage applications
- An adaptation of markets rules (day-ahead, intraday, balancing) to make them fit for variable solar electricity

In addition to the above-mentioned highlights, SolarPower Europe worked intensively on sensitive and important topics for the solar industry such as the trade case.

To enhance its voice, SolarPower Europe has built coalitions with utilities, system operators, sectoral industry associations, NGOs and other relevant stakeholders. It also took an active role in the enhancement of the e-mobility platform which promotes the further electrification of the transport sector.

SolarPower Europe also increased substantially its presence on social media and organised several successful events, in particular the celebration of 100 GW of solar capacity installed in Europe in presence of the European Commission Vice-President Maroš Šefčovič and which was granted the award of the "Best Networking Event of the Year" by the European Association Awards.



Fig. 2 – Launch of the Global Market Outlook at Intersolar Europe 2016.

Throughout the year SolarPower Europe pursued and reinforced its service-oriented approach towards members by coordinating several task-forces on:

- Operations and Maintenance (O&M), which led to the publication of industry-led best practices guidelines
- Solar tenders, which allowed our members to present their expectations regarding the design of tenders in Europe
- Solar and storage, which developed 10 policy priorities for the deployment of such combined solutions
- BIPV, through which our industry made several proposals to deploy solar in the building sector
- Digitalisation, which will look inter alia at how to make solar accessible to all consumers
- The final report of the *Solar Bankability* project, which aims at analysing the risks associated with solar PV investments, establishing a common practice for professional risk assessment based on technical and commercial due diligence.
- The *CrowdfundRES* project, which explores how crowdfunding can provide additional and new sources of financing for renewable project developers.
- The *Cheetah* project, 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.

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. It also took a very active role in the setting-up and reinforcement of the Global Solar Council and is currently chairing the Council.

Finally, SolarPower Europe's policy and business objectives were again supported in 2016 by thought-leading research in fields such as solar PV market forecasts, financing, and electricity market design. Notably, the SolarPower Europe team published and/or contributed to:

- The Global Market Outlook 2016-2020, describing European and global solar PV market trends until 2020.
- The final report of the *Market4RES* project, which investigates 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 Best Practices Guidelines and the European Advisory Paper of the *PV Financing* project, which looks at the most promising business models and financing schemes for solar PV systems, such as self-consumption and PPAs based business models.

# SPAIN

## PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

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

### GENERAL FRAMEWORK

The development of photovoltaic solar energy in Spain during the year 2016 has been similar to the previous one; with very low installation grid connected and no increase in industrial activity related to PV. At the same time, the 11 months to have the new government in place have led to an extension of regulation existing in the previous year and the issuing of new laws that might have had positive impact on PV deployment have been postponed.

Self-consumption, seen as an interesting possibility, did not take off yet. All the political parties, except one, fully support this scheme and the results of the elections might have made a change to the deployment scenario. However, the delay for a new government has also stopped this activity.

Concerning the electricity generation in the country and the contribution of the renewable energies to the demand coverage during 2016, the results are shown in Figure 1. As almost no new capacity was added on PV or on wind, the increase in percentage of demand coverage with respect to 2015 is due mainly to the higher contribution of hydraulic power and a slight increase in wind power.

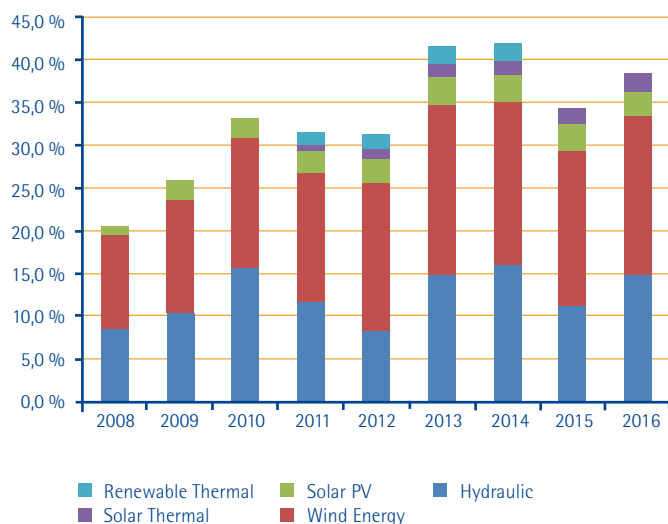


Fig. 1 - Percentage of demand coverage from renewable energies (2008, 2009 data out of CNE, 2010 -2016, REE ).

In numbers, the total coverage of electricity demand by renewable energies was close to 40 % (38,4 % estimated); four points more than in 2015. In the case of Spain peninsular, this value goes up to 41,1 %. This positive trend with respect to 2015 has been due to the increase of hydro (3,4 points) and wind (0,6) contributions. In these circumstances of almost no renewable capacity added, it is mostly meteorology that is responsible for the electricity generation variations. Champion among all RREE generation was Wind (18,6 %), followed by Hydraulic (14,9 %). Photovoltaic was 3 % (slightly lower than in 2015) and Solar Thermal was 1,9 %.

In the case of absolute values and the comparison with the generation of different sources, the results are presented in Figure 2. Total absolute demand has increased close to 0,8 % to 265,3 TWh in 2016, and it can be seen that, while the evolution of most of the sources is quite stable, the decrease in generation due to coal has been compensated with the increase of hydraulic and slightly on wind, and the total demand has been completed with net imports of 7 313 GWh from outside of Spain.

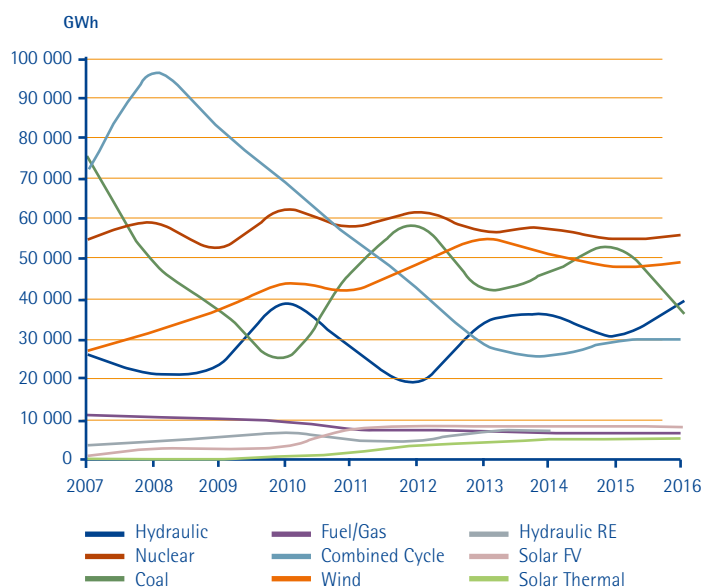


Fig. 2 - Evolution of electricity generation (all sources).

PV was responsible for 7 979 GWh, lower than the 8 236 GWh from 2015. Apart from meteorological aspects, there are no clear reasons for this decrease. Figure 3 shows the PV installed capacity in Spain (grid connected), with very little new capacity added since 2013. The absolute value of GWh remains stable with slight variations since 2012. If the tendency to lower values of electricity generation continues, an analysis should be made in order to identify the reasons for this (apart from meteorological aspects, the normal evolution of the technology, lower maintenance activities due to lower income or any other reason that might exist). Isolated capacity in the shape of small installations has been added in the country; however, it is not easy to have a reasonable value. Reference should be made to the UNEF report for this, which includes contributions from all actors in the PV chain in Spain. The first numbers from this report announce a capacity increase close to 55 MW.

Electricity generation and installed PV

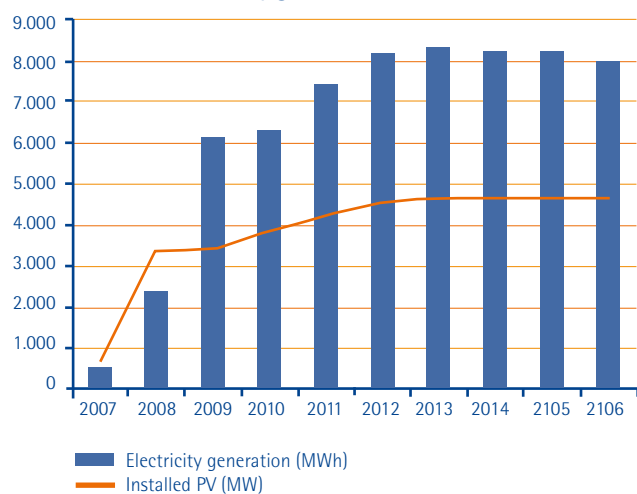


Fig. 3 - Evolution of yearly electricity generation and accumulated installed power for PV technology (Source: UNEF-CNMC; production 2012 - 2016 REE-preliminary data).

Finally, and considering the use of the electricity produced by PV technology, it is interesting to review the evolution of the demand coverage that the PV generation on its own can supply. The monthly absolute demand (4a) and the percentage of coverage due to PV (4b) is represented in Figure 4. The demand evolution has two maximum zones related to winter and summer.

Demand coverage by PV

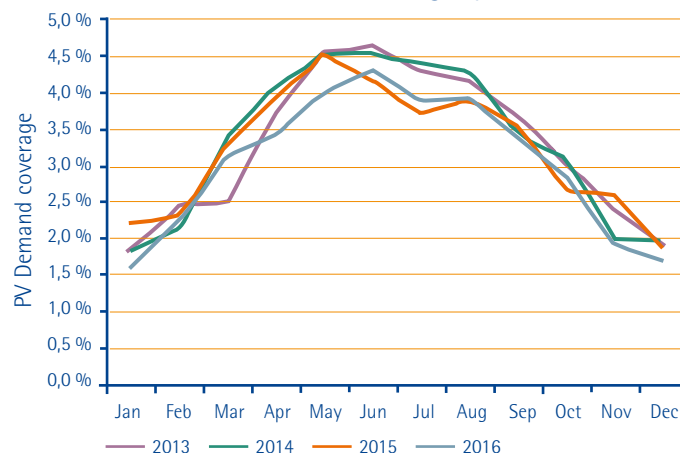


Fig.4b - Monthly evolution of electricity demand coverage.

The period considered (2013-2016) in both cases corresponds to the almost constant PV capacity installed. The opportunity of high electricity generation out of PV is during the summer months in the northern hemisphere and the highest value of demand coverage for 2016 corresponds to 4,3 % in the month of June. Many facts contribute to the evolution of demand coverage, among them the most relevant one has to do with the peak temperatures during summer months driving higher demand due to air conditioning needs. However, in these months, PV technology usually has a drawback related to the temperature influence on their efficiency.

Information presented corresponds to consolidated values up to 2015, reported by grid operator REE (Red Eléctrica de España). For 2016 data are estimations as of December 14<sup>th</sup> for both peninsular and extra-peninsular territories. Final information for the year will appear in the July 2017 timeframe.

#### NATIONAL PROGRAMME

The results of 2016 are aligned with the goal of 38,1 % demand coverage established for 2020 in the Plan de Energías Renovables (PER). However, the proposals of the plan are not valid anymore as a new law is regulating the objectives of electricity generation due to renewable energies in the country. In this law, strength is put on wind and PV technologies. In the case of PV, the 2020 objective is established at 5 700 MW, 1 GW higher than the power installed now. However, those are goals for the PV installation to be considered as "Installation to receive a specific retribution" and will be managed through specific calls for proposals. Apart from that, it is desirable that the PV installations could be free to sell their electricity to customers or to the electrical grid, which could soon be an option.

Monthly electricity demand

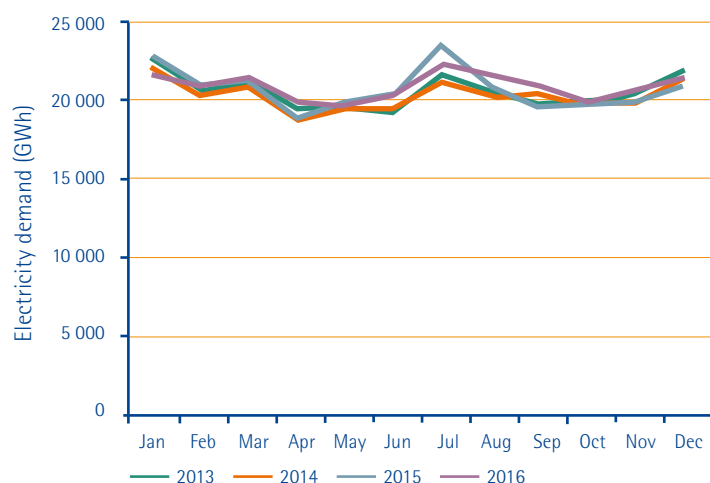


Fig.4a - Monthly electricity demand in Spain.



## IMPLEMENTATION

A more detailed analysis of historical implementation of PV technology can be seen in Figure 5, where, annual installation is represented. The evolution has been clearly driven by the existing feed-in-tariff (it represents just grid connected power). As can be seen, the first reduction in tariff happened at the end of 2008 and further reductions, until the non-feed-in tariff in 2012, were being applied.

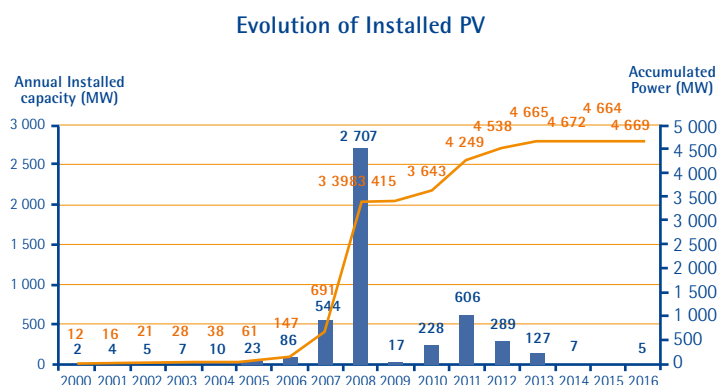


Fig. 5 – Evolution of grid connected PV power installed in Spain (Source: REE, 2016 estimate data as of December 14<sup>th</sup>).

Spain's official databases for PV installations report grid connected PV systems are noted with their AC value (the nominal power injected into the grid). The 4,7 GW nominal AC power reported translates into 5,4 GW peak power of PV modules installed in the field. With regard to the annual market in 2016, installations were in the range of 50 MW when all installations, connected or off-grid are considered.

Nowadays, even with no feed-in-tariff support at all, but with actual prices of PV plant components and considering the price of electricity, the good irradiation conditions in the country allow the final cost of electricity generated by PV means to be advantageous, compared to other sources. In this circumstance, self-consumption is being seen as a good opportunity by many actors, not only at the individual level, but also at the industrial level and even for the multi-megawatt plants to sell electricity in the market. This business model, foreseen for a long time, has not yet taken off and the reason might be the need for a clearer legal framework for it.

Specifically, clarity should exist with respect to changes of regulation and administrative procedures. Changes should not be frequent, nor retroactive, and administrative procedures need some simplification, too.

Figure 6 shows the evolution of the average spot price of electricity in Spain for the year 2016. The price is not a constant and depends on many facts (mix of generation technologies, fuel price, renewable resource, demand, etc.). 2016 values are represented in Figure 6. The average value (3,96 EURcents) is lower than prior to 2015 (5,03 EURcents) and 2014 (4,20 EURcents). However, the tendency is clearly increasing towards the end of the year.

## Monthly average spot price 2016

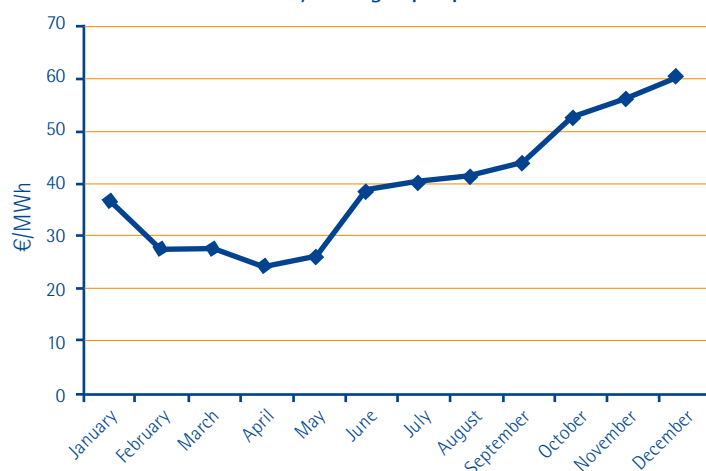


Fig. 6 – Monthly average spot price (Source: UNEF).

Nevertheless, when looking at the prices of electricity in the spot market and analysing the latest announcements of PPAs worldwide (in very sunny regions), it is clear that there is opportunity for the PV technology in Spain.

The values of spot price are the same all around Spain and some regions have clear advantages due to specific irradiation conditions when applying for PV. Also, depending on the activity in every region, the percentage of local demand coverage by PV has a wide variation (going up to 25 % in Extremadura), so it is interesting to see that. Figure 7 shows the percentage of demand coverage due to PV in the different autonomous regions of Spain as of 2015 (2016 segregation not available yet. However, no big variations are expected).

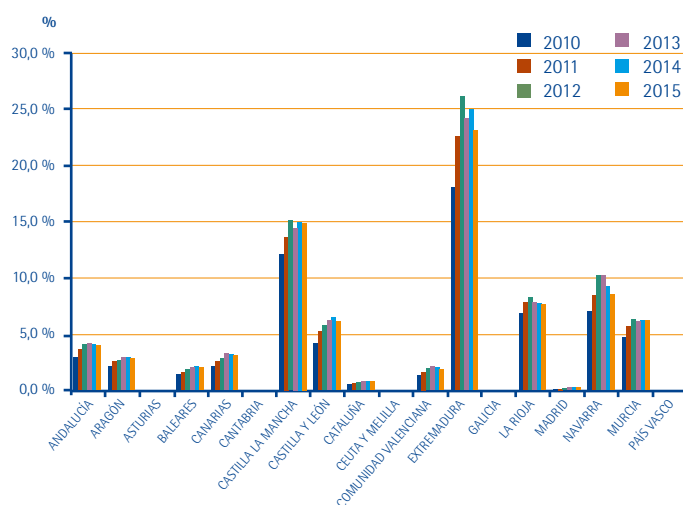


Fig. 7 – Evolution of percentage demand coverage by PV per autonomous community.

## R&D, D

The achievement of goals for the development of PV technology depends heavily on the improvements on efficiency and cost reduction, allowing lower cost of kWh produced by PV means. The knowledge of the technology is basic for driving activity focused on these goals.

R&D activity in Spain follows the track of previous years and is aligned with the European strategies presented in the proposals of H2020, SOLAR-ERA.NET and other less specific calls. At the same time, Spanish institutions are part of the alliances for a more efficient R&D in PV through Europe (European Energy Research Alliance, EERA), EPVTP (European Photovoltaic Technology Platform) among others and contribute to support EC on their decisions of subjects to promote through influence both, at the country and European levels.

Specifically and country related, the two aspects of R&D (scientific and technological), are developed, on one side through the formal investigation of materials and new concepts for PV, where Spanish groups have a relevant participation, and on the other side with support to the Spanish industry in order to contribute to new products development (technological approach).

Activity of Spanish R&D groups is aligned with Europe proposals and on the more technological side, when speaking about the rest of components of BOS, there is important activity related to increasing the performance and functionalities of PV inverters, developing supporting structures and in general new schemes of monitoring and control. The new concept of big mega-plants or the smaller usually BIPV ones have both the need for reducing and optimizing activities that contribute to the most efficient operation of the PV plant, which should be done through the control and monitoring of parameters that could help lowering maintenance activities (big PV plants), or making them almost unnecessary (in case of BIPV).

Both aspects of support to big plants and BIPV are the new paradigm of development. However, also in both cases due to specificities of manageability of the PV technology, the relationship with researchers on the subject of smart grids is a must. As in all cases, the final goal is the control and stability of the electricity generation and supply, as much as possible.

Another important R&D activity is related to increasing the penetration of PV in the electrical grid of islands. Both Balearic and Canary Islands have very insolated conditions and a system partially connected to the peninsula (Balearic) but not the case with the Canary Islands. Apart from the known case of "El Hierro" where all electricity comes from renewable sources, new approaches up to replacing existing diesel generators with PV has been developed in "La Graciosa" as part of Lanzarote in the Canary islands, too. The capacity of managing the energy so as not to interrupt the distribution is basic. In that sense an interesting development is centered on that kind of microgrid scheme with a lot of effort on generation capacity prediction and analysis.

## INDUSTRY STATUS

During 2016, the photovoltaic industry in Spain has continued on the slow side. The internal market is also in the same situation and the result is the very low amount of PV power added during the year (55 MW as noted by the UNEF).

A few Spanish companies have been successful in the international arena, some of them on the manufacturing side (the BIPV company ONYX SOLAR ([www.onyxsolar.com](http://www.onyxsolar.com)), the module manufacturer ATERSA ([www.atersa.com](http://www.atersa.com)) and less on the materials development (Silicio Ferrosolar ([www.ferroatlantica.es/index.php/en/ferrosolar-home](http://www.ferroatlantica.es/index.php/en/ferrosolar-home)). Concerning UMG-Silicon or EVASA for encapsulants ([www.evasa.net](http://www.evasa.net)), and on the BOS, it should be mentioned that the inverter manufacturer INGETEAM ([www.ingeteam.com](http://www.ingeteam.com)) or the manufacturers of supporting structures (fixed or tracked) such as STI-NORLAND, Grupo Clavijo, SOLTEC and others).

However, the most successful activity of the Spanish companies on the PV market during 2016 has been again, as in the previous year, the development and installation of big PV plants. TSK, FRW, ACCIONA, ISOLUX, X-HELIO among them have been responsible for construction of some the biggest plants lately, around the world.

## MARKET DEVELOPMENT

There has not been any tangible market development for PV in Spain during 2016. However, interest exists in development of big PV plants. In that sense, and in order to accomplish the country goals for renewable capacity installed, the government has announced some auctions in 2017 for adding new wind and PV capacity under the terms of the Royal Decree 213/2014. This regulation modifies the terms for retribution of electricity produced while still keeping the preferential access to the grid for the electricity out of RREE.

Residual market activity has also been developed in relation to change of ownership of small and medium PV plants already built. Investment institutions are buying groups of those PV plants usually with more than five years of operation which are being sold because of economic reasons from owners or banks.

No information has transcended yet about the results of the self-consumption products that some electrical utilities (Iberdrola or Gas Natura Fenosa at least) have commercialized during the year. However, an important fact for developing these kinds of installations, apart from economic aspects, has to do with the feeling of the society and now this feeling is very positive with respect to self-consumption through PV. The self-consumption PV-Kits and BIPV related products are attracting the interest of the population.

Nevertheless, as good irradiation conditions and prices of components make "grid parity" a reality in the country and all types of PV deployment a good option, sooner or later, big grid connected PV plants with no feed-in-tariff or generation for self-consumption will start to become a reality again in Spain.



Fig. 8 - Mohammed bin Rashid Al Maktoum Solar Park, Dubai (UAE) - Phase II, built by Spanish TSK Company. 260 MW photovoltaic plant. Type of module: CdTe. Fixed supporting structure.



Fig. 9 - "El Romero", 246 MWp, built by the Spanish Company ACCIONA in North Chile (connected end of 2016).



Fig. 10 - Fustiñana, Navarra (Spain), 5 MW 2-axis tracking built and maintained by Rios Renovables (connected 2015).

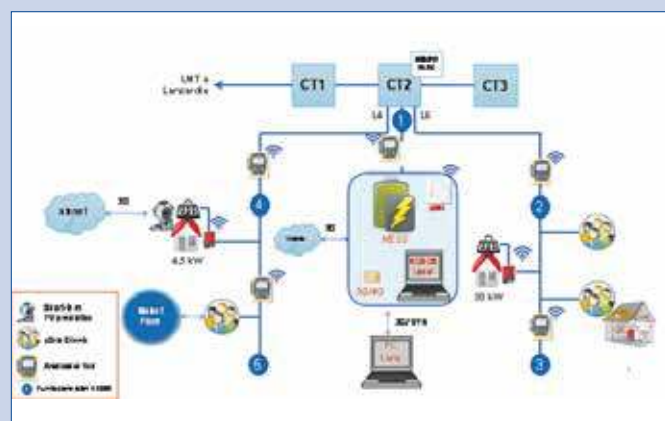


Fig. 11 - Microgrid in La Graciosa (Canary Islands), Spain.

## FUTURE OUTLOOK

The future outlook for PV in Spain has a first stage related to the new announced auctions for increasing renewable capacity installed (wind and PV) under the RD 213/2014, with specific retribution to kWh produced. Apart from that option, what supposes for PV a real competition with wind technology for the capacity to be installed, the hope is to achieve a reasonable regulation in order to be able to install PV plants for community use or self-consumption (more than one self-consumer) and in the end with the right to connect to the grid with reasonable access taxes.

The technical knowledge for that exists and the irradiation conditions of the country allow for having reasonable economic success, apart from other intangible advantages. In that sense, most of the political parties are positive towards this idea, so the year 2017 appears as a transition point in achieving that model.

# SWEDEN

## PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

TOBIAS WALLA, SWEDISH ENERGY AGENCY

PIERRE-JEAN RIGOLE, SWEDISH ENERGY AGENCY



Fig. 1 - A helicopter lifting PV modules while constructing 1,1 MW rooftop system on Väla centrum, Helsingborg (Photo: Niklas Lydeen).

### 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<sub>2</sub>-emissions related to electricity production are very low, since hydro, nuclear, bio and wind energy are the main contributors.

Since a capital subsidy for PV installations 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 become popular 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 116 MW in 2015. However, PV still accounts for less than 0,1 % of the Swedish electricity production. Since November 2016, there is an additional capital subsidy for households investing in electricity storage in order to increase the PV self-consumption.

In 2015, a new tax credit scheme on small-scale renewable electricity production, which in practice acts much like a feed-in tariff, was introduced. The scheme entitles the owner of a PV system to a tax credit of 0,06 EURcents per kWh of electricity fed into the grid, as long as you are a net electricity consumer. The tax credit is drawn from the income tax, and has a cap of 1 900 EUR per year.

The main subsidy for renewable electricity in Sweden is a market-based certificate scheme. It is designed to increase power generation from renewable energy sources such as wind, solar, waves and biomass.

There is a strong opinion in favour of 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 2016, a proposal for the first national strategy in order to promote solar electricity was developed by the agency. It suggests that a yearly production of 5-10 TWh electricity from PV can be feasible in Sweden in 2040. However, this figure is not an official national target, as the proposal is still undergoing a comprehensive referral procedure. The target would be equivalent to 7-10 % of the electricity consumption (assuming that energy usage is the same 2040 as today).

The Swedish Energy Agency is responsible for the national energy research programme. In 2016 a new research and innovation programme was launched, "El från solen", covering PV and solar thermal electricity (STE). The budget for the entire programme period (2016-2020) is about 17 MEUR. One call has so far been performed, with a total budget of 7 MEUR. The programme includes both national and international research and innovation projects, innovation procurement and expert studies. International projects are conducted in the EU collaboration SOLAR-ERA.NET Cofund.

In 2017, the "SolEl-programmet" (an applied research programme in cooperation with the industry) will be brought to an end. About 15 projects, all of them relevant to the current PV deployment in Sweden, have been carried out in the last program period (2013-2017).





Fig. 2 - The new PV power plant "Solsidan" in Varberg (2,7 MW) can reduce electricity connection costs thanks to co-location with wind turbines (Photo: Solkompaniet).



Fig. 3 - PV integrated roof tiles by Soltech Energy on a residential building in Linköping (Photo: Soltech Energy Sweden AB).

The programme has in various forms been going on since the 90s. The programme's objectives and means are now transferred to the new programme, "El från solen".

Additional resources for PV research come from several research councils, universities and private institutions.

## 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, perovskites 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 group's objectives 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 these 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 Solfilm 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 cells.

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.

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 2015 was 127 MW, with ten times as much grid-connected installations compared to off-grid installations. These 127 MW can produce about 114 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 over 40 TWh per year.

There is only one remaining solar cell factory for silicon PV in Sweden; in Glava in Värmland. After the bankruptcy of SweModule AB, the company Renewable Sun Energy AB recently overtook the business. Production is expected to start in early 2017.

There are a few companies exploring other 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. Soltech Energy Sweden AB is developing their own PV integrated roof tiles, and PPAM Solkraft AB is developing different niche products such as bifacial (two-sided) PV modules. Some companies (e.g. Ferroamp AB and Optistring AB) develop balance-of-system equipment such as smart inverters or energy hubs.

A fast-growing number of small to medium-sized enterprises exist, that design 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. Some utilities are selling turn-key PV systems, often with assistance from PV installation companies.

The Swedish PV market is dominated by customers who buy and own the PV systems by their own, although sometimes using bank loans as financing sources. Over the last few years, some companies have also started to offer third-party financing as a method of realizing a PV installation.

# 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 2 over San Francisco Bay area, 9<sup>th</sup> Leg. Hawaii to Mountain View Landing and S12-Team after Landing and completion of the round the world flight in Abu Dhabi (Photos: ©Solar Impulse / Revillard / Rezo.ch / Chammartin).

## 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 2016). The recent deployment trends (1,55 TWh end of 2016) are presently above the long term scenarios and underline that such contributions appear as feasible and possibly well before 2050.

In 2016, the first package of policy measures of the new energy strategy 2050 in conjunction with Switzerland's phase-out of nuclear energy were decided as an amendment to the energy law by the two political chambers (National Council and Council of States). These measures will have impacts on all levels from research to implementation and use, as well as regarding legislative and normative issues. A referendum has been taken against this political decision leading to a vote on the new energy strategy by Swiss citizens in May 2017.

Among the actions of the new energy strategy, an action plan for an increased energy research throughout all relevant energy technologies has been launched in 2013. Building on existing research activities, eight national competence centres for energy research (SCCERs) have taken up their research activities in seven different areas during 2014 and have accomplished their first term ending 2016. During 2016, the following term of the SCCERs for the period 2017 – 2020 was prepared and launched. The goal of these energy research centres is to build up new permanent research and innovation capacities, as well as institutional networks in the different technology areas, thereby accelerating the energy transition. In addition to the SCCERs, CSEM (Centre Suisse d'électronique et microtechnique) 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](http://www.nfp70.ch)) and NRP 71 "Managing Energy Consumption" ([www.nfp71.ch](http://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 continued on a high level, 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. A new edition has been approved in 2016 for the period 2017 – 2020. The master plan developed by the Federal Commission for Energy Research (CORE) in cooperation with the Swiss Federal Office of Energy (SFOE) is based on strategic policy goals (energy & environment, science & education, industry & society) ([www.energy-research.ch](http://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.

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.photovoltai.ch](http://www.photovoltai.ch)). The SFOE research programme Photovoltaics focuses on R&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](http://www.solar-era.net)) is coordinated by Switzerland and continued in 2016 with a fourth joint call covering both PV and concentrated solar power (CSP). Furthermore, the new SOLAR-ERA.NET Cofund Programme started in late 2016 with another joint call. Within the IEA PVPS Programme, Switzerland presently leads Task 9 *Deploying PV Services for Regional Development* and the newly established Task 16 *Solar Resource for High Penetration and Large Scale Applications* (see this report p.15 to 20 and p.10).

### RESEARCH, DEVELOPMENT AND DEMONSTRATION

In 2016, 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.



Fig. 2 - Hofwiesen- / Rothstrasse, Zurich, detailed view of the façade. Modules from PVP Photovoltaik GmbH, glass-glass module, based on monocrystalline cells (Photo: ©Viridén + Partner AG, Zürich).

Work at the Swiss Federal Institute of Technology (EPFL) and the CSEM PV Technology Centre in Neuchâtel has 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 21,2 % efficiency was presented in monolithic integration, and 25,2 % for 4 terminal measurements. 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 certified record efficiency of 29,8 %, with results over 30 % presented at the end of 2016. 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 more fundamental project explores the route towards 25 % efficiency CIGS solar cells. On the way towards industrial implementation of flexible CIGS solar cells, cooperation continued with the Flisom Company which is commissioning a new 15 MW pilot production plant.

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 21,6 %.

Organic solar cells are the research subject at EMPA, the University of Applied Sciences in Winterthur (ZHAW) as well as at CSEM in the Basel region.

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 made good progress in 2016 (Figures 2 & 3).

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





*Fig. 3 - First energy self-sufficient apartment building in Switzerland is a project of the Umwelt Arena realised together with exhibition partners. The PV system on a multifamily building consists of an 80 kWp inroof system based on monocrystalline silicon roof system (512m<sup>2</sup> / MegaSlate II) and a 47 kWp micromorph silicon façade system (485 m<sup>2</sup>). (Photo: ©Umwelt Arena Schweiz, Architekt René Schmid Architekten, Zurich; "Umwelt Arena" is the world's first permanent exhibition dealing with the subject of environmental sustainability.).*

PV on the distribution grid. Through detailed modelling work, methods to considerably increase the share of PV in distribution grids have been identified. 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](http://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, Wädenswil, Rapperswil) 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](http://www.solarimpulse.com)) by Bertrand Piccard, André Borschberg and their team successfully completed the first round the world flight in July 2016 in Abu Dhabi from where the flight started in March 2015 (Figure 1). In total, SolarImpulse covered over 40 000 km in 17 legs, flying from the United Arab Emirates to India, China, Japan and Hawaii in 2015, continuing in 2016 to the US mainland and finally the transatlantic flight to Spain, Egypt and completing the tour in Abu Dhabi.

The new SolarStratos project has been announced in 2016 by Raphaël Domjan, the founder of the solar boat PlanetSolar, aiming at a flight to the stratosphere at an altitude of 22 km with a solar powered airplane ([www.solarstratos.com](http://www.solarstratos.com)).

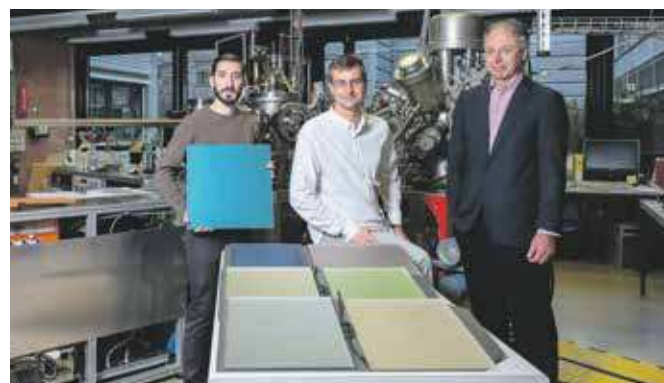
## INDUSTRY AND MARKET DEVELOPMENT

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 confirm 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, glassglass modules) and further developed a silicon heterojunction (HJT) solar cell pilot production line together with CSEM. The target of the pilot line upon further process optimisation was to reach a PV module efficiency of 21 % with a production cost below 0,6 CHF/Wp. The project has been successfully completed in 2016: Pilot lines were installed and ramped-up for HJT cells manufacturing, with innovations conducted at material, processes and design levels. The project enabled going from 21 % cell efficiency using lab-tools to 22,2 % average efficiency achieved with Meyer Burger mass-production equipment, and with efficiencies up to 22,8 % achieved with CSEM metallization R&D pilot line. The cumulated wafers, cells and modules costs using technologies demonstrated in this project result in a minimum calculated cost of 0,41 CHF/Wp (using standard wafer price) for the silicon heterojunction technology, achieving strong reduction in comparison to the initial project targets, and enabling for high competitiveness. Other technology companies active in the supply of equipment for solar cell manufacturing include Indeotec and Evatec.

Flisom, a company active in CIGS thin film technology on flexible substrates, has progressed with the implementation of 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. For this purpose, Flisom continues to work closely with the Swiss Federal Laboratories for Materials Testing and Research EMPA.

Small production facilities for PV modules are operated by Megasol, Meyer Burger and Sunage. Different companies are active in the manufacturing of coloured PV modules by various techniques, e.g. Swissinso (Figure 4 and cover picture), Solaxess and Üserhuus, as well as for dye-sensitized solar cells, e.g. glass-2-energy and Solaronix. Measuring equipment for PV module manufacturers is produced by Pasan (a part of Meyer Burger Group). Solar cabling and plugging systems are offered by Huber & Suhner, Leoni Studer and Multicontact. A number of companies work on mounting systems such as Designergy, dhp technology, Montavent or Schweizer Metallbau.



*Fig. 4 - Research team working on development of laminated glazing with coloured reflection and high solar transmittance suitable for solar energy systems: Nicolas Jolissaint Engineer R&D of Swissinso, Andreas Schüler Research Associate, Jean-Louis Scartezzini Director of the Solar Energy and Building Physics Laboratory (Photo: ©EPFL, Alain Herzog).*





Fig. 5 - Solar power plant Courgenay (JU). GEFCO, EDJ and BKW built Switzerland's presently most powerful solar plant. The installation comprises 23 886 modules built on a site measuring 43 000 m<sup>2</sup>. It corresponds to the size of four and a half football pitches and also houses GEFCO Switzerland's car fleet. The new solar power plant has an installed capacity of 6,7 MWp, which covers an average consumption of over 1 550 households, and is therefore Switzerland's most powerful photovoltaic installation (Photo: ©BKW).

Based on the US company Power One, ABB is now 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.

System sizes have increased over the past years with up to 6,7 MW systems being installed on building complexes. In recent years, the support schemes have evolved and, 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. As a consequence of the capped support within the feed-in-tariff scheme and the resulting waiting list, the annual market volume for grid-connected systems is estimated at 250 MWp for 2016, about 25 % lower than 2015. The total installed capacity by the end of 2016 has risen to above 1,6 GW (Figure 6) corresponding to about 200 W/capita. With this installed capacity, close to 2,5 % 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.

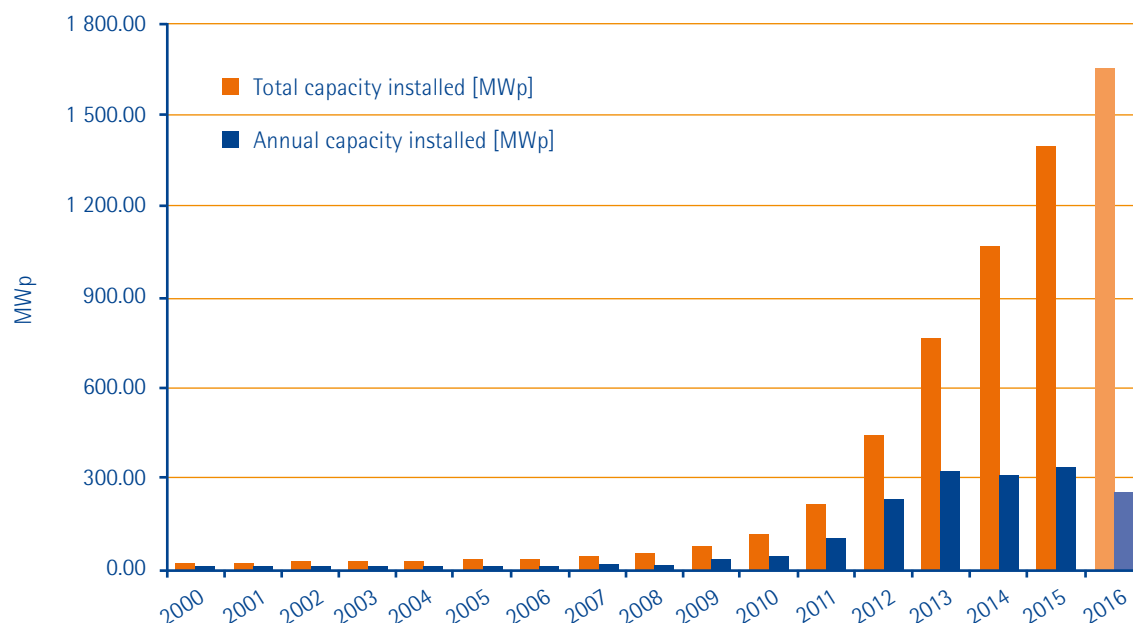


Fig. 6 - Evolution of the installed photovoltaic capacity in Switzerland since the year 2000 (total and annual installed capacity, estimated values for 2016).

# THAILAND

## PV TECHNOLOGY STATUS AND PROSPECTS

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Fig. 1 - The solar rooftop at Thammasat University is the biggest solar rooftop of the University in Asia. The total installation target is 15 MW in 2016 (2015: 6 MW, 2016: 9 MW) (Photo: Solartron Public Company Limited).

## GENERAL FRAMEWORK AND IMPLEMENTATION

Thailand's solar power installation is driven by the Alternative Energy Development Plan (AEDP) with the target set for the year 2036 of 6 000 MWp, which is the highest installed capacity target when comparing with other renewable technologies. In 2016, Thailand continued to be a major leader of PV generation in the region. The main measures which favor the solar power sector are the Feed-in Tariff Incentive for improvement of production efficiency and the support for energy efficiency in governmental buildings.

The Feed-in Tariff scheme has a major role in additional installations for the year 2016. In April, the newly installed capacity resulted in the SCOD extension of FiT ground-mounted PV power plants from December 2015 to April 2016, and the end of the year results of Solar Program for governmental agencies and agricultural cooperatives for ground-mounted systems.

In addition, in favor of the PV rooftop sector, the PV rooftop pilot program was released in August with the objective to identify barriers and impact to grid network and all stakeholders in the market. The result will be used for policy and measures improvement for the future PV rooftop policy.

PV rooftop is one of the most popular options for energy efficiency as well. So far, there are two measures to support energy efficiency implementations: the incentive for improvement of production efficiency measures proposed by Board of Investment (BOI) and the government budget for total energy efficiency investment for governmental buildings.

## NATIONAL PROGRAM

The cumulative installed PV power, reported in October 2016, had reached about 2 146 MWp with an increase of 726,42 MWp; which almost doubled the previous year's performance. In September, the National Energy Policy Committee (NEPC) adjusted the FiT rate from 5,66 THB/kWh to 4,12 THB/kWh for the very small PV power plants due to lower solar installation costs and improved project efficiency.

At the moment, Thailand has supporting policies for both PV ground mounting and rooftop. In terms of PV ground mounting, there are 281,32 MWp from 67 Agricultural Cooperatives which have been awarded PPA in the first phase of the PV ground mounting of The Governmental Agency and Agricultural Cooperatives program. These projects will operate under the FiT rate at 5,66 THB/kWh for 25 years and must also be connected to the grid by December 30, 2016.

Since 2014, PV installations have also been for own-use in the public sector. In 2016, there was 5,7 MWp of installation for 31 projects and the total accumulative installed capacity was around 21 MWp for 153 projects. With huge advantages for reduction of electricity expense in the public sector, the implementation still continues to expand.

The important project to support PV Rooftop is the pilot project for self-consumption or "Quick Win" program, for which the target was set at 100 MWp for households and buildings/factories with electricity consumption during the daytime. As a prosumer concept, the applicants are allowed to feed electricity back to the grid without any compensation from the government. There were about 32,72 MWp from 358 applicants that were awarded contracts under this program and the systems must be connected to the grid by January 31, 2017.

In the future, the strategy will encourage using PV electricity in households, building, factory and public sector first and decrease the subsidy for making solar power generation cost-competitive with other renewable energy technologies.

## RESEARCH, DEVELOPMENT AND DEMONSTRATION ACTIVITIES

In 2016, several research projects focused on the Rooftop PV self-consumption and the direction of its policies in the future. Chulalongkorn University has conducted research to analyse the Rooftop PV self-consumption pilot project evaluation, administered by Department of Alternative Energy Development and Efficiency (DEDE) and the scope of work consists of three aspects: Economical, Technical and Social. The School of Renewable Energy Technology, Naresuan University, has conducted the research project title "The impacts of self-consumption solar rooftop policy towards the operations of Provincial Electricity Authority (PEA)". This study aims to understand the impact on PEA, focusing on non-technical issues.

In addition, the National Electronics and Computer Technology Center (NECTEC) has developed a PV potential estimation tool, solar PV calculator, based on information models and simulation methodologies. The Solar Energy Technology Laboratory of NECTEC has a research and development project on the topic of high efficiency heterojunction solar cells on n-type single crystalline silicon substrate. King Mongkut University of Technology Thonburi has a feasibility study on cleaning technologies for PV arrays and has been working on the performance of PV rooftop systems and the degradation of PV modules. The Electricity Generating Authority of Thailand (EGAT) has developed a project with a floating PV power plant by applying available technology.

By the end of the year, DEDE had started revising solar radiation maps and applying the Geographic Information System (GIS) to re-estimate the potential of solar farms and solar rooftops in the industrial sector. The result of both studies will be beneficial for solar investment and policy direction with the most updated information.

## INDUSTRY AND MARKET DEVELOPMENT

Thailand's support measures still remain the same as last year: A feed-in tariff scheme and indirect policy support, especially the supports from BOI. In 2016, 4 new projects of Solar PV cell and module manufacturing have been submitted and are now in the approval process from BOI, with a total amount of investment of 10 293 MTHB.

By mid-2016, 520 projects with a total capacity of 2 206,3 MWp from solar power plants, for both solar ground mount and solar rooftop, were approved from BOI. In total, Thailand has 12 module manufacturers with a total production capacity about 4 000 MWp/year; most of the manufacturers are from China and Taiwan, and their productions are mainly exported.



# TURKEY

## PV TECHNOLOGY STATUS AND PROSPECTS

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### GENERAL FRAMEWORK

Turkey's primary energy consumption has increased by 52 % compared to the last decade, and it is expected to continue more rapidly in the future [1]. This high increase rate has required Turkey to take actions in order to increase energy efficiency, decrease greenhouse gas (GHG) emissions, foster security of supply, as well as to create a sustainable energy sector and efficiently functioning liberal energy market [2]. The energy sector of Turkey is governed by a very large number of institutions. The main actor and the leading institution is the Ministry of Energy and Natural Resources (ETKB) which is responsible for development of policy, legislating and enforcement of legislation in all areas of the sector.

Turkey had 78,5 GW installed capacity of electricity by the end of 2016. The breakdown of installed capacity of electricity by sources is as follows: 56,6 % thermic (natural gas, coals, liquid fuels etc.), 34 % hydro, 7,3 % wind, 1,1 % solar and 1 % other renewables [3]. 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 74,4 % in 2016 [4]. Turkey's power distribution network is completely in the private sector's hands.

In the face of increase in energy consumption, 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 sources rapidly. Renewable energy sources – 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's National Renewable Energy Action Plan (REAP) was published by the ETKB on December 2014 to establish strategies to promote the development of renewable energy in Turkey. Turkey aims to obtain at least 30 % of its electricity requirements via renewable energy sources by the year 2023, the centennial founding of the Republic. The specific renewable energy goals for the country by 2023, known as Vision 2023 energy targets, are: 34 GW of hydroelectric, 20 GW of wind energy, 1 GW of geothermal, 1 GW of biomass and 5 GW of solar electricity (photovoltaic and concentrated solar power) [5]. Also, according to the Strategic Plan (2015-2019), it is aimed to reach 3 GW of solar electricity by the end of 2019 [6]. The total amount of investments to be made to meet the energy demand in Turkey until 2023 is estimated around 110 BUSD [4]. In addition to these targets, it is stated to increase solar power to 10 GW until 2030 among the plans and policies to be implemented in the Intended Nationally Determined Contribution of Turkey [7].

Besides this situation, strengths, weaknesses, opportunities, and threats (SWOT) for PV power investments in Turkey can be mentioned briefly as follows [8]:

- Strengths (S): Turkey has a developed energy sector controlled via international rules and regulations. The country has major international and local contracting and engineering services experience in energy investments. Turkey's renewable energy potential, especially wind, geothermal and solar, is very high. Renewable energy sources are free as a resource.

- Weaknesses (W): The level of financial resources and appropriate credit opportunities for domestic entrepreneurs is lower than some European countries. Also, there are some bureaucratic inefficiencies and structural issues especially for small investors.
- Opportunities (O): There is possibility of finding high resource potential. There is an increasing demand for environmentally benign technologies. There is an expectation to increase its utilization.
- Threats (T): Turkey is dependent on foreign technology for renewable energy investments. There is a delay in the process of energy market liberalization and sufficient private sector investments. The geographical location of Turkey near the high-tension regions is a little bit frightening for foreign investors.

### NATIONAL PROGRAMME AND LEGISLATION

Solar Energy is the most important renewable energy source, which is still untapped in Turkey, but with a potential of minimum 500 GW. At the end of 2016, the cumulative installed PV power in Turkey reached about 832,5 MW and increased very rapidly with a 235 % growth compared to the previous year's data, 248,8 MW [9].

In Turkey, two main laws, the Laws 6446 (New Electricity Market Law) and 6094 (Law Amending the Law on the Utilization of Renewable Energy Resources in Electricity Generation), are directly related to the utilization of solar energy. 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. Law 6094 introduces significant amendments to improve the incentive mechanism under the Renewable Energy Law (Law No: 5346) and encourage renewable energy investment opportunities [5].

According to 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 five 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 Turkish electrical energy market has recently undergone significant changes in Law 6446, also significant amendments have been made to Law 5346. A new procedure for privatizing certain assets of the Electricity Generation Corporation (EÜAŞ), or its affiliates, as appropriate for the purposes of developing power plants based on



renewable energy resources has been introduced. Moreover, retail sale companies are now empowered by law to charge their customers special fees for technical and non-technical line losses. Apart from the foregoing, some of the rules governing licensed and unlicensed generation have been amended [10]. Some of these major changes related to the solar energy are:

- Measurement of solar radiation for pre-license applications is now required to be obtained for the last five years, instead of three years, preceding the subject application. As an exception to the above measurement requirement, if any solar power plant was proposed to be installed on any designated "renewable energy resource area" as defined in the regulation, then no pre-license application phase measurement data shall be required.
- In case there are multiple applications for connecting to the same connection point and/or to the same connection site within the grid, Turkish Electricity Transmission Corporation (TEİAŞ) will now organize a competition for determining the winner who will qualify for connecting to the grid up to the announced capacity. In determining the winner, the lowest electricity sale price offered over the legally permissible maximum sale prices i.e., the feed-in tariffs, as set forth under Annex I of Law 5346 will be taken as a basis. Previously, the winner of the competition was the applicant who proposed to pay the highest total contribution fee per megawatt to TEİAŞ within a maximum period of three years following the commissioning.
- To underpin the latest amendments which were made to the Unlicensed Electricity Generation Regulation dated March 23, 2016, it is stipulated that shareholders in unlicensed generation companies operating wind or solar power plants of maximum 1 MW capacity, each are prohibited from doing any share transfers until the provisional acceptance of the subject power plant by the ETKB. In case of a breach of this prohibition, the invitation letter sent to the generation company concerned for executing a grid connection agreement with the related network operator may be cancelled.
- Prohibitions from applying for unlicensed wind and solar power generation have been introduced in respect of those persons and entities who are described by law as being "related" to distribution companies or to designated supply companies, as the case may be, which operate in any given distribution region [10].
- The Renewable Energy Designated Areas (YEKAs) are defined under a separate regulation issued in Law 5346. YEKA in privately owned or state owned lands identify the feasible areas for large-scale renewable energy projects. The ETKB provided the details as follows: (i) determination of potential YEKAs, (ii) feasibility and infrastructure studies, (iii) publication of final YEKAs in the Official Gazette, (iv) prerequisites and procedures for the applicants, (v) auction procedures, (vi) implementation of manufacturing facilities, (vii) construction of renewable energy power plants.

The Regulation on YEKAs has come into force following its promulgation in the Official Gazette dated October 9, 2016. Although the concept of YEKAs was introduced in Turkish legislation in 2005, it remained mostly inactive until this date. The objectives of the

Regulation can be regarded as forming large-scale YEKAs in order to make effective and efficient use of renewable energy sources, and rapidly completing investment projects by assigning these areas to investors, and enabling high-tech equipment used in the generation facilities to be domestically manufactured or supplied and contribute to technology transfer. YEKAs will be determined and developed following either (i) the necessary studies undertaken by the General Directorate of Renewable Energy, or (ii) following a tender to be held for the allocation of connection capacity [11].

While projects conducted within the framework of YEKA benefit fifth-area investment incentives, companies with the highest rate of domestic transfer of technology and production will be given priority [11]. The first bidding will be held in Karapınar, Konya, with an allocated capacity of 1 GW since the tender announcement for Karapınar YEKA (announced as a YEKA in 2015) was published by the ETKB on October 20, 2016. The project is expected as a major step for large-scale renewable energy investments. The project will be developed by one investor with the requirement to set up a manufacturing facility and conduct research and development activities [12]. The bidding is scheduled for March 2017. The bidding will be held at a reserve auction in the form of a competition with the tender being awarded to the maximum bidder. Some of the important features of this bidding are:

- Allocation of assigned 1 GW capacity allocated to one developer.
- The developer is required to develop a manufacturing facility and conduct R&D activities. The manufacturing facility must have the capacity to produce 500 MWp of photovoltaic modules per year. The tender specifications also include further technical details as to the required manufacturing facility, components and R&D activities.
- Completion of the manufacturing facility must be within 18 months of the execution of the agreement. The power plant must be completed within 36 months of completion of the manufacturing facility.
- In order to qualify, applicants must have previously operated a facility which manufactured PV modules of 3 GWp between January 1, 2014 and July 30, 2016.
- Provided that at least 25 % of the shareholding in the applicant entity is by Turkish nationals and the technology provider (separately), the applicant entity (or joint venture) may have foreign shareholders.
- If the bid is submitted by a joint venture, a company must be established prior to the execution of the agreement. Consortia, where each partner's responsibility is limited to the part of the work it assumes, may not apply for the tender.
- Applicants must submit a 50 MUSD indefinite and irrevocable bank letter of guarantee (bid bond).
- The ceiling feed-in rate for the underbidding tender is 80 USD/MWh.
- The facility will sell electricity over the agreed feed-in rate for a period of 15 years from the date of the agreement. The agreement will likely include provisions applicable to the sale of electricity after the expiry of the 15-year period (e.g., through bilateral power sale agreements) [12].



Fig. 1 - One of the two PV power plants in the licensed segment in Elazığ (8 MW) [15].



Fig. 2 - SOLAR TR2016 Conference and Exhibition, December 2016 [17].

## MARKET DEVELOPMENT

By the end of 2016, there were 1 045 PV power plants (832,5 MW in total) in operation, of only two (12,9 MW in total) are in the licensed segment. The legislation defines the unlicensed electricity power limit as max. 1 MW. In Turkey, 1 043 small-scale, unlicensed, PV power plants (up to 1 MW) are already in operation with an installed capacity of 819,6 MW in 2016 [3,13,14]. It is obvious that there is an acceleration since the cumulative grid-connected installed PV power were about 6 MW, 55 MW and 248,8 at the end of 2013, 2014 and 2015, respectively.

In 2016, two PV power plants in the licensed segment were connected to the national grid. These are 4,9 MW in Erzurum (Halk Enerji) and 8 MW in Elazığ (Solentegre Enerji Yatırımları San.Tic. A.Ş.) (Figure 1). It is expected that the other tenders and license procedures will be concluded in 2017.

Regarding PV manufacturing activities, currently there are not any manufacturers of feedstock, ingots and wafers in Turkey, but investments for cell manufacturing already started. Currently, there are 20 PV module manufacturers in Turkey with a production capacity of more than 1 500 MW annually [16]. There are also a few PV module constituents (glass, frame etc.) manufacturers in Turkey.

The PV market of Turkey is being accelerated and development is seen in all dimensions from production to installation with the support of raising awareness in all levels of society. The Turkish Solar Energy Associations continued their endeavors to facilitate information flow for healthy market development. One of the events organized by GÜNDER and UFTP entitled "SOLAR TR2016 Conference and Exhibition" was concluded in Istanbul on December 6-8, 2016, in addition to several trainings, meetings and workshops organized for capacity building and removing the barriers throughout the whole year. The conference has been organized with the participation of the leading organizations in the solar energy industry and from researchers to industry representatives, from public to contractors all stakeholders came together to evaluate solar energy and the development of the industry.

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# THE UNITED STATES OF AMERICA

## PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

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### GENERAL FRAMEWORK AND IMPLEMENTATION

In the United States (U.S.), photovoltaic (PV) market development is supported by both national and state level financial incentives, though state and local policies in support of increased solar deployment are more varied. 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, as well as rapidly declining technology costs have enabled PV to continue to grow rapidly in the U.S. By the end of 2016, the U.S. was expected to reach 40,5 GW<sub>dc</sub> of cumulatively installed capacity. This level of cumulative installations was up from 25,7 GW<sub>dc</sub> in 2015, and 18,3 GW<sub>dc</sub> in 2014 [1]. Moreover, while state mandates, in the form of renewable portfolio standards (RPSs), have historically been a major driver to solar deployment, 2016 is notable for seeing a significant number of systems being installed outside of state mandates, due to solar's cost competitiveness with conventional sources of generation.

Several policy and financing mechanisms have emerged that have the potential to encourage 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 (a mechanism that allows a developer to build and own a PV system on a customer's property and then sell the generation back to that customer) continues to be a popular option for financing the installation of PV, particularly in the residential sector. However, loans and cash purchases of systems are increasing in popularity due to both the declining cost of solar and new loan products entering the market. Loans have even eclipsed third-party

ownership in some residential markets [2]. Companies have also issued innovative financing mechanisms to raise cheaper sources of capital through public markets.

### NATIONAL PROGRAM

The U.S. supports the domestic installation and manufacturing of PV generating assets for domestic consumption. Financial incentives for U.S. solar projects are provided by the national government, state and local governments, and some local utilities. Historically, national incentives have been provided primarily through the U.S. tax code, in the form of a 30 % Investment Tax Credit (ITC) (which applies to residential, commercial, and utility-scale installations) and accelerated 5-year tax depreciation (which applies to all commercial and utility-scale installations and to third-party owned residential, government, or non-profit installations). Though the ITC was set to expire in 2016, the 30 % credit has been extended to 2020. Beginning in 2020, the credits will step down gradually until 2022 where they will remain at 10 % for commercially owned systems, and expire for systems owned by individuals [3].

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 August 2016, twenty-nine states and Washington D.C. had RPS policies with specific solar or customer-sited provisions, with an increasing number of states adopting aggressive RPS goals of procuring 50 % or more of their electricity from renewable sources [4]. 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 2016, the number of states with net metering laws decreased from 45 to 41, as some states have begun to transition to new compensation mechanisms for customer-connected PV systems.

The U.S. government also supports the advancement of photovoltaics through its work at the Department of Energy's (DOE) SunShot Initiative, discussed in the section below, and has supported the demonstration of PV and other renewable technologies through the DOE Loan Program Office's Loan Guarantee Program [5].

U.S. Annual PV Installations

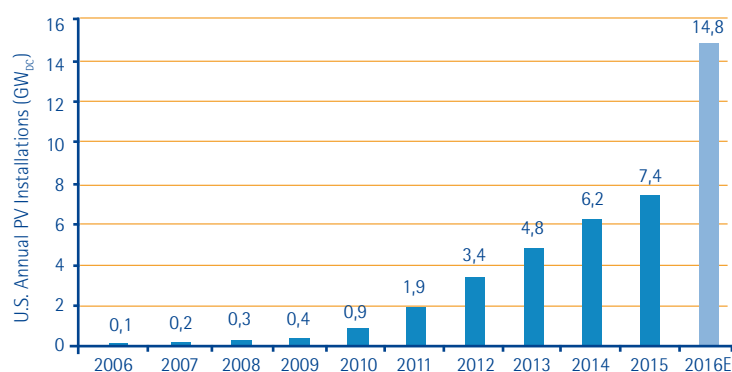


Fig. 1 - U.S. Annual PV Installations. Source: GTM/SEIA, U.S. Solar Market Insight Report Q4 2016. December 2016.

[1] GTM Research SEIA, 2016 Year in Review: U.S. Solar Market Insight. March 2017.

[2] Ibid.

[3] The credit for residential customers drops to 26 % and 22 % for projects placed in service in 2020 and 2021, respectively. Commercial and utility projects under construction before 2020 receive the full 30 % credit. The credit then falls to 26 % for commercial and utility projects starting construction in 2020 and 22 % for commercial and utility projects starting construction in 2021. For any solar project that starts construction after 2021, or which fails to be placed in service by January 1, 2024, the ITC for commercial and utility projects reverts to 10 %.

[4] North Carolina Clean Energy Technology Center. Renewable Portfolio Standard Policies. Accessed January 13, 2017. <http://www.dsireusa.org/resources/detailed-summary-maps/>

[5] A full list of projects funded with DOE loan guarantees is available at: <https://energy.gov/lpo/loan-programs-office/>





Fig. 2 - Engineers examine a photovoltaic systems being evaluated at the U.S. Regional Test Center in New Mexico, USA.

## 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, several DOE offices, including DOE's Solar Energy Technologies Office (SETO), Office of Science, and Advanced Research Projects Agency - Energy (ARPA-E) collaborate to support efforts by national laboratories, academia, and private companies to drive down the cost of utility-scale solar electricity to about 6 USDcents per kilowatt-hour by the year 2020. Recently, the DOE issued an update to the SunShot goal and will now work to further reduce the installed cost of solar energy to 3 USDcents per kWh by 2030. This in turn, could enable solar-generated power to account for 20 % of America's electricity generation by 2030 and 40 % by 2050 (assuming other systemic issues are addressed as well) [6].

By funding a portfolio of complementary RD&D concepts, the SunShot Initiative promotes a transformation in the ways the U.S. generates, stores, and utilizes solar energy. As the majority of RD&D funding under the initiative is provided by the Solar Energy Technologies Office, this summary focuses on programming funded and executed through SETO. These research, development, and demonstration activities fall into five broad categories, which in fiscal year 2016, were funded at the levels found in Table 1:

1. Photovoltaic (PV) Research and Development, which supports the research and development of PV technologies to improve efficiency, durability, and reliability, as well as lower material and process costs to reduce the levelized cost of solar generated electricity.

2. Concentrating Solar Power (CSP), which supports research and development of CSP technologies that reduce the cost of solar energy with systems that can supply solar power on demand, even when there is no sunlight, through the use of thermal storage.
3. Systems Integration, which develops technologies to enable improved integration of solar power with the grid including power electronics and systems-level research on renewables integration.
4. Balance of Systems Soft Cost Reduction, which works with stakeholders at the state and local levels to cut red tape, streamline processes, and increase access to solar.
5. Innovations in Manufacturing Competitiveness, which helps groundbreaking technologies and business models transition to the market by supporting efforts on developing commercial prototypes and scaling-up.

TABLE 1 – BREAKDOWN OF SOLAR ENERGY TECHNOLOGIES PROGRAM FY 16 ENACTED FUNDING

Photovoltaic R&D	MUSD 53,2
Concentrating Solar Power	MUSD 48,4
Systems Integration	MUSD 52,4
Balance of Systems/Soft Cost Reduction	MUSD 34,9
Innovations in Manufacturing Competitiveness	MUSD 43,5
National Renewable Energy Laboratory Site-Wide Facility Support	MUSD 9,2
<b>Total</b>	<b>MUSD 241,6</b>

[6] U.S. Department of Energy (DOE). (2016). *The SunShot Initiative's 2030 Goal: 3¢ per Kilowatt Hour for Solar Electricity*. DOE/EE-1501 Washington, DC: U.S. Department of Energy.





Fig. 3 - Solar panels on the roof of the U.S. Department of Energy Building in Washington, D.C., USA.

Funding in FY16 provided by SETO, as shown in Table 1, accounted for approximately 50 % of all public RD&D for PV technology development in the U.S. In addition, the Department of Energy's Office of Science and ARPA-E, the National Science Foundation, the Department of Defense, the National Aeronautics and Space Administration, and states such as California, New York, Florida, and Hawaii also fund solar R&D.

### INDUSTRY AND MARKET DEVELOPMENT

In 2016, the U.S. market, in terms of annual installations, is expected to double, from roughly 7,1 GW in 2015 to an expected 14,8 GW in 2016. This dramatic change is due both to the declining cost of solar energy, and previous expectations from developers and utilities that the ITC would expire in 2016. Though the ITC was ultimately extended, and some of the projects that originally intended to interconnect in 2016 were pushed to 2017, the development cycle still resulted in a boom in utility-scale installations [7]. Although much of the growth in 2016 came from utility-scale installations, the distributed market also increased in size.

PV capacity continues to be concentrated in a small number of states, such as California, which represents roughly 50 % of the national market. However, this trend is changing slowly as 28 states currently have 100 MW or more of PV capacity [8]. With 20 GW of contracted utility scale PV projects in the pipeline as of October 2016, total installations in 2017 are expected to remain robust [9]. Additionally, due to the continued reduction in system pricing, as well as the availability of new loan products and financing arrangements, a

significant portion of PV systems have recently been installed without any state incentives, and analysts have estimated that 70 % of utility-scale PV installed in 2016 had been procured outside of RPS obligations, based on solar's competitiveness with other sources of generation [10].

U.S. PV manufacturing continued to grow in 2016 (after contracting in 2011-13). Module production increased 18 % from Q3 15 to Q3 16. Crystalline silicon modules make up the majority of production (64 %), though both CdTe and CIGS modules constitute a significant minority [11]. Additionally, U.S. manufacturing has a significant presence in other parts of the PV value chain, including polysilicon, encapsulants, wiring, and fasteners. The manufacturing sector employed 38 121 people in 2016, a 25 % increase since 2015. In the near term, job growth is expected to continue in the manufacturing sector, with an expected growth rate of 6 % in 2017 [12].

Industry-wide, approximately 166 575 jobs relating to solar were added from 2010 to 2016, as the industry grew to a total of over 260 000 employees in 2016 (51 000 of which were added in 2016 alone). The growth rate from 2015 to 2016 was seventeen times faster than what the overall U. S. economy experienced during that same time period [13].

[7] GTM Research/SEIA, 2016 Year in Review: U.S. Solar Market Insight. March 2017.

[8] Ibid.

[9] GTM Research/SEIA, Q4 2016: U.S. Solar Market Insight. December 2016.

[10] Ibid.

[11] Ibid.

[12] Solar Foundation. (2017). National Solar Jobs Census 2016. Washington, DC: The Solar Foundation.

[13] 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](http://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.

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## COMPLETED TASKS

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

#### OVERALL OBJECTIVE

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

When the **first programme (1993–1999)** was approved, the stand-alone photovoltaic sector was largely comprised of solar home systems for rural electrification, remote 'off-grid' homes in industrialised countries and PV consumer goods. PV hybrid systems and niche off grid applications such as PV powered bus shelters were also being introduced in certain countries.

As part of this programme, a number of documents were published as information about installed stand-alone PV systems worldwide. These included a **lessons learned book** featuring case studies from each country, as well as a survey of **PV programmes in developing countries**.

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

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

#### Task 3 Aimed:

- To collect, analyse and disseminate information on the technical performance and cost structure of PV systems in these applications
- To share the knowledge and experience gained in monitoring selected national and international projects
- To provide guidelines for improvement of the design, construction and operation of photovoltaic power systems and subsystems
- To contribute to the development of improved photovoltaic systems and subsystems"

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

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

#### SUBTASK 1: QUALITY ASSURANCE

##### Activity 11: Critical Review of Implementation of Quality Assurance Schemes

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

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

To identify and establish practical performance assessment guidelines.

#### SUBTASK 2: TECHNICAL ISSUES

##### Activity 21: Hybrid Systems

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

##### Activity 22: Storage Function

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

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

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

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

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



## PUBLICATIONS

Task 3 publications can be downloaded from the IEA PVPS website [www.iea-pvps.org](http://www.iea-pvps.org) and are listed below:

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

## SCOPE FOR FUTURE ACTIVITIES

A proposal was introduced at the 23<sup>rd</sup> 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 26<sup>th</sup> 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](http://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

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## COMPLETED TASKS

### TASK 5 – GRID INTERCONNECTION OF BUILDING INTEGRATED AND OTHER DISPERSED PHOTOVOLTAIC SYSTEMS

#### OVERALL OBJECTIVE

The objective of Task 5 was to develop and verify technical requirements, which served as the technical guidelines for grid interconnection with building-integrated and other dispersed PV systems. The development of these technical requirements included safety and reliable linkage to the electric grid at the lowest possible cost. The systems to be considered were those connected with a low-voltage grid, which was typically of a size between one and fifty pea kilowatts. Task 5 was officially concluded in 2003.

#### MEANS

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

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

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

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

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

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

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

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

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

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

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

#### TASK 5 REPORTS AND WORKSHOP PROCEEDINGS:

Task 5 produced the following reports and workshop proceedings:

##### Task 5 Reports

1. «Utility aspects of grid interconnected PV systems», IEA-PVPS T5-01: 1998, December 1998
2. «Demonstration tests of grid connected photovoltaic power systems», IEA-PVPS T5-02: 1999, March 1999
3. «Grid-connected photovoltaic power systems: Summary of Task V activities from 1993 to 1998», IEA-PVPS T5-03: 1999, March 1999
4. «PV system installation and grid-interconnection guideline in selected IEA countries», IEA-PVPS T5-04: 2001, November 2001
5. «Grid-connected photovoltaic power systems: Survey of inverter and related protection equipments», IEA-PVPS T5-05: 2002, December 2002
6. «International guideline for the certification of photovoltaic system components and grid-connected systems», IEA-PVPS T5-06: 2002, February 2002
7. «Probability of islanding in utility networks due to grid connected photovoltaic power systems», IEA-PVPS T5-07: 2002, September 2002
8. «Risk analysis of islanding of photovoltaic power systems within low voltage distribution networks», IEA-PVPS T5-08: 2002, March 2002
9. «Evaluation of islanding detection methods for photovoltaic utility-interactive power systems», IEA-PVPS T5-09: 2002, March 2002
10. «Impacts of power penetration from photovoltaic power systems in distribution networks», IEA-PVPS T5-10: 2002, February 2002
11. «Grid-connected photovoltaic power systems: Power value and capacity value of PV systems», IEA-PVPS T5-11: 2002, February 2002

#### Task 5 Internal Reports (Open to Public)

1. «Grid-connected photovoltaic power systems: Status of existing guidelines and regulations in selected IEA member countries (Revised Version)», IEA-PVPS V-1-03, March 1998
2. «Information on electrical distribution systems in related IEA countries (Revised Version)», IEA-PVPS V-1-04, March 1998

#### Proceedings of Final Task 5 Workshop

1. Introduction and table of contents
2. Flyer of the workshop
3. List of participants of the workshop
4. Final programme of the workshop
5. Key note speech
6. Islanding detection methods
7. Probability of islanding in power networks
8. Risk analysis of islanding
9. Conclusions of task V islanding studies
10. Recapitulation of first day
11. Overview of (inter)national interconnection guidelines for PV-systems
12. State of the art inverter technology and grid interconnection
13. Impacts of PV penetration in distribution networks
14. Power value and capacity of PV systems

#### DELIVERABLES – Where to get them?

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

A Task 5 CD-ROM including all the reports was published for distribution. This can be ordered at the contact address below.

#### CONTACT INFORMATION

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## COMPLETED TASKS

### TASK 6 – DESIGN AND OPERATION OF MODULAR PHOTOVOLTAIC PLANTS FOR LARGE SCALE POWER GENERATION

#### OVERALL OBJECTIVE

Task 6 officially completed its activities in May 1998. The main objective of this Task was to further develop large-scale modular photovoltaic plants for peaking and long-term baseload power generation in connection with the medium-voltage grid.

#### MEANS

The Task 6 work was performed by structural engineers and PV industry experts. The work was structured into four subtasks, for a total of fifteen activities.

#### SUBTASK 10: Review of Design and Construction Experiences of Large-Scale PV Plants

To perform, on the basis of the Paestum Workshop results, an in-depth review of existing large-scale PV plants aimed both to identify the remarkable technical solutions adopted in such plants and the main common criteria applied for their design, installation, operation, monitoring, and to perform a detailed cost analysis of the plants taken into account.

#### SUBTASK 20: Review of Operational Experiences in Large-Scale PV Plants

To perform, also utilising the work in progress of Subtask 10 and on the basis of the Paestum Workshop results, an in-depth review of operational experiences in existing large-scale PV plants. The analysis of the acquired data was focused on the comparison between the expected and actual results, both technical and economical; the information flow was continuously updated through acquisition of data from all the plants in operation.

#### SUBTASK 30: Development of Improved System Design and Operational Strategies for Large-Scale PV Plants

Based on the work of Subtasks 10 and 20, the evaluation work, together with the information gathering activity, let the assessment of most appropriate, innovative technical options for modular design of large-scale PV plants. Both PV and BOS components were dealt with, taking into account: performances improvement, costs reduction, and realisation simplification.

The co-operation among utilities and industries of many countries offered the opportunity to review in detail the performance data and the technical aspects which determined the design approach of the largest PV plants in the world, and to develop improved system design, and operational strategies for such plants.

#### SUBTASK 40: Outlook of Perspectives of Large-Scale PV Plants

Based on the assumption that large grid connected PV power plants have proven their applicability under the technical point of view, the Subtask was aimed at identifying the path in order to let such plants become a substantial option and play an increasing role in a future oriented energy concept in OECD countries, as well as in developing countries.

#### TASK 6 REPORTS AND WORKSHOP PROCEEDINGS

Task 6 produced the following reports and workshop proceedings from 1993 to 1998:

1. The Proceedings of the Paestrum Workshop.
2. A PV Plant Comparison of 15 plants.
3. The State of the Art of: High Efficiency, High Voltage, Easily Installed Modules for the Japanese Market.
4. A document on "Criteria and Recommendations for Acceptance Test."
5. A paper entitled: "Methods to Reduce Mismatch Losses."
6. Report of questionnaires in the form of a small book containing organized information collected through questionnaires integrated with statistical data of the main system parameters and of the main performance indices.
7. The "Guidebook for Practical Design of Large Scale Power Generation Plant," edited by the Japanese expert.
8. The "Review of Medium to Large Scale Modular PV Plants Worldwide."
9. Proceedings of the Madrid Workshop.

#### DELIVERABLES – Where to get them?

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

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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, Subtask 7 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

## 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.

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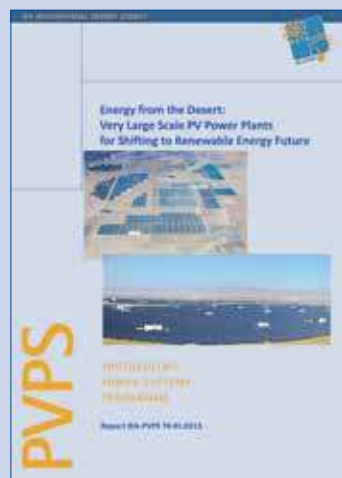


Fig. 1 - Energy from the Desert: Very Large Scale PV Power Plants for Shifting to Renewable Energy Future.

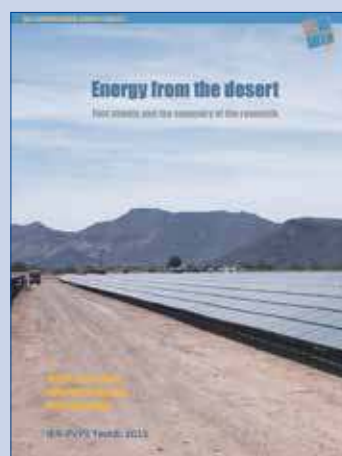


Fig. 2 - Brochure "Energy from the Desert: Fact sheets and the Summary of the Research".

## 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

*2<sup>nd</sup> International Symposium - Electricity From the Sun, Feb. 11,*

2004 Vienna, AUS

*PV integration in urban areas, Oct.6, 2005, Florence, ITA*

*Photovoltaics in Buildings - Opportunities for Building Product*

*Differentiation, Mar.16, 2005, Lisbon, POR*

*Photovoltaic Solar Cities - From global to local, June 1, 2005,*

Chambéry, FRA

*International Workshop: Photovoltaic in Cities, Sept 13, 2006,*

Malmö, SWE

*Lisbon Ideas Challenge (LIC I) Final Ceremony, Nov. 23, 2006,*

Lisbon, POR

*PV in the Urban Planning Process, Oct 24, 2007, Madrid,*

ESP (PV-UP-Scale)

*PV international experiences towards new developments,*

May 13, 2009 Rome ITA

## DELIVERABLES - WHERE TO GET THEM?

All reports are available for download at the IEA PVPS website:

<http://www.iea-pvps.org> and the Task 10 website:

<http://www.iea-pvps-task10.org>

## PARTICIPANTS

Fifteen PVPS members supported Task 10 activities:

Australia, Austria, Canada, Denmark, France, Italy, Japan, Korea, Malaysia, European Union, Norway, Portugal, Sweden, Switzerland and the USA. Moreover, through PV-UP-Scale, Germany, The Netherlands, Spain and the United Kingdom made contributions to Task 10 work.

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## COMPLETED TASKS

## TASK 11 – HYBRID SYSTEMS WITHIN MINI-GRIDS

## INTRODUCTION

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

## TASK 11 STRATEGY AND ORGANIZATION

In general, Task 11 followed a strategy, similar to previous PVPS Tasks, in which the current states of technology and design practice in the participating countries were first assessed and summarized. Further work then focused on those areas where technology improvements or better design practices are needed. This may require new research or data, or simply an expert consensus on best practices.

Task 11's Workplan was divided into four subtasks and a number of detailed work activities on key aspects of PV hybrid and mini-grid technology and implementation.

## SUBTASK 10: Design Issues

Subtask 10 addressed PV hybrid system design practices. Tradeoffs have to be made between first cost, energy efficiency, and reliability. The correct choice of components and system architecture is critical. The subtask had the following three activities:

- Review, analysis and documentation of current hybrid mini-grid system architectures;
- Evaluation and comparison of software based design tools for PV hybrid systems and mini-grids;
- Documentation of best practices for design, operation, and maintenance of PV hybrid projects.

## SUBTASK 20: Control Issues

Subtask 20 addressed the need for new coordinating control mechanisms in hybrid mini-grids to maintain grid stability and to optimize the contribution of all generation sources. It had the following five activities:

- Investigation of existing methods for stabilizing voltage and frequency in mini-grids and recommendations for further development;
- Investigation of data communication architectures and protocols for mini-grids;
- Evaluation of supervisory control parameters and strategies for mini-grids;
- Evaluation of the role of energy storage technologies to stabilize mini-grid operation;
- Investigation of technical issues associated with autonomous and interconnected operation of mini-grids and a main utility grid.

## SUBTASK 30: PV Penetration in Mini-Grids

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

- Development of performance assessment criteria for PV hybrid systems that allow objective comparison of different systems;
- Development of recommendations to increase the solar fraction in hybrid systems through demand side management and optimization of the battery energy storage system.

## SUBTASK 40: Sustainability Conditions

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

- Documentation of field experience and learning that demonstrate the social and political framework for successful operation of PV hybrid systems within mini-grids;
- Evaluation of the financial aspects of PV hybrid power systems, considering both first costs and operating costs, and determining the conditions for economic sustainability;
- Evaluation of the environmental impacts and benefits of PV hybrid systems with focus on greenhouse gas emission mitigation and potential for recycling of system components.

## TASK 11 KEY DELIVERABLES

Task 11 completed the majority of its Workplan. The following deliverable reports were published:

- 1 Worldwide Overview of Design and Simulation Tools for PV Hybrid Systems - T11-01:2011
- 2 The Role of Energy Storage for Mini-Grid Stabilization - T11-02:2011
- 3 Sustainability Conditions for PV Hybrid Systems: Environmental Considerations - T11-03:2011
- 4 COMMUNICATION BETWEEN COMPONENTS IN MINI-GRIDS: Recommendations for communication system needs for PV hybrid mini-grid systems - T11-04:2011
- 5 Social, Economic and Organizational Framework for Sustainable Operation of PV Hybrid Systems within Mini-Grids - T11-05:2011
- 6 Design and operational recommendations on grid connection of PV hybrid mini-grids - T11-06:2011
- 7 PV Hybrid Mini-Grids: Applicable Control Methods for Various Situations - T11-07:2012
- 8 Overview of Supervisory Control Strategies Including a MATLAB® Simulink® Simulation - T11-08:2012

## DELIVERABLES – WHERE TO GET THEM?

Task 11 deliverable reports have been published electronically on the IEA PVPS website <http://www.iea-pvps.org>.

## PARTICIPANTS

In the final year of the Work Plan, eleven IEA PVPS countries participated in Task 11: Australia, Austria, Canada, China, France, Germany, Italy, Japan, Malaysia, Spain, and the USA. The management of the Task – the Operating Agent – was executed by Canada.

## SUBSEQUENT ACTIVITY

PVPS Task 9 has taken on the dissemination and further development of several of the Task 11 results and activities.

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## COLOPHON

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